UNITED STATES
NUCLEAR REGULATORY COMMISSION
ATOMIC SAFETY AND LICENSING BOARD PANEL
WASHINGTON, D. C. 20555

September 21, 1977

MEMORANDUM FOR: James R. Yore, Chairman
Atomic Safety and Licensing Board Panel

FROM: Walter H. Jordan, ASLBP

SUBJECT: ERRORS IN 10 CFR §51.20, TABLE S-3

Licensing of a nuclear power plant includes a consideration of the environmental costs of building and operating the plant. This includes the environmental costs of the fuel cycle such as mining, milling, fabrication of fuel elements and waste disposal. These costs have been summarized in Table S-3 of 10 CFR §51.20(e), revised*.

One section of the table deals with radiological effluents. The quantity of radioactivity discharged is given in curies for each important nuclide and is stated as being the total amount emitted "per annual fuel requirement or reference reactor year." For example, the maximum quantity of Kr-85 that might be released to the atmosphere as a consequence of operating a reference reactor (1000 MWe, 80% capacity factor) for one year would be 400,000 curies and would be released from the plant that reprocesses

* 42 F.R. 13803, March 14, 1977

the fuel. The table includes $1.1 \times 10^7$ curies of high-level wastes (to be buried at a Federal Repository) that would be generated for each reference reactor year (RRY) of operation. With one exception the figures given do indeed conservatively state the total amoun of radioactivity that would be released as gas, liquid, or solid as a consequence of operating a reference power plant for one year or alternatively as a consequence of mining and milling the quantity of uranium required to fuel such a plant for one year, the so called annual fuel requirement (AFR).

The one important exception has to do with the quantity of Rn-222 where the figure given is "74.5 curies. Principally from milling operations and excludes contribution from mining". This figure is in error. The correct value would be some 100,000 times greater! The technical basis for my conclusion will be discussed in a later section, but is based on the fact that a mill tailings pile continues to emit radon for thousands of years.

The curie quantity for Rn-222 appeared in the original S-3 Tables and remain unchanged in the March 10, 1977 revision of the Table. However, the footnote 5 of the revised table is new and also contains an important error. The penultimate sentence states (accurately I believe) that "... (NUREG-0002) indicates a maximum release of about

4800 Ci of Rn-222 when contributions from mining are included." This is indeed the total from the mining of one "annual fuel requirement" that is emitted during the approximately 25-year life of the mine. At the end of the life of the mine it will be sealed and no further radon emitted.

The final sentence of footnote 5 is incorrect. It reads as follows: "NUREG-0002 also indicates that mining contributes about 500 person-rem (total body) and that milling contributes about 100 person-rem (total body) of a total of about 610 person-rem (total body) to offsite U. S. population per annual fuel requirement." I have no quarrel with the dose from mining. But there is no justification for limiting the dose from tailings piles to that from radon emitted during the period of 1975 to 2000. The dose figure integrated appropriately into the future would be more nearly 10 million person-rem taking into account the long half-life of the parent nuclide of radon, as will be shown later.

The source of the error for the quantity of radon emitted per AFR is apparent. It was copied from Table S-3 of WASH-1248 (reprinted as the last two pages of NUREG-0116, supplement to WASH-1248). WASH-1248 was the AEC Staff

testimony in the rulemaking hearing RM-3 and somehow the error was not caught at that time.

The error in footnote 5 is surely due to misapplication of the data in Table VIII (A)-6 from GESMO, also reprinted in NUREG-0116 and corrected in NUREG-0216.

TECHNICAL CONSIDERATIONS

NUREG-0002 is concerned with the environmental consequence of the operations of light water reactors for electric power production during the period from 1...5 to year 2000. The authors assume that the installed nuclear capacity will grow from 45 GWe in 1975 to about 500 GWe in the year 2000. They assume that the reactors will operate at 80% capacity and will produce a total of some 4700 GWe-year of electric energy during the 26-year period. This will require the mining of $1.60 \times 10^9$ MT of ore which can be converted into about $1.50 \times 10^6$ MT of $U_3O_8$; the ore mined is assumed to have a uranium concentration of 0.1%. The production of 4700 GWe-year of electricity will require 5875 reference reactor years of operation, since the reference reactor operates at 80% capacity.

Table VIII (A)-6 from NUREG-0002 (reproduced in NUREG-0116) gives the total amount of Rn-222 emitted during the 26-year period as a consequence of the mining and milling

of $1.6 \times 10^9$ MT of ore. The quantity of Rn-222 from mining is $2.4 \times 10^7$ Ci: from milling is $4.1 \times 10^6$ Ci for a total of $2.84 \times 10^7$ Ci. If this quantity is apportioned equally to each of the 5875 annual fuel requirements (AFR) the result is

4085 Ci per AFR from mining
750 Ci per AFR from milling
4835 Ci per AFR total

Presumably this is how the figure of 4800 Ci was arrived at in footnote 5 to Table S-3.

I would suggest that footnote 5 be changed to show only the 4085 Ci from mining. Since the mines are closed and radon emission stopped it is logical to apportion the total emitted during the life of the mine among the number of AFRs mined. The correct procedure for apportioning the radon from milling is different as will be seen shortly.

The last sentence of footnote 5 to Table S-3 deals with the offsite doses due to radon. Again, the origin of the numbers shown is apparent but the logic is faulty. Table VIII (A) G shows the following dose commitments to offsite U. S. population

Total body dose - mining -- $3.0 \times 10^6$ person-rem
Total body dose - milling -- $5.8 \times 10^5$ person-rem

If these numbers are divided by the 5875 AFRs mined during the 26 years one obtains 510 person-rem from mining and 100 person-rem from milling as stated in the footnote.

Again, I suggest that only the dose from mining be retained in the footnote inasmuch as the 106 person-rem from milling is grossly in error.

Let us now consider how to treat properly the radon from the tailings piles associated with the uranium mills. Although the mill recovers most of the very long lived uranium from the ore, the Th-230 which was in radioactive equilibrium with the uranium is returned to the tailings piles. Consequently the Rn-222, a daughter of Th-230 is continually generated in the tailings pile and will diffuse to the surface of the pile and escape into the atmosphere. Since Th-230 has a half-life of about 80,000 years the tailings pile becomes a long lived source of radon. Therefore the total amount of Rn-222 that is emitted by 2.7 x $10^5$ MT of tailings (approximately that associated with 1 AFR) becomes a very large number when integrated over the radioactive life of Th-230. NUREG-0002 does not include that number, however, it does estimate that the amount of Rn-222 that would be emitted <u>each year</u> from the 1.6 x $10^9$ MT of tailings in piles at the end of this century would be about 420,000 Ci, assuming a 2-foot thick earth cover over the piles. If this number is divided by the 5875 AFRs which produced the piles, one arrives at a figure of 71 Ci/yr. This is numerically near the 74.5 Ci figure of Table S-3 --

hence changing that table from "Ci per AFR" to "Ci/yr per AFR" might be the easiest way out. The total amount of per AFR over all future years would be 71 x 1.44 x 80,000 ≈ 8,000,000 Ci, and is the proper figure to show in Table S-3 if the units are not changed.

Since the radon continues to seep from the tailings pile for a very long time, the total dose to people over all future generations could become very large. Deaths in future generations due to cancer and genetic effects resulting from the radon from the uranium required to fuel a single reactor for one year can run into the hundreds. (See Pohl, Search, Vol. 7 No. 8, Aug. 1976). It is very difficult to argue that deaths to future generations are unimportant. But it can be shown that the number is insignificant compared to those due to the radon contribution in natural background.*

In summary the values given in Table S-3 for the amount of Rn-222 emitted per annual fuel requirement is grossly in error. So also is the dose to offsite population from milling due to one annual fuel requirement -- the correct number is more nearly 10 million person-rem rather than 100 person-rem.

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* NUREG-0002 (Vol. 1. p-30) points out that by the year 2000, the radon release rate from tailings piles would be less than 0.3% of the radon released annually from the soil of the United States.

I would suggest that emission be given in curies per year per ADR; that doses be expressed in person-rem per generation per annual fuel requirement.

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