UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matters of:	)	
	)	
PHILADELPHIA ELECTRIC COMPANY et al.	)	Docket Nos. 50-277
	)	50-278
(Peach Bottom Atomic Power Station, Units 2 and 3)	)	
	)	
METROPOLITAN EDISON COMPANY et al.	)	Docket No. 50-320
	)	
(Three Mile Island Nuclear Station, Unit No. 2)	)	
	)	
PUBLIC SERVICE ELECTRIC AND GAS CO.	)	Docket Nos. 50-354
	)	50-355
(Hope Creek Generating Station, Units 1 and 2)	)	
	)	
ROCHESTER GAS AND ELECTRIC CORPORATION et al.	)	Docket No. STN 50-485
	)	
(Sterling Power Project, Nuclear Unit 1	)	

NRC STAFF TESTIMONY
OF RALPH M. WILDE

(Reclamation of Worked Out Uranium Mines and Long-Term Radon Releases from Worked Out Uranium Mines - Alleged Deficiencies Nos. 3, 4, and 5)

I am Program Assistant to the Director, Division of Fuel Cycle and Material Safety, Nuclear Regulatory Commission. A Statement of My Professional Qualifications appears in the Perkins[1/] record (Fg. Tr. 2369).

[1/] Duke Power Co. (Perkins Nuclear Station, Units 1, 2 and 3), Docket Nos. STN 50-488, 50-489, and 50-490. All transcript references in this testimony are from the Perkins record.

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This testimony addresses certain alleged deficiencies which the intervenors in these proceedings had asserted as to the Perkins record. Specifically, I have reviewed and analyzed alleged deficiencies Nos. 3, 4, and 5 as well as the Intervenor's Response to Applicants' Joint Motion for Summary Disposition concerning these alleged deficiencies. The results of my analysis are set forth in this testimony and show that the above asserted deficiencies in the Perkins Record are without foundation.

Introduction

In ALAB-562 the Appeal Board, in part, denied the motions for summary disposition of twelve of the twenty-six alleged deficiencies which the Tyrone and Sterling intervenors had asserted as to the Perkins record. The Appeal Board grouped the twelve deficiencies for which summary disposition was denied into five categories according to their general subject matter and summarized those areas where factual disputes appear to remain. The Appeal Board summaries of the two subject areas that encompass alleged deficiencies Nos. 3, 4, and 5 are set out below.[2/]

2. Underground Mines The record does not indicate the extent to which abandoned underground mines can and will actually be "sealed." Moreover, we cannot determine at present the extent to which an

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[2/] Numbering is from ALAB-562.

unsealed mine could continue to emit radon through, for example, natural convection (Deficiency No. 3[3/]).

3. Open Pit Mines There is uncertainty over the rate of emissions from both unreclaimed and reclaimed open pit mines. In particular, releases from unreclaimed mines may be higher than expected, due to

3/This alleged deficiency asserts that: "In the long run, radon emissions depend on the extent to which underground [mines] are sealed and open pit mines are reclaimed. The NRC has no jurisdiction over mines. In Perkins Staff and Applicant wittnesses (sic) refered (sic) to state laws which require sealing and reclamation as adequate to insure the cessation of emissions after mine's (sic) useful lives. In testimony on June 27, 1978, before the House Subcommittee on Energy and Environment, Betty Perkins from the New Mexico Energy and Mineral Department, indicated in New Mexico abandoned mines have been improperly sealed, have contaminated the soil, and have left ore storage piles exposed. Measurement at abandoned mines shows gamma radiation levels 10 to 100 times above background, a fact which demonstrates the existence of radiologic pathways for radon. In view of the actual facts regarding abandoned mines, it is incumbant (sic) upon the NRC to make a detailed examination of the statutory standards imposed on the operators of mines, the penalties fro (sic) failure to comply with such standards, and each state's enforcement experience before leaping to unwarranted conclusions regarding the efficacy of state regulation of mines."

the physical rearrangement of overburden as it is replaced in the pit (Deficiencies Nos. 4[4/] and 5[5/]).

[4/] This alleged deficiency asserts that: "The testimony in Perkins regarding emissions from open pit mines is extremly (sic) sketchy. Mr. Wilde at page seven of his affidavit states, "For open pit mines ... there is just no reliable information available upon which to base estimates of radon release." Pages 2543 through 2558 Of (sic) the transcript enumerate many of the uncertainities (sic) regarding emissions from open pit mines. Nevertheless, at page 2610 of the transcript, Mr. Wilde performs a "quick and dirty" computation of emissions using a model open pit mine. He makes what is an apparently completely arbitrary choice of a mine which covers one square mile. He computes a release of 100 curies/yr/AFR. Apparently the Board in Perkins was somewhat skeptical about Mr. Wilde's calculation since in paragraph 13 of the Perkins decision the rate of emission from open pit mines was doubled to 200 curies/yr/AFR.

The Sweetwater DES indicates a release rate of 6090 curies per year. The Sweetwater mine will have a capacity sufficient to produce 410 MT yellow cake per year during its estimated 15 year life. Using the Staff figure of 245 MT yellow cake per AFR would result in an annual release rate for the Sweetwater mine of approximately 250 curies/yr/AFR. This is another example of the actual facts deviating from the Staff's assumptions regarding radon emissions."

[5/] This alleged deficiency reads as follows: "Also with respect to open pit mines, the Perkins record gives no consideration to emissions from overburden. Testimony before the Senate Subcommittee on Energy Production and Supply on July 24 and 25, 1978, indicates the overburden has a volume of 8 to 35 times the volume of the mine. Therefore all of the overburden cannot be returned to the mine. The overburden has as much as 10% of the radioactive concentration of mill tailings. South Dakota, with a mine reclamation law on the books, has former mining areas that are now sterile and bare. The overborden (sic) has been indiscriminately piled on the landscape just like mill tailings."

The two subject areas specified by the Appeal Board both involve the issues of reclamation of worked out mines, that is, the refilling of open pit mines and the sealing of underground mines, and the potential for long-term release of radon from worked out mines.

In order to respond to the issues at hand, the following questions should be addressed:

- Can worked out mines be reclaimed?
- Will worked out mines be reclaimed?
- What is the staff's current estimate of the long-term radon release from reclaimed mines?
- What is the staff's current estimate of the long-term radon release from unreclaimed mines?

The answers to some of these questions are straightforward and are supported by an adequate data base. However, some of the answers require extrapolation from or interpretation of existing data and the application of professional judgment. I address each of these questions in the following discussion.

Discussion

- Can worked out mines be reclaimed?

When an open pit mine is worked out, the overburden or waste rock can be returned to the pit from which it was removed. The top soil can be replaced and vegetation reestablished if appropriate for the intended future use of the

site. When an underground mine is worked out, the hoisting and ventilation shafts of the mine can be sealed by filling them with overburden, waste rock or soil. An additional seal may be provided by placing a concrete plug in the collar of the shafts.

It is, therefore, my opinion that the technical feasibility of reclaiming worked out mines has already been adequately demonstrated.

o Will worked out mines be reclaimed?

The responsibility for the promulgation and enforcement of reclamation regulations for uranium mines rests primarily with the State in which the mines are located. In one State, New Mexico, the U.S. Geological Survey, through an agreement with the U.S. Bureau of Indian Affairs,[6/] has assumed responsibility for defining and enforcing reclamation requirements on Indian lands. The U.S. Nuclear Regulatory Commission presently does not have Congressional authority to regulate either uranium mining or mine reclamation.

The actual regulation of reclamation for uranium mines varies from State to State. Some States have extensive regulations and others have few or no State-imposed regulations. Similarly, enforcement of and compliance with reclamation regulations varies considerably from State to State.

Thus, because the NRC has no authority under present law to regulate reclamation of uranium mines and because regulation and enforcement of reclamation requirements

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[6/] Both of these agencies are constituent parts of the Department of the Interior.

by the States is not uniform, the NRC cannot give absolute assurance that all worked out uranium mines will be reclaimed. The staff, therefore, is providing in this testimony, estimates of the radon releases from both reclaimed and unreclaimed mines.

- What is the staff's current estimate of the long-term radon release from reclaimed mines?

In the Perkins proceeding, I noted that various efforts were underway to upgrade the data base for radon releases from uranium mines (Wilde p. 7, Fg. Tr. 2369). Two interim reports providing updated information from ongoing research projects on the subject of radon releases from uranium mines have now been published by Battelle Pacific Northwest Laboratory (BPNL). These are: NUREG/CR-0627 (PNL-2888 REV.) September 1979, "Radon Emissions in Ventilation Air Exhausted from Underground Uranium Mines,"* and NUREG/CR-0628 (PNL-2889 REV.) September 1979, "Prediction of Net Radon Emission from a Model Open Pit Mine." These reports provide recent information on radon exhalation rates and also analyses of current and projected mining methods and practices which were used to develop mine models and radon releases both for the period of active mining and for the period after the mines are shutdown. Therefore, we now

*NUREG/CR-0627 is currently being revised to include the latest information that is available from this ongoing research project. It is anticipated that the revised report will be issued by February 1, 1980. Preliminary information now available from BPNL (copies of which have been furnished to the Appeal Board and parties) indicates that the radon release from underground mines per reference reactor year (RRY) may be as much as 50 to 60% greater than previously reported. I expect to be in a position to testify concerning this latest information at the evidentiary hearings which are presently scheduled to commence on February 26, 1980.

have available a much improved data base for predicting the long-term release of radon from worked out mines that have been reclaimed. This improved data base has been used to develop the estimates given below.

In NUREG/CR-0628, the status of the model open pit mine, at the end of its active mining period, is assumed to be a compromise between the completely reclaimed mines anticipated for many present and future mining operations and the abandoned and unreclaimed open pits left by many past mining operations. Approximately 85% of the model open pit mine volume has been refilled with overburden (20 ppm U_3O_8) and the balance of the overburden, approximately 15%, remains as a pile on the surface. There is also a surface pile of subore (150 ppm U_3O_8). This subore represents material containing uranium which is of insufficient grade to be economically useful at the present time and is commonly set aside from overburden for possible future use. This model of a reclaimed open pit mine projects radon emanation from overburden fill in six pits, subore and overburden exposed in the last unfilled pit, and subore and overburden dumps piles. These sources contribute to the long-term radon release of approximately 40 Ci/year per Reference Reactor Year (RRY) (271 MT U_3O_8)[7/] during the post-mining period of a reclaimed open pit mine.

In NUREG/CR-0627 it is assumed that shafts of underground mines will be sealed and that with proper sealing, the radon emission rates from worked out underground

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7/ Size of RRY assumed for Perkins (Wilde, pp. 4 and 5, Fg. Tr. 2369). It should be pointed out that in the Perkins record the RRY is presented in terms of 2.71×10^5 MT of uranium ore containing 0.1% U_3O_8. From this information one can calculate the value of an RRY in terms of MT U_3O_8 as follows: (2.71×10^5 MT uranium ore) (0.1% U_3O_8) = 271 MT U_3O_8.

mine shafts will be a negligible fraction of the rate during active mining. A small amount of waste rock (250 ppm U_3O_8) that remains on the surface will be the principal source that will contribute to long-term radon release of approximately 20 Ci/year per RRY (271 MT U_3O_8) during the post-mining period of a reclaimed (sealed) underground mine.

On the basis of the information now available from the BPNL interim reports, the staff believes that it has an adequate data base from which to predict the long-term radon release during the post-mining period of reclaimed open pit and underground uranium mines. The staff's current estimate for this release is based on: data from NUREG/CR-0627 and NUREG/CR-0628, an RRY of 271 MT U_3O_8 for uranium mining, and a projected distribution of U_3O_8 production of 60% from underground mines and 40% from open pit mines. On these bases, it can be shown that the long-term release of radon from reclaimed mines is approximately 25 to 30 Ci/year per RRY.

- What is the staff's current estimate of the long-term radon release from unreclaimed mines?

The BPNL reports, NUREG/CR-0627 and 0628, do not explicitly estimate the long-term radon releases from abandoned, unreclaimed mines. However, the information in these reports can be used to make such estimates as is explained below.

By using the model open pit mine parameters given in NUREG/CR-0628 and by simply considering that none of the worked out pits are refilled, an estimate

of the long-term radon releases from unreclaimed mines can be obtained. This model of an unreclaimed open pit mine projects radon emanation from the overburden and subore exposed in seven unfilled pits, seven overburden piles, and a subore pile. For ease of comparison, these data are presented in the following Table A in a manner analogous to Table V of NUREG/CR-0628.

Table A

Radon Emissions from Unreclaimed Model Open Pit Mines

Source	Area (m^2)	(ppm U_3O_8)	Emission Rate (Ci/yr)
Abandoned pits			
Subore exposed in pits	$7(5.85 \times 10^4)$	150	565
Overburden exposed in pits	$7(8.86 \times 10^5)$	20	1141
Dump piles			
Subore pile	2.02×10^5	150	279
Overburden piles	$7(9.45 \times 10^5)$	20	1217
Total Radon Emissions			3202
Undisturbed surfaces eventually affected by mining	1.21×10^7	4	-445*
Net Radon Emissions Due to Mining			2757

*This represents natural background emissions.

NUREG/CR 0628 states that the model mine will have produced 9620 MT U_3O_8 during its 17-year lifetime. Therefore, the emission of 2757 Ci/year represents a long-term radon release of approximately 80 Ci/year per RRY (271 MT U_3O_8) during the post mining period of an unreclaimed open pit mine (see calculation below).

$$\frac{(2757\ \text{Ci/yr})(271\ \text{MT}\ U_3O_8/\text{RRY})}{9620\ \text{MT}\ U_3O_8} = 78\ \text{Ci/yr per RRY}$$

The estimation of radon releases from abandoned, unsealed underground mines presents a much more difficult problem. The phenomenon that would result in radon release from an unsealed underground mine is natural convective ventilation. This is the air circulation caused by the variation of air density with temperature and the action of gravity. The amount of air flow induced by convection is primarily dependent on the difference in elevation between the openings of a mine and the temperature difference between air inside and outside of the mine. Even within a single mine the air flow induced by convective ventilation will be neither constant in volume nor consistent in direction. Thus, it would be extremely difficult, if not impossible, to predict, with any degree of accuracy, the radon release from an individual unsealed underground mine and even more difficult to make such a prediction for underground mines in general.

However, by making certain assumptions and using radon release and U_3O_8 production data from NUREG/CR-0627 it is possible to postulate a model that may be used to make an estimate of an upper range value for the radon release from an unsealed underground mine as is explained below.

As stated in NUREG/CR-0627, the model underground mine produces 285 tons U_3O_8/year. At the end of its 20-year estimated lifetime the model mine will have produced 5700 tons U_3O_8 (5170 MT U_3O_8).

It is assumed that the amount of radon released under conditions of natural convective ventilation from the unsealed shafts of a worked out mine will be the same as that released from an active mine under conditions of forced ventilation.

In addition to the release of radon from the mine shafts, there will also be a continuing release of radon from waste rock stored above ground.

The total and net releases of radon from an abandoned underground mine as defined above are summarized in the following Table B:

Table B

Radon Releases from Abandoned Model Underground Mine

Source	Emission Rate Ci/yr
Release from unsealed shafts	4532
Release from wastes on surface	376
Total Radon Releases	4908
Natural background emissions from surfaces affected by mining	-6
Net Radon Release Due to Mining	4902

Since the model mine will have produced 5170 MT U_3O_8 during its 20-year lifetime, the release of 4902 Ci/yr represents a long-term release of approximately 260 Ci/yr per RRY (271 MT U_3O_8) during the post mining period of an abandoned underground mine with unsealed shafts (see calculation below).

$$\frac{(4902 \text{ Ci/yr})(271 \text{ MT } U_3O_8/\text{RRY})}{5170 \text{ MT } U_3O_8} = 257 \text{ Ci/yr per RRY}$$

It should be clearly understood that the foregoing estimation of radon release from abandoned underground uranium mines involves extrapolation from established data to a somewhat hypothetical conclusion. There are limitations and uncertainties in this analysis and for this reason, there are certain caveats that should be explicitly stated at the outset.

In the BPNL study, radon release rates were determined for several active underground mines under conditions of forced mechanical ventilation. Under these conditions, that is, continuous operation of the ventilation fans and high air flow rates, all of the radon emanating within a mine is promptly discharged from the ventilation shafts to the atmosphere. The BPNL study, therefore, provides an estimate of the quantity of radon that is emitted within underground mines and which is available for release to the atmosphere by either forced ventilation or natural convective ventilation.

The BPNL data show a good correlation between the quantity of radon emitted within a mine and the cumulative tons of ore which have been extracted from a mine. From this it may be inferred that radon emission will increase as more ore is extracted and will reach a maximum when a mine is worked out at the end

of its active lifetime. However, the BPNL data for the radon released from a model underground mine have been used directly with no adjustment for increase in radon emission with mine age.

It is implicit in the assumptions made for estimating the radon release from abandoned underground mines that the air flows induced by natural convective ventilation will be sufficiently large to exhaust to the atmosphere all of the radon that is emitted within a mine before a significant fraction of that radon has been lost by radioactive decay. It is inconceivable that such a condition could exist in an actual underground mine. The forces which drive convective ventilation are simply too small to induce the large air flow rates needed to satisfy this assumption.

There are also other factors that will tend to restrict or prevent air flow. The workings of many underground mines are located below the water table and water must be pumped continuously from the mines to keep them dry. When such a mine is abandoned and pumping is stopped, the water level will rise and flood the mine workings and restrict or preclude underground air flow and radon release to the atmosphere. Caving and collapse of workings and shafts will occur in abandoned mines which will also restrict or preclude air flow through the mine.

Considering the foregoing, it is my opinion that the estimate of 260 Ci/yr per RRY for the long-term radon release from abandoned unsealed underground mines is conservatively high and that actual releases will be appreciably less.

The staff's current estimate of a conservative upper range value for the long-term radon release during the post mining period of unreclaimed open pit and unsealed underground uranium mines is approximately 180 to 190 Ci/year per RRY. This estimated release is based on: the data developed above, an RRY of 271 MT U_3O_8 for uranium mining, and a projected distribution of U_3O_8 production of 60% from underground mines and 40% from open pit mines.

In the following summary, Table C, the staff's current estimates of the long-term radon releases from worked out uranium mines are compared with the staff's estimates of same radon releases as given in Perkins.

Table C

Staff Estimates of Radon Releases from Worked Out Uranium Mines

	Current Estimates Ci/year per RRY	Perkins Estimates Ci/Year per RRY
Reclaimed Open Pit Mines	40	none given
Unreclaimed Open Pit Mines	80	100[8]
Sealed Underground Mines	20	0[9]
Unsealed Underground Mines	260	0[10]
Combined Uranium Mining Industry		
Lower Range Value	25 to 30	none given
Upper Range Value	180 to 190	none given

[8] TR. 2609-2613.
[9] Tr. 2542.
[10] Tr. 2542.

The staff's current estimate of radon release from unreclaimed open pit mines is slightly smaller than, but not significantly different from, that given in Perkins.

The small increase in the staff's current estimate of radon release from sealed underground mines, 20 Ci/year per RRY, is attributable to a previously neglected source of radon emission, namely, a small amount of waste rock that remains on the surface when an underground mine is worked out.

The staff's current estimate of radon release from unsealed underground mines, 2. i/year per RRY, is made up of two components. The 20 Ci/year per RRY from waste rock stored on the surface and the hypothetical release of 240 Ci/year per RRY from unsealed mine shafts. It is my opinion, as stated earlier in this testimony, that the estimate of 260 Ci/year per RRY for the long-term radon release from abandoned unsealed underground mines is conservatively high and that actual releases will be appreciably less. In my judgment, the actual radon release from such mines will be much closer to 20 Ci/year per RRY than 260 Ci/year per RRY.

Conclusion

In the Perkins proceeding, I provided information concerning the long-term radon release from worked out uranium mines (Tr. 2541-2542 and 2609-2613). Some additional information was provided by Perkins applicant's witness Dr. Morton Goldman (Tr. 2639-2640). Based on this information, the Perkins Licensing Board in their Partial Initial Decision, Environmental Consequences of the Uranium Fuel

Cycle, adopted a value of 100 Ci/yr/AFR (RRY) for the long-term release of radon from worked out uranium mines.[11/] This value is near the mid-point of the range of the staff's current estimates for this release (lower range value of 25 to 30 Ci/year per RRY, upper range value of 180 to 190 Ci/year per RRY). Furthermore, the value of 100 Ci/year per RRY, adopted by the Perkins board is, in my opinion reasonable and conservative and would be supported by the staff today. To put it another way, the staff's current estimate of the long-term radon release from worked out uranium mines is not significantly different from the value adopted by the Perkins Licensing Board.

11/ Perkins Partial Initial Decision, Paragraphs 11, 12, and 13, (pages 6, 7 and 8).