NUREG-1060

Answers to Questions About Updated Estimates of Occupational Radiation Doses at Three Mile Island, Unit 2

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

TMI Program Office

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U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

INTRODUCTION

The purpose of this question and answer report is to provide a clear, easy-to-understand explanation of revised radiation dose estimates which workers are likely to receive over the course of the cleanup at Three Mile Island, Unit 2, and of the possible health consequences to workers of these new estimates. We will focus primarily on occupational dose, although pertinent questions about public health and safety will also be answered.

The answers to these questions, prepared by the staff of the NRC Three Mile Island Program Office, are based principally on the detailed examination of occupational dose in Draft Supplement 1 to the "Programmatic Environmental Impact Statement Related to the Decontamination and Disposal of Radioactive Wastes Resulting from the March 28, 1979, Accident at Three Mile Island, Unit 2" (PEIS), NUREG-0683 issued December 1983. The views expressed in this question and answer report are those of the NRC staff.

Draft Supplement 1 to the PEIS on Occupational Exposure (NUREG-0683, Supp. 1) is available for public comment. Copies are available for inspection at the NRC TMI Program Office, 100 Brown Street, Middletown, Pennsylvania,* the NRC Public Document Room, 1717 H Street, N.W., Washington, D.C., and at the TMI-2 Local Public Document Rooms at the Government Publications Section, State Library of Pennsylvania, Education Building, Commonwealth and Walnut Streets, Harrisburg, Pennsylvania, and at the York College of Pennsylvania, Country Club Road, York, Pennsylvania.

Requests for single copies of the PEIS Supplement should be addressed in writing to the Director, Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

Send your comments to Dr. Bernard J. Snyder, Program Director, Three Mile Island Program Office, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. They are due to NRC by February 29, 1984.

Dr. Bernard J. Snyder, Program Director
Three Mile Island Program Office
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

*Hours: Tuesdays, Noon to 2 p.m.
Wednesdays, 5 p.m. to 8 p.m.
Thursdays, 3 p.m. to 5 p.m.

Q.1. Why has NRC issued Draft Supplement 1 to the Programmatic Environmental Impact Statement at this time for cleanup operations at Three Mile Island, Unit 2?

A. For two reasons. First, to revise the estimates of radiation doses workers are likely to receive during the entire cleanup. Second, to reconsider what these revised estimates could mean to worker health.

Q.2. Is other information in the original Programmatic Environmental Impact Statement out of date because Supplement 1 has been issued?

A. No. Draft Supplement 1 was issued for the sole purpose of updating estimates of radiation exposures and their possible effects on worker health. This information supplements one part of the cleanup discussed in the original Programmatic Environmental Impact Statement. The original Statement remains the valid source of information for all other facets of the cleanup.

Q.3. What are the revised estimates of doses workers could receive?

A. When the original Programmatic Environmental Impact Statement was issued in March 1981, the radiation dose to the work force was estimated to be between 2,000 and 8,000 person-rem. According to revised estimates, cleanup workers are likely to receive a total collective radiation dose of between 13,000 and 46,000 person-rem for the entire cleanup project.

(For an explanation of person-rem, see the answer to Question 15.)

Q.4. How could this increased dose range affect worker health?

A. Statistically, these increased dose estimates slightly raise the chances of cancer for the group as a whole. It is possible that this radiation dose could result in two to six fatal cancers in the worker population.

Q.5. The original Programmatic Environmental Impact Statement estimated that approximately one additional cancer death could occur because of radiation doses to the cleanup work force. Should this one possible death be added to the two to six fatal cancers predicted in the Supplement?

A. No.

Q.6. How does the potential for fatal cancer to cleanup workers compare with risks of fatal cancer to the entire U.S. population?

A. The average member of the U.S. population has about a 1-in-5 chance of developing fatal cancer. That is, for every 10,000 people living in the U.S., approximately 2,000 will die of cancer. For a member of the cleanup work force active in decontamination work over the course of the cleanup, the chances are about 1 in 4.9, based on statistical estimates.

Q.7. Would nonfatal cancers also result from the level of radiation dose workers could receive?

A. Yes. Statistically, the number of nonfatal cancers could be approximately one and one-half to two times the number of fatal cancers, according to the best scientific estimates. That is, in addition to the possibility of fatal cancers, there could be 3 to 12 nonfatal cancers. (The basis for these estimates comes from a 1980 report of the National Academy of Sciences' Advisory Committee on the Biological Effects of Ionizing Radiation.)

Q.8. Would there be other adverse health effects?

A. Yes. There could be from 3 to 12 genetic effects in the offspring of the workers. Should genetic effects occur, it is possible that they could occur in more than one generation of offspring.

Q.9. Do these new estimates mean that individual workers will be exposed to larger amounts of radiation than was previously thought?

A. No. NRC regulations strictly limit the amount of radiation that an individual worker can receive. These regulations have been and will continue to be strictly enforced.

The additional radiation estimated may be distributed among a larger number of workers, so that an individual worker will still receive no more than the regulations permit.

(For additional information about these limits, see the answers to Questions 27 and 35.)

Q.10. Will these new estimates result in increased health or safety risks to the public?

A. Other than the possibility for genetic effects discussed in the answer to Question 8, the dose to workers will not affect the general public. Generally, public health and safety will be enhanced because of fuel removal and cleanup.

(For additional information about public protection, see Questions 60, 83, and 91.)

Q.11. How can NRC, the Environmental Protection Agency, and other involved organizations be confident in the accuracy of their estimates of these health risks to workers?

A. These estimates are based on principles developed by internationally recognized authorities on the health effects of harmful radiation. The data used to predict health effects for cleanup workers are those recommended by the U.S. National Academy of Sciences' Committee on the Biological Effects of Ionizing Radiation; the United Nation's Scientific Committee of the Effects of Atomic Radiation; the National Council on Radiation Protection in the U.S.; and the International Commission on Radiological Protection.

Q.12. To what type of radiation will workers be exposed and why does the radiation have the potential to be harmful?

A. Cleanup workers will be exposed to ionizing radiation. This type of radiation has enough energy to pass through living tissue. As it does, it can displace electrons from the atoms and molecules of the living tissue. Atoms or molecules with displaced (or missing) electrons are called ions. (That's why it's called ionizing radiation.) Living tissue exposed to ionizing radiation may be damaged.

(See the answer to Question 51 for information about types of ionizing radiation.)

Q.13. What are some sources of ionizing radiation?

A. Ionizing radiation can come from both natural and manmade sources.

Ionizing radiation found in nature includes - -

- cosmic radiation from outer space
- certain elements which occur naturally in the human body
- certain elements from the soil and rocks that may be contained in the things we eat and smoke

Manmade sources include - -

- medical and dental X-rays
- radioactive materials used to detect and treat diseases
- nuclear power plant fuel and its byproducts
- combustion of fossil fuel (coal-fired power plants)
- fallout from nuclear weapon testing in the atmosphere
- consumer products (for example, color television tubes and some types of smoke detectors)

Q.14. What units are used to measure ionizing radiation?

A. For its biological effects in people, it is measured in units called rems. To account for small exposures, rems are frequently broken down into thousandths of a rem, or millirems. That is, one rem equals 1,000 millirem.

Q.15. If radiation doses are measured in rems and millirems, why does Draft Supplement 1 to the Programmatic Environmental Impact Statement refer to worker dose in a unit called person-rem?

A. Person-rem refers to the sum of individual radiation doses that may be received by members of a certain group, in this case workers doing the actual cleanup work. Person-rem is calculated by multiplying the average dose per person by the number of persons in a group. For example, 1000 people each exposed to 1 millirem of radiation would have a collective dose of 1000 millirem, which is 1 person-rem.

Q.16. Why were estimates of worker dose in March 1981 lower than the most recent estimates?

A. There are several reasons. The most important reason is that GPU Nuclear now has actual experience in performing decontamination in the reactor building at TMI-2. When the Programmatic Environmental Impact Statement was written, the reactor building had been entered only five times, and that was so that workers could collect data about conditions in the building. The actual cleanup of the reactor building had not begun at that point. Another important reason is that delays have made cleanup tasks more difficult to perform, as noted in the answers to the next three questions.

Q.17. What has experience since March 1981 shown?

A. GPU Nuclear has learned that draining the highly contaminated water from the lower level of the reactor building did not lower radiation levels because the building surfaces covered by the water were also highly contaminated. They have also learned that decontaminating the surfaces at the upper levels of the reactor building is much more difficult than previously thought. This is probably because of the long time lapse between the accident and the start of the cleanup. During that time contamination penetrated both unpainted concrete surfaces and the rust that formed on metal surfaces.

Q.18. If all the money needed for the cleanup were available, would the increased risk from worker exposure be necessary?

A. Although there is a relationship between the availability of funds and radiation doses to workers, that relationship is not a simple one and cannot easily be quantified. Nevertheless, several issues seem clear. A lack of funds causes delays. Delays, in turn, can increase worker doses for two reasons. First, workers must enter the reactor building periodically for routine inspection and maintenance activities and to take samples required to ensure safety. These entries, however, do not contribute to the progress of the cleanup. Second, as time passes, the radioactive contamination becomes more difficult to remove because it seeps further into concrete and becomes part of the layer of corrosion that forms on metal surfaces.

Q.19. Were delays, whatever their cause, considered in the updated dose estimates?

A. Yes, to a limited extent. The lower dose estimates in Draft Supplement 1 to the Programmatic Environmental Impact Statement (about 13,000 person-rem) assume little additional delay. The higher dose estimates (about 46,000 person-rem) allow for some delay, but are based on more or less continuous progress. None of the estimates take into account the worst case of delay, where workers receive relatively small doses year after year to keep the reactor safely shut down, but where no real progress in the cleanup is made.

Q.20. How do scientists arrive at the upper and lower numbers when they give the range of person-rem likely for the entire cleanup?

A. Each cleanup task was analyzed in two ways to arrive at high and low estimates. For the low estimate, the radiation specialists considered how long each task would take if the work went very well, and what the dose rate (the rems per hour) in the work area would be if previous decontamination and shielding had reduced dose rates as much as can reasonably be expected, based on current cleanup experience. The number of worker hours times the dose rate in units of rem per hour gave them the low (or optimistic) estimate of dose (in person-rem) for each task. The low estimates for all future tasks were then summed and added to the dose to date. This total gave them the low estimate of 13,000 person-rem for the alternative in which the fuel is removed prior to building decontamination.

For the high estimate, they considered how long the task would take if things went slowly and if some tasks had to be redone. They estimated the dose rate as if previous decontamination and shielding had been less effective than they would hope. These time and dose rate values were multiplied together and then summed in the same way as for the low estimate. This total gave them the high (or pessimistic) estimate of 46,000 person-rem for the alternative involving fuel removal followed by reactor building decontamination.

Q.21. Given this increased range of worker exposure, why should the cleanup go forward?

A. The TMI site is not suitable as a permanent repository for radioactive wastes generated by the accident. (The reactor was designed for a normal operating life of about 40 years with an adequate margin of safety; it was not designed or built to contain radioactive wastes for an indefinite number of years, particularly when those wastes include damaged fuel and other hazardous byproducts from an accident.) Given that limitation, the waste will have to be removed at some time in the future.

Most of the short-lived radioactive material has already decayed to insignificant levels (that is, has essentially stopped emitting ionizing radiation), and the dose rate currently affecting workers is due almost entirely to cesium-137, a radioactive material which has a 30-year half-life. A 30-year half-life means that if GPU Nuclear waited 30 years before cleanup, the dose rate would decrease to one half its present value. However, cleanup workers have already learned that waiting makes cleanup more difficult because contamination can penetrate building and equipment surfaces, as was noted in the answer to Question 17. Since more effort would be required to remove contamination that had penetrated certain surfaces, waiting is not expected to reduce worker doses very much.

Another reason for going ahead with the cleanup is that there is a possibility, however slight, that some radioactive material could escape to the environment outside the reactor building. The risk of this happening, even though small, increases over time.

Q.22. What is the risk to the public of leaving the damaged fuel in the core?

A. The damaged fuel in its present condition, under a boron-water solution, cannot harm anyone outside the reactor building. The borated water, the reactor vessel, and the reactor building all play a part in assuring safety. But a small probability exists that in any given period of time something could happen to the borated water,to the reactor vessel, or to the building to impair safety. NRC cannot regulate for a limited period. They must look at long-term conditions at TMI. The probability of something eventually happening to the borated water, the reactor vessel or the building over a long period of time is too high to leave them in their present condition. Because of these possibilities, NRC has concluded that the building must be cleaned up.

(See the answer to Question 77 for an explanation of why the chemical boron is added to the water.)

Q.23. What organizations are monitoring the radiation doses workers receive?

A. Worker doses are monitored by GPU Nuclear. In addition, NRC has a full-time professional staff of radiation specialists at Three Mile Island. They conduct ongoing reviews of the GPU Nuclear radiation protection program and the methods that GPU uses to monitor worker doses.

Q.24. What kinds of radiation monitors are being used to measure worker doses?

A. GPU Nuclear has a number of options as to the kind of radiation-monitoring instruments they can use. A device called a dosimeter is used to register the radiation dose a worker receives. GPU Nuclear assigns each radiation worker a thermoluminescent dosimeter (TLD). This device registers a worker's accumulated dose from ionizing radiation. The TLDs are analyzed or "read" every month, and the dose indicated for each worker is added to previous readings for that individual.

GPU Nuclear also provides a direct-reading, or self-reading, dosimeter for each worker who enters a radiation area. Workers can read this dosimeter during work to know how much dose they have received from the time they enter a radiation area. Workers are required to read these devices before, during, and after work and report the results of their readings. These devices allow workers to tell immediately if a dose is larger than expected. If it is, workers can leave the area at once. These devices also allow GPU Nuclear to keep track of each worker's dose between TLD readings and to determine how much dose is being received for each job. These doses are then added to the worker's cumulative exposure record. Both NRC and GPU officials review these records for their compliance with NRC regulations governing dose limits.

Other instruments, some in fixed locations and some carried by workers, are used to locate sources of radiation, to estimate the dose workers could receive, to determine the concentration of radioactive substances in air, and to do other specific jobs.

Filtered ventilation systems, instruments for monitoring airborne radioactivity and respirators are in use to minimize the possibility that workers could inhale, swallow, or otherwise get radioactive materials into their bodies. To monitor for such a possibility, GPU Nuclear requires all workers to be measured for internal radiation before they are employed and at least once a year thereafter. A worker suspected of internal contamination is examined in a special radiation-detection device for this purpose (a "whole-body counter") and, depending on the results, may also have urine and/or fecal samples analyzed.

Q.25. What range of dose will the dosimeters measure?

A. At TMI, TLDs used by workers are good from about 10 millirem to 200 rem (200,000 millirem). For self-reading dosimeters, the range is not as large, but it is more than sufficient to cover the dose that a worker could receive during a single entry to the reactor building or in performing work in any other radiation area.

These dosimeters also warn workers of overexposures because they are equipped with alarms that sound when radiation readings reach a certain point. Should the alarm sound, workers would leave the area immediately.

Q.26. Will a long-term survey of the medical histories of cleanup workers be conducted by GPU Nuclear?

A. No such survey is planned at this time. GPU Nuclear keeps medical records on workers while they are employed by the company, but other than that there is no long-term survey program. Such a survey would not be statistically meaningful because of the relatively small number of health effects expected when compared to the normal incidence of cancer and genetic diseases. (See the answer to Question 6 for figures about the normal incidence of cancer.)

Doses that individual workers have been and will continue to receive throughout the cleanup are well within the requirements in NRC regulations and are typical of doses for other radiation workers.

Q.27. Do NRC regulations spell out how much radiation a worker can receive?

A. Yes. A radiation worker may receive no more than 3 rem of radiation dose in any three-month period. No worker may average more than 5 rem per year for each year past age 18. There is also another more limiting guideline in NRC regulations (Code of Federal Regulations, Title 10, Part 20, "Standards for Radiation Protection") requiring that all NRC-licensed facilities

> make every reasonable effort to maintain radiation exposures as low as is reasonably achievable. The term "as low as is reasonably achievable" means as low as is reasonably achievable taking into account the state of technology, and the economics of improvement in relation to benefits to the public health and safety, and other societal and socioeconomic considerations....

Q.28. Does GPU Nuclear have a program to comply with these guidelines?

A. Yes. GPU Nuclear has a dose-reduction program to comply with the ALARA (As Low As is Reasonably Achievable) principles. This program is the responsibility of upper-level management with the authority to carry out the program. As part of the program, all workers receive training in how to limit radiation doses. GPU Nuclear officials review equipment modifications and work procedures and control who may enter radiation zones. Shielding and protective equipment and clothing are also used, as appropriate.

(The types of training workers receive are explained in the answer to Question 44.)

Q.29. What steps does the dose reduction program involve?

A. First, GPU Nuclear identifies significant sources of worker radiation doses. Then they evaluate the various alternatives for removing, decontaminating and/or shielding workers from these sources. They then select a method for reducing the radiation and carry out an evaluation to determine whether the cleanup work can be performed under existing procedures. Then GPU Nuclear gives the method an extensive review to consider the benefit in worker dose reduction that can be expected. NRC also reviews all such procedures for how well they comply with ALARA guidelines.

Q.30. What controls does NRC use to ensure that worker doses are limited?

A. Special procedures are in place at TMI for reviewing GPU Nuclear's work. Before GPU Nuclear begins any part of the cleanup involving radioactivity, they must submit plans, procedures, and safety analyses to NRC radiation specialists for approval.

Q.31. Has NRC rejected any of GPU Nuclear's cleanup proposals?

A. Yes. NRC has rejected approximately 10% of the proposals reviewed and required GPU Nuclear officials to modify or further justify them.

Q.32. What dose reductions have been achieved so far as a result of the dose reduction program?

A. The so-called "transit dose" (that is, the dose to a worker who enters the reactor building, goes upstairs to the main work area, and then leaves the reactor building) has been reduced from an average of 40 millirem per entry to an average of 18 millirem. The program has also reduced radiation in particular work areas. For example, the average dose rate on the first floor was 430 millirem per hour when entries were first made in the fall of 1980. By late 1982, but before the dose reduction program began, the rate was 350 millirem per hour. In the summer of 1983, it was down to about 140 millirem per hour.

Q.33. What are the goals of the dose reduction program?

A. The goals of the dose reduction program are specific radiation reductions in various areas of the building at specified stages of the cleanup. The dose reduction goals become lower for the later stages of cleanup. Ultimately, the goal is to reduce the dose rate in most of the building work areas to 10 millirem per hour and reduce airborne concentrations so that workers no longer have to wear respirators. (A detailed description of the licensee's dose rate reduction goals is given in Table 2.1 of Draft Supplement 1 to the Programmatic Environmental Impact Statement.)

Q.34. How does 10 millirem per hour compare with the dose rate inside the reactor building of a normally operating plant?

A. This dose rate is comparable to that in a very clean operating plant, or to one that has operated for only a short period of time.

Q.35. Does GPU Nuclear also have radiation dose limits for workers? If so, what are they?

A. Yes. GPU Nuclear has established limits to ensure that NRC regulations will not be violated. Almost all workers are limited to 1 rem every three months, a dose rate below the NRC limit. Those workers whose jobs require doses of 1 to 2 rem in any three-month period must receive special prior authorization from GPU Nuclear's Radiological Engineering Manager after the need for these dose levels have been reviewed. If a worker's job were to require 2 to 3 rem in a three-month period, the approval of both the Radiological Engineering Manager and the Radiological Controls Director would be required. These approvals are very difficult to obtain.

Q.36. How many person-rem have workers received since the accident in March 1979?

A. As of August 22, 1983, workers had received approximately 1,700 person-rem since March 28, 1979.

Q.37. What level of doses have cleanup workers received during the cleanup at TMI on an annual basis, and how do these compare with the dose levels permitted in NRC regulations?

A. We show a breakdown of this information on page 1.9 of Draft Supplement 1 to the Programmatic Environmental Impact Statemnt. The information, combined for TMI Units 1 and 2, shows that 9,915 workers have received less than 1 rem per year since 1979. Another 509 workers have received 1 to 2 rem per year; 111 workers have received 2 to 3 rem per year; 20 workers have received 3 to 4 rem per year; and only 7 workers have received 4 to 5 rem in any one year. No workers have received more than 5 rem per year. More of the total dose received was incurred at Unit 1 than at Unit 2. Furthermore, the doses at TMI-2 are lower than the doses received by workers at the majority of NRC-licensed reactors.

Q.38. How many rem could the average worker expect to receive during the cleanup?

A. There is probably no average worker because the majority of those involved in cleanup are involved in design, engineering, planning, and support functions; these workers do not enter radiation areas very often and generally average less than ½ rem per year. The workers who do cleanup work in the reactor building will receive a larger dose, but cleanup experience to date indicates that they receive much less than the maximum allowable dose permitted by NRC regulations.

Q.39. What adverse health effects are possible from this level of dose?

A. The health effects will depend, of course, on a number of factors, including the age and health of the worker, the actual amount of dose received (at TMI and elsewhere), and the time period over which the dose is received. For example, consider a 30-year old person who works nine years and receives 1 rem per quarter for each year worked (that is, 9 x 4 = 36 rem). Statistically, that person has a 1 in 210 chance of premature death from cancer. This is in addition to the 1-in-5 probability of death from cancer from other causes, which is the average for the entire U.S. population.

Q.40. How many workers will be involved in the cleanup?

A. NRC cannot say for certain at this time because of things like normal turnover among workers and the need for specialists in various disciplines. In Draft Supplement 1 to the Programmatic Environmental Impact Statement, NRC estimated that about 10,000 workers would eventually be involved.

Q.41. Is the work force made up only of GPU Nuclear people?

A. GPU Nuclear, its contractors, and other GPU utility personnel make up the cleanup work force. Some NRC and Department of Energy personnel and some of their contractors will also receive some dose.

Q.42. What's the age range of cleanup workers?

A. They range between 18 and 70 and are primarily male. The average age at present is 42.

Q.43. You indicate that there are some women in the work force. Could a woman of childbearing age work in areas contaminated by radioactivity?

A. Yes. All women radiation workers receive training for work in radiation zones when they are first hired and annually thereafter. At these training courses they are provided with NRC's guidance on exposure of the fetus. In addition, the doses received by women employees are maintained separately on a special computer code and are reviewed weekly by the Radiological Engineering Department. When any woman's dose approaches ½ rem, which is the NRC-recommended limit for a fetus, the woman is contacted and again reminded of the guideline and the reason for it. When a woman radiation worker becomes pregnant she is given the opportunity to limit her dose, whenever possible, without her job being put in jeopardy.

Q.44. Are all radiation workers informed about the possible risks they face?

A. Yes. In accordance with NRC regulations, all radiation workers receive training in the subject. Workers receive three types of training. New employees are given both classroom and on-the-job training. All employees are also given annual refresher courses, both in class and on the job. Finally, all workers about to enter a radiation area are given a pre-job briefing that informs them about the nature of the task, the radiation levels anticipated, and the types of protective clothing and respirators they will have to wear. In addition, women who work in radiation zones are given special instructions and a copy of NRC's recommended guidelines on the protection of the fetus.

Q.45. Have discussions been held with unions representing cleanup workers about the nature of the work and about the potential risks?

A. Yes. Some meetings have been held and NRC plans to hold additional meetings in the future.

Q.46. Have outside workers been brought in because regular workers might use up their quarterly or annual dose limits?

A. No, they have not.

Q.47. What kind of protective clothing do workers wear in contaminated areas?

A. Protective clothing is selected for the conditions in the work area and also for the job the worker will be doing. At a minimum, workers are required to wear one pair of coveralls, a hood, and a respirator (an air filter for breathing) for all work in the reactor building. For work in wet areas, plastic outer clothing is also used.

A.48. Isn't it hard for the workers to get their work done in all that protective clothing?

A. Yes. It is a problem because the clothing is both bulky and hot to wear. Workers in areas with high temperatures may wear ice vests to cool themselves.

Q.49. Do protective clothing and respirators protect workers from receiving a radiation dose?

A. Yes and no. Protective clothing and respirators help to protect workers from becoming contaminated by radioactive material, but they do not keep them from receiving a radiation dose from sources of penetrating gamma radiation. (The answer to Question 51 explains why protective clothing will not shield against some radiation.) Even though respirators are not effective against some types of airborne radioactive materials, these types of contamination are not present in the reactor building atmosphere at TMI-2 in concentrations high enough to be hazardous to workers.

Q.50. Why is it important to cover workers with protective clothing?

A. A worker's skin must be protected for two reasons. First, if radioactive material gets on the skin, the material continues to give off radiation until it is removed. Second, radioactive material on the skin has a chance of being taken inside the body if the skin is broken. Finally, workers must avoid swallowing or inhaling radioactive material because the material will continue to give off radiation until it is eliminated from the body, a process which could take from several hours to several years.

Q.51. What kind of radiation will protective clothing stop?

A. There are three types of ionizing radiation: alpha, beta, and gamma. The one that gives workers at TMI a whole-body radiation dose is predominantly gamma radiation. ("Whole-body" refers to radiation exposure in which the entire body rather than an isolated part -- an arm or leg -- is exposed.) Gamma radiation is like the X-rays used in medicine and dentistry in that it will penetrate clothing and other lightweight materials. It takes something heavy, like lead or a lot of water, to stop it. Alpha and beta radiation are responsible for much less of the radiation dose.

Alpha radiation is stopped by almost anything (a piece of paper, human skin, clothing, etc.) and is therefore only a health problem if it gets inside the body. Beta radiation is more penetrating than alpha radiation. Although some beta radiation can penetrate protective clothing, its effects are greatly weakened as a result. It can affect the lens of the eye and other soft tissues, but it is easily shielded by the plastic eye cover of the respirator or by ordinary safety glasses.

Q.52. Were alternative cleanup plans considered in Draft Supplement 1 to the Programmatic Environmental Impact Statement that might result in lower occupational doses?

A. Yes. Three alternatives were considered, but only one of these was found to result in significantly lower worker doses.

Q.53. What was the first alternative for cleanup discussed in Draft Supplement 1?

A. The first alternative considered was to clean the reactor building thoroughly before removing the damaged fuel from the reactor.

Q.54. Does the present cleanup plan differ from this plan?

A. Yes. The current plan calls for removal of the fuel as soon as possible (while implementing a plan to reduce worker exposure) and completion of the building cleanup later.

Q.55. Why isn't the original plan going to be followed?

A. The cleanup of the reactor building and equipment will require more time and involve more radiation dose to workers than was originally anticipated. Removing the fuel is considered too important to leave until after the building cleanup is completed. Also, removing the fuel is likely to cause some additional contamination, necessitating that some areas in the reactor building be cleaned again.

Q.56. Why is removing the fuel so important?

A. For three reasons. First, the fuel is the source of the majority of radioactivity in the reactor building at TMI-2. Second, the presence of the fuel in the reactor represents a potential hazard to workers and the public because there is a small chance that the fuel could begin a self-sustaining chain reaction and give off unwanted heat and radiation. Third, scientists and engineers expect to learn a lot about preventing and controlling nuclear accidents from examining the damaged fuel from TMI-2.

Q.57. After the fuel is removed, why don't workers seal the building shut for 30 years rather than take the risks associated with decontaminating the rest of the building?

A. The main reason for not accepting this approach is concern for the safety of the public. As long as there are potentially harmful levels of radiation in the reactor building, workers will need to make periodic inspections, take samples, change filters, and do other work to protect the public. All these activities will expose workers to radiation without contributing toward permanent removal of the radioactivity.

In addition, as was discussed in the answer to Question 21, the radioactive chemical cesium-137 has a 30-year half-life, so the amount of radioactivity it emits would decrease only by one-half in 30 years. More time and therefore more exposure would be required to clean the building, even after a 30-year wait. Waiting also increases the difficulty of decontamination. However, if there were reason to expect breakthroughs in useful robotic technology to save workers from significant radiation doses, there could be merit to this approach.

(For information about the potential use of robots, see Questions 59 through 68.)

Q.58. Would decontaminating the entire reactor building before removing the fuel lower the radiation dose to workers?

A. Probably not. The current cleanup will likely result in from 13,000 to 46,000 person-rem. Decontaminating the reactor building first will likely result in from 12,000 to 42,000 person-rem. This is really not a significant difference in view of the large degree of uncertainty in these estimates.

Q.59. What were the other alternatives considered, and would they reduce worker exposure?

A. A second alternative would be to design and build equipment to vacuum the fine fuel particles out of the reactor vessel through one of the small openings in the reactor top (or head) where a small TV camera has already been inserted for a visual inspection of the core. Unfortunately, this alternative would result in just as much radiation dose to the workers as the current plan.

The third alternative considered was to remove the fuel, just as proposed in the current plan, but then wait until robots were available to finish the reactor building cleanup. This alternative would lower worker radiation doses and it would get the fuel out as soon as possible, but no one can be sure that this alternative is technically feasible.

Q.60. Aside from risks to cleanup workers, is one cleanup alternative safer for the public than the others?

A. Although the alternative cleanup methods were all selected to meet the objective of protecting the public, there are slight differences in how well they do so. The current cleanup plan provides for the earliest possible removal of the damaged fuel, and we believe that its removal is important to public safety and peace of mind. Because the other alternatives put certain other tasks before fuel removal, they are slightly less desirable from the standpoint of public health and well-being. In the third alternative, the fuel would be removed first, but there would be a significant delay in cleaning the rest of the facility while robot technology is being developed. The effects on public safety of such a delay have not been evaluated, but they are not expected to be as beneficial as proceeding with the cleanup.

Q.61. What do you mean by "technically feasible" in connection with robots?

A. Cleaning the building by robotics could not begin in earnest until robotic technology has advanced beyond its present stage of development. No one can at this time say how long such developments would take.

Q.62. What is the difference between "robots" and "robotics"?

A. To most of us, robots conjure up the devices we see in science fiction movies. They are mobile, self-contained, and able to perform a wide variety of tasks -- and sometimes they have personalities. The current state of robotic technology is a long way from producing such versatile devices, however. The term robotics, as used here and in Draft Supplement 1, refers to the technology of remotely controlled devices which can do one or perhaps two jobs well. These are the types of devices that would have to be used at TMI.

Q.63. How much could the radiation dose to workers be reduced by using robotic technology?

A. This alternative would reduce worker dose by about 40% -- to between 6,900 to 28,000 person-rem.

Q.64. If this alternative is not feasible now, could it eventually be used?

A. Yes, if developments in robotics are rapid.

Q.65. Assuming that developments in robotic technology permitted their use in the cleanup, would the robots become contaminated?

A. Yes. Workers would probably have to take special precaution to prevent vital parts, such as electronic circuits, from becoming contaminated, but any part that came in contact with contaminated building surfaces or equipment would become contaminated.

Q.66. Would workers decontaminating the robots be exposed to contamination and radiation?

A. Workers would be protected from contamination by the same type of protective clothing and respiratory protection that they now wear in the reactor building. They would, however, be exposed to some radiation, and they would receive some radiation dose.

Q.67. How much?

A. Current estimates are that they would receive between 5% and 15% of the dose they would receive if the work being done by robots were done manually.

Q.68. If robotic technology was advancing fast enough so that its use was feasible, would workers at TMI-2 still be exposed to radiation during the period while the robotics technology was being developed?

A. Yes. There are certain tasks that would be required whether or not cleanup work was going on. Estimates are that these tasks could result in worker exposure of between about 2 and 31 person-rem per year.

Q.69. What are the most up-to-date estimates of doses workers could receive from each cleanup task?

A. Disassembling the reactor and removing the fuel is expected to require between 2,600 and 15,000 person-rem; cleaning the reactor building and equipment, 5,900 to 21,000 person-rem; and all other activities, including work to date, between 4,500 and 9,900 person-rem.

Q.70. That seems like quite a large dose for the "other activities." What are they?

A. They include the dose reduction program, decontaminating the reactor's primary cooling system, cleaning the auxiliary and fuel-handling building, managing and transporting radioactive wastes, routine inspection and maintenance activities, and those cleanup activities completed so far.

(Details about the dose reduction program are discussed in Questions 28 and 29.)

Q.71. Why do estimates of doses workers could receive vary so widely for each task? For example, the range for cleaning the reactor building and equipment varies from 5,900 to 21,000 person-rem.

A. Even though the engineers and radiation specialists have a good idea of the cleanup required for most of the reactor building and equipment, there are still unknowns. One big unknown is the condition of the basement of the reactor building, because it was under contaminated water for so long. Some decontamination is being done from above this level, but radiation specialists can only estimate what the dose rates will be when hands-on decontamination has begun. They also must estimate the amount of time workers will spend on each task. Given these unknowns, it really is not surprising that there is such a difference between the high and low estimates.

For the low estimate, the assumption was made that the work would be done in the shortest time at the lowest dose rates. For the high estimate, the assumption was made that everything would take the maximum amount of time at the highest dose rate that might be estimated.

Q.72. How are workers being protected from contamination at the present time?

A. Cleanup workers wear the protective clothing and respiratory protection discussed in Question 47. After each entry to the reactor building, each worker is examined for contamination after the protective clothing is removed. Only a few workers have been contaminated. In each case, simple decontamination methods, such as washing the affected area, eliminated the contamination.

(See the answer to Question 24 about radiation-detection devices.)

Q.73 What type of radioactive material accounts for the major source of contamination?

A. Cesium-137 is the major contributor to worker dose because it emits gamma radiation. Strontium-90 is also a problem, but because it emits beta radiation, protective clothing reduces worker exposure.

(See the answers to Questions 49, 50, and 51.)

Q.74. Where did these radioactive materials come from? Aren't they present in normally operating reactors as well?

A. Yes. They are present in all reactors, but they are usually trapped in the fuel. The accident at TMI-2 damaged much of the fuel, resulting in the release of these radioactive materials.

Q.75. When workers remove the top (or head) of the reactor vessel, will the fuel expose workers to large doses of radioactivity?

A. No. When the head is removed, the fuel will be under at least 10 feet of water, which will shield the workers (as noted in the answer to Question 51). Head removal, however, will entail some radiation dose from contamination on structures on the underside of the head. Radiation-protection measures will be implemented to reduce this dose.

Q.76. When the damaged fuel in the core is removed, will it be exposed to the air or will it be moved under water?

A. The fuel will be kept under water at all times to shield the workers from radiation. The canisters into which the fuel will be placed will also be kept under water, not only while they are filled, but continuously until they are placed in shielded, crash-resistent casks for shipment.

Q.77. Would worker exposure be reduced if the fuel was not removed and the entire reactor vessel was flooded with water?

A. Workers are exposed to radiation only when they are in a radiation area, so in that sense you could reduce worker doses substantially (2,600 to 15,000 person-rem) by leaving the fuel in place forever--if that were acceptable from a safety standpoint. NRC, however, believes that the risk of leaving the fuel in place is unacceptable in the long term. Accordingly, the fuel will have to be removed.

The fuel is currently flooded with a boron-water solution and will continue to be throughout defueling. Boron is added to the water because it absorbs the neutrons (atomic particles) necessary for the uranium fuel to sustain a chain reaction. Without a chain reaction, the fuel will not achieve criticality and hence will not produce additional radiation or heat. In a normally operating reactor, this chain reaction is carefully controlled to produce the steam that rotates turbines to generate electricity.

Q.78. Has any sampling been done to measure radiation levels under the reactor vessel head?

A. Yes. Radiation detection devices provide this information. In addition, samples of reactor coolant water are taken regularly, and there is an ongoing program to sample both the particulate material inside the reactor and the damaged fuel itself.

Q.79. What are current radiation levels?

A. Radiation levels below the reactor vessel head are about 200 to 1,000 rem per hour. Remember that these are radiation levels inside the reactor vessel. They do not represent readings in areas where workers will be positioned to remove the head and fuel. These tasks will be performed in areas with lower radiation levels.

Q.80. What would happen if radiation levels are higher than expected when the reactor head is lifted?

A. The sampling procedures detailed in Question 78 will ensure that this type of surprise doesn't occur. Even so, there will be procedures in effect should something like this happen. For instance, if radiation levels at a particular point reach a certain level as the head is lifted, then the head could be replaced immediately. Further, workers will be instructed to leave the building if radiation reaches levels that could result in worker doses exceeding permissible levels. Even though all the data have not been accumulated at this writing, GPU Nuclear and NRC will have sufficient data to know what to expect before the head is lifted.

Q.81. What would the risk be for a worker who received an overexposure?

A. The risk to a worker from an overexposure would depend on the level of dose received. An overexposure usually means receiving more radiation dose than was planned. For example, an overexposure may mean exceeding GPU Nuclear's 1-rem-per-three-month-period limit without having the special authorization required or it may mean exceeding NRC's 3-rem-per-three-month-period limit. The response to Question 39 notes that a worker who receives 36 rem during the entire cleanup has a 1 in 210 chance of premature death from cancer induced by the dose. If the dose due to overexposure were 36 rem, the risk would be about the same.

Q.82. Would flooding the area around the reactor vessel cut down on the radiation level that workers could be exposed to when the head is lifted?

A. Flooding the area around the reactor vessel could potentially reduce worker doses. Prior to flooding, several time-consuming modifications would be required. As one example, a high-volume water decontamination system would have to be installed to prevent the flood water from itself becoming a major source of radiation. The potential reduction in doses to workers would be too small to justify flooding the area for a "wet" head lift.

Q.83. Can radiation trapped inside the reactor building penetrate the walls to the outside environment?

A. Yes, to a very limited extent. Radiation is reduced in intensity as it passes through heavy materials. (This is why you get a good image of dense tissues like bone on an X-ray film, but less dense tissues, like the heart, do not show up well.) The strongest sources of radiation at TMI-2 are in areas of the building below ground level. They are shielded not only by the building itself, which is made of reinforced concrete several feet thick, but also by the ground. In addition, the inside of the entire building is lined with a 3/8-inch thick steel liner. Radioactive materials in the upper part of the building do emit some radiation that passes through the approximately 3-1/2 feet of concrete and steel that form the reactor dome.

If cesium-137, for example, gives a dose rate of 100 millirem per hour inside the dome, this rate is reduced 10,000 times to 1/100 of a millirem per hour on the outside surface of the dome. This level of radiation would be virtually impossible to measure at the plant property boundary.

Q.84. Can radioactive materials contaminate the reactor building's steel liner?

A. Yes. There is some radioactive contamination on the steel liner, especially at the lower elevations of the building.

Q.85. Will this contamination be difficult to remove from the steel liner?

A. The liner is one of the easier surfaces to decontaminate. It has a painted surface, and workers do not expect to find much contamination beneath the paint.

Q.86. Can radioactive contamination penetrate concrete surfaces inside the reactor building?

A. Unpainted concrete surfaces within the building are expected to be highly contaminated since concrete is a porous material.

Q.87. How can you tell how far the contamination has penetrated the unpainted concrete surfaces?

A. Samples of concrete from structures in the upper areas inside the reactor building are still being taken and analyzed, but workers expect contamination may have penetrated only the first few tenths of an inch. For samples of concrete that were underwater, they expect that contamination may have penetrated up to a few inches.

Q.88. What methods can be used to remove contamination from unpainted concrete surfaces?

A. The most effective methods are those that chip away the surface of the concrete. Machines that do this have been used successfully to clean concrete surfaces in the auxiliary building.

Q.89. Does the sandblasting method of scrubbing surfaces release contaminated particles into the atmosphere?

A. Dry sandblasting is seldom used for decontamination without a vacuum attachment to collect particles that would otherwise spread contamination. The so-called vacuum blasting and various wet-blasting techniques have been used successfully where contamination is not too deep. (Wet blasting involves the use of jets of high pressure water.)

Q.90. Have contaminated materials in the reactor building since the accident lessened the building's capacity to prevent these materials from leaking to the outside environment?

A. No. The building materials at TMI and other reactors were selected, designed, and fabricated to be resistant to radiation. Normal physical processes, such as rust caused by high humidity and degradation caused by caustic cleaning materials, may over an extended period of time weaken the capability of the reactor building to contain the accident-generated material. This is one incentive to decontaminate the building so that it is not left in its present condition. GPU Nuclear conducts a continuous environmental-monitoring program to evaluate building conditions.

Q.91 Does any radioactive material escape to the outside environment when workers enter and leave the reactor building? If so, how much?

A. Now that the krypton gas has been vented and the reactor building is continually being ventilated to the outside through high-efficiency air filters, there is little radioactive contamination, except for particulate material. These particles are trapped by filters in the ventilation system and cannot reach the outside environment. Some contaminated particles cling to the protective clothing that workers wear, and this leaves the reactor building on the clothing. Even so, virtually none of this material reaches the environment outside the building because of stringent controls on how this clothing is handled in the changing area where workers remove their protective garments.

Q.92. Are explosions possible during any part of the cleanup?

A. There is virtually no possibility of an explosion associated with the cleanup. Of course, the potential always exists that a hose under high pressure could burst, something that would be hazardous to workers in the immediate vicinity. Also, there has been concern about the possibility of a pyrophoric explosion.

Q.93. What are pyrophoric explosions?

A. Pyrophoric explosions result from the extremely rapid burning of very reactive metals. For example, metallic sodium undergoes pyrophoric burning (or explosion) in air or if wet. Less-reactive metals, such as aluminum, magnesium, and zirconium, will undergo pyrophoric reactions if they are finely powdered.

The zirconium tubes that surround the uranium fuel could undergo pyrophoric reactions if exposed to air, although the tubes are now under water and will remain there throughout the cleanup. (Wet particles may undergo pyrophoric reactions when exposed to air, but such reactions do not take place under water.) However, this possibility was investigated. Tests were also made on samples of reactive metals taken from the structures near the top of the reactor vessel. Based on the results of these investigations and tests, such explosions are considered highly unlikely. Nevertheless, workers will perform fuel removal tasks very carefully to avoid even the small chance of such an explosion.

Q.94. What radiation dose is received by truckers who haul radioactive waste from TMI to waste disposal locations?

A. Truck drivers who haul radioactive waste are radiation workers and are subject to the same NRC dose limitations as other radiation workers (see Question 27). In addition, the U.S. Department of Transportation (DOT) limits the dose rate in the driver's seat of any vehicle hauling radioactive material to 2 millirem per hour. For a trip of 2300 miles from TMI to Richland, Washington, the driver might spend up to 60 hours in the truck cab, thereby receiving 120 millirem on the trip. The return trip most likely would not involve the transportation of radioactive material.

For an extreme case, consider a truck driver who spends 2000 hours per year driving, half of that hauling radioactive material, with the maximum allowable dose rate of 2 millirem per hour in the cab. The driver would receive at most 2,000 millirem (2 rem) per year, a dose well below the NRC guideline of 5 rem.

Q.95. What are the potential adverse health effects these doses could result in?

A. The risk to a truck driver receiving 2 rem per year for 9 years would be approximately ½ the risk to the worker we discussed in Question 39, or about a 1 in 420 chance of premature death from cancer.

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