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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	
CONSOLIDATED EDISON COMPANY OF NEW YORK, INC. (Indian Point Unit 2)	Docket Nos. 50-247-SP 50-286-SP
POWER AUTHORITY OF THE STATE OF NEW YORK (Indian Point Unit 3)	7 February 1983

UCS/NYPIRG TESTIMONY OF STEVEN C. SHOLLY ON THE CONSEQUENCES OF ACCIDENTS AT INDIAN POINT
(Commission Question One and Board Question 1.1)

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Q.01 Please state your name, your position, and your business address.

A.01 My name is Steven C. Sholly. I am a Technical Research Associate with the Union of Concerned Scientists. My business address is Union of Concerned Scientists, Dupont Circle Building, 1346 Connecticut Avenue, N.W., Suite 1101, Washington, D.C. 20036.

Q.02 Have you prepared a statement of professional qualifications?

A.02 I have prepared a statement of professional qualifications which is attached to this testimony.

Q.03 To which Commission Question in this proceeding is your testimony addressed?

A.03 This testimony addresses in part Commission Question One and Board Question 1.1. Commission Question One states as follows:

"What risk may be posed by serious accidents at Indian Point 2 and 3, including accidents not considered in the plants' design basis, pending and after any improvements described in (2) and (4) below? Although not requiring the preparation of an Environmental Impact Statement, the Commission intends that the review with respect to this question be conducted consistent with the guidance provided the Staff in the Statement of Interim Policy on 'Nuclear Power Plant Accident Considerations under the National Environmental Policy Act of 1969;' 44 F.R. 40101 (June 13, 1980)."*

* "In particular, that policy statement indicates that:

Attention shall be given both to the probability of occurrences of releases and to the environmental consequences of such releases;

The reviews 'shall include a reasoned consideration of the environmental risks (impacts) attributable to accidents at the particular facility or facilities. . .';

'Approximately equal attention should be given to the probability of occurrence of releases and to the probability of occurrence of the environmental consequences. . .'; and

Such studies 'will take into account significant site and plant-specific features. . .'

Thus, a description of a release scenario must include a discussion of the probability of such a release for the specific Indian Point plants."

Board Question 1.1 states as follows:

"What are the consequences of serious accidents at Indian Point and what is the probability of occurrence of such accidents? In answering this question the parties shall address at least the following documents: (a) the <u>Indian Point Probabilistic Safety Study</u> (IPPSS) prepared by the Licensees; (b) the Sandia Laboratory "Letter Report on Review and Evaluation of the Indian Point Probabilistic Safety Study" (Letter Report), dated August 25, 1982; and (c) any other reviews or studies of the IPPSS prepared by or for the Licensees, the NRC Staff, or the Intervenors, or any other document which addresses the accuracy of the IPPSS."

Q.04 What are the purposes of this testimony?

A.04 My testimony reviews the consequence model known as CRACIT and its application to the calculation of the consequences of accidents at Indian Point as set forth in the Indian Point Probabilistic Safety Study (IPPSS). The testimony also reviews the consequence models known as CRAC and CRAC2 and their application to the calculation of the consequences of accidents at Indian Point. The testimony identifies areas of uncertainty in the calculation of accident consequences for Indian Point, omissions in the consequence calculations are noted, and where possible conclusions are reached as to the impact of these uncertainties and omissions on the risk posed by Indian Point Units 2 and 3.

Q.05 Would you briefly summarize the history to date of reactor accident consequence analysis?

A.05 The first major study of reactor accident consequences was carried out for the Atomic Energy Commission by Brookhaven National Laboratory and was published in March 1957. The report, WASH-740, constituted an "upper-bound" calculation of accident consequences for three types of highly stylied accident scenarios at a 500 MWt commercial nuclear reactor (of unspecified design) located at a hypothetical site [WASH-740].

The first comprehensive assessment of reactor accident consequences which modeled in detail the transport and dispersion of radioactive materials into the environment and predicted the resulting health and economic consequences was the Reactor Safety Study, WASH-1400, published in October 1975 [WASH-1400]. A major part of this study was the development of a set of models for use in predicting reactor accident consequences. The model has become known as CRAC, an acronym for Calculation of Reactor Accident Consequences.

CRAC is described in detail in Appendix VI of WASH-1400 and in more general terms in a separate NRC report, NUREG-0340 [NUREG-0340]. A draft user's manual for CRAC has been released by the NRC [CRAC]. After the release of WASH-1400, the NRC chartered a "Risk Assessment Review

Group" (RARG) chaired by Dr. Harold W. Lewis to review peer comments on the report. The RARG's review of CRAC is included in Section V of the group's September 1978 report [NUREG/CR-0400].

In response to criticisms of the CRAC model, the NRC contracted with Sandia National Laboratories to undertake a revision of the models in CRAC. The revised code, known as CRAC2, corrected known errors in the CRAC code, and made modifications to the atmospheric dispersion model, the protective response model, and the meteorological sampling model. A draft user's guide has been released by the NRC [CRAC2]. The CRAC2 model and the differences between CRAC and CRAC2 are described in Appendix E of the recent Sandia siting study [NUREG/CR-2239, Appendix E].

In addition to CRAC and CRAC2, other reactor consequence models have been developed. These include CRACIT (Pickard, Lowe, and Garrick, Inc.) and NUCRAC (Science Applications, Inc.). These and other reactor accident consequence models are being evaluated in an international benchmark exercise under the auspices of the Committee on the Safety of Nuclear Installations of the Nuclear Energy Agency, Organization of Economic Cooperation and Development. This exercise included application of a large number of consequence models to the solution of standard reactor accident consequence problems. The detail results from this project are due to be published in 1983, but some results have been reported in conference papers presented in 1981 [ALDRICH, 1981a; BLOND, 1981]. Recent developments in offsite accident consequence modeling werer reviewed in a recent paper published in <u>Nuclear Safety</u> [ALDRICH, 1981b].

Q.06 What factors principally determined the predicted consequences of an accidental release of radioactive materials to the environment?

A.06 In general terms, the predicted consequences of an accidental release of radioactive material are dependent on four main factors: (a) the source term; (b) the meteorological conditions coincident with and subsequent to the release; (c) the number of people exposed to the released material through various exposure pathways; and (d) the effectiveness of protective actions taken to mitigate the exposures. In terms of modeling accident consequences, once the source term is defined, the meteorological conditions and population magnitude and distribution are more or less fixed. It is in the modeling of protective actions that the predicted consequences that the consequence modeler can have the greatest influence on consequence estimates, particularly so with respect to early consequences which are modeled as threshold effects [NUREG/CR-2300, page 9-13; NUREG/CR-2239, page 2-23].

Q.07 What protective actions might be modeled which could mitigate the consequences of reactor accidents?

A.07 There are a variety of actions which might be taken depending upon the particular circumstances of a given accident. Among the most frequently discussed protection response options are evacuation, sheltering, relocation, interdiction, respiratory protection, and thyroid prophylaxis.

Q.08 What consequence model was used by the NRC Staff in the preparation of their testimony on accident consequences?

A.08 The NRC Staff used a version of the CRAC code (developed for WASH-1400) which has been modified to permit site-specific consequence calculations.

Q.09 How does the CRAC code model protective actions?

A.09 There are two protective action phases in the CRAC model, namely the acute exposure phase and the chronic exposure phase. For acute exposures (those in the first week of the accident), the principal protective actions modeled are evacuation, sheltering, and relocation. Evacuation is typically defined as the expeditious movement of people to avoid exposure to a plume. Sheltering is typically defined as the expeditious movement of persons indoors and, if possible, into structures of masonry construction and/or basements to take advantage of the shielding from radiation provided by such structures. Relocation is typically defined as the movement of exposed persons out of contaminated areas following passage of a plume [NUREG/CR-2239, page 2-38].

Evacuation modeling incorporates a delay time followed by evacuation radially away from the reactor at a constant speed. Shielding factors and breathing rates are selected by the modeler, and vary depending upon whether the population is stationary or in transit. The evacuating population is assumed to travel to a fixed distance, and are then removed from the problem. This allows for the possibility that evacuees could learn of their location relative to the plume and take steps to avoid prolonged immersion in the plume. This evacuation model ignores the possibility that some people might not leave the evacuation zone. It has been widely suggested that, on the basis of observations by Civil Defense personnel, a nonparticipating minority of approximately 5% might be expected. To the extent that the CRAC model neglects this phenomenon, application of the model results in an upper bound estimate of evacuation effectiveness for a given set of assumptions about delay time and evacuation speed [SAND78-0092; SAND79-0095].

Beyond the evacuation zone (assumed to be 10 miles in most applications), the population is assumed to take shelter. Relocation occurs within varying time limits depending upon the rate of exposure accumulated due to ground-deposited radionuclides.

Q.10 What accident consequence model was used in IPPSS?

A.10 The consequence calculations in IPPSS were carried out using CRACIT. CRACIT is a proprietary code developed by Pickard, Lowe, and Garrick, Inc., and is a modification of the NRC's CRAC code.

Q.11 How does CRACIT model protective actions?

A.11 The CRACIT model for protective actions is somewhat more detailed than the corresponding model in CRAC. In the application of CRACIT, doses are calculated only for those times in which the evacuation path (or stationary location) of the population is coincident with the plume trajectory. This level of detail is permitted in part due to the finer grid (as compared with CRAC) upon which the model is based.

IPPSS modeled five sets of population and evacuation data: (a) nighttime; (b) weekday-school-in-session; (c) weekday-school-out; (d) summer holiday; and (e) winter holiday. Evacuation is modeled to 10 miles from the site (i.e., the Plume Exposure Pathway Emergency Planning Zone).

Delay time before evacuation are considered for each grid location. A base delay time of one hour is assigned to each grid location for all scenarios except for weekday-school-in-session. For this scenario, twelve grid locations [IPPSS, page 6.2-9] are assigned a base delay time of 5.5 hours. To account for the possibility that portions of the grid may be delayed by more or less than the assumed base delay tiem, a subjectively-weighted probabilistic multiplier is applied according to the following schedule: (a) a 5% probability of a 0.5 multiplier; (b) a 15% probability of a 0.7 multiplier; (c) a 50% probability of a 1.0 multiplier; (d) a 15% probability of a 1.5 multiplier; and (e) a 15% probability of a 2.0 multiplier.

Further, to account for "communications failure" or "severe weather", an additional time delay is added once the base delay time is calculated by using the probabilistic multiplier. This additional delay is added according to the following subjectively-weighted schedule: (a) a 90% probability of no additional delay time; (b) a 7% probability of an additional delay of one hour; and (c) a 3% probability of an additional delay of two hours.

Transit time during evacuation was determined on a site-specific basis using an evacuation time study. Speeds in each "link" in the evacuation route model were determined individually.

Shielding factors were assigned as follows: (a) 1.0 and 0.5 for evacuees exposed to the plume and contaminated ground; (b) 0.75 and 0.33 for non-evacuees; and (c) beyond 50 miles, 90% of the population was assumed to be sheltered in basements and shielding factors of 0.5 and 0.08 for cloud and ground dose, respectively, were used, with the remaining 10% of the population having shielding factors of 0.75 and 0.33. In addition, CRACIT takes credit for an inhalation dose reduction for persons remaining indoors, but the precise nature of this dose reduction is not specified in IPPSS.

Q.12 What are the principal differences between CRAC and CRACIT?

A.12 The CRACIT code is generally described in Section 6 of IPPSS. The alterations made in modifying CRAC to create CRACIT are described in Section 6.1.2 of IPPSS. There are a number of differences between the two codes, but the three principal differences are: (a) CRACIT models changes in plume trajectory, whereas CRAC models straight-line plume trajectories; (b) CRACIT models evacuation as a set of vectors at a variety of speeds determined by analysis of the roadway network, whereas CRAC models evacuation radially away from the reactor site at a constant speed; and (c) CRACIT is capable of modeling releases in up to four separate phases, whereas CRAC models all releases as a "puff".

Q.13 Into what general areas do your criticisms of CRACIT as applied in IPPSS fall?

A.13 Based upon my review of IPPSS, I have identified criticisms of the CRACIT model and its application in IPPSS in the following five areas: (a) failure to consider the impact of hurricanes, earthquakes, and area-wide power failures on protective action feasibility; (b) questionable modeling assumptions; (c) omission of economic consequences and genetic effects from risk expressions for Indian Point; (d) modeling of uncertainties in the consequence analysis; and (e) the applicability to Indian Point of certain sensitivity studies using CRACIT.

Q.14 Referring to your first area of criticism of CRACIT as applied in IPPSS, have reactor risk studies other than IPPSS considered events such as earthquakes, hurricanes, and area-wide power failures?

A.14 Area-wide power failures are generally considered as accident initiators under the rubric of loss of offsite power. Most risk studies have not, however, considered "external events" such as earthquakes and hurricanes. In fact, probabilistic risk assessments (PRA's) of eight reactors performed in two NRC-sponsored programs (i.e., RSSMAP and IREP) explicitly excluded external events from consideration. In addition, the recent Limerick PRA excluded external events.

WASH-1400 and the Zion Probabilistic Safety Study considered external events to varying degrees. WASH-1400 discussed the probability of accidents caused by hurricanes and earthquakes, but concluded that these events contributed negligibly to risk [WASH-1400, Main Report, Section 5.4]. Thus, no modeling of the impact of these events on the implementation of protective actions was undertaken. WASH-1400 included loss of offsite power as an accident initiator, but did not explicitly consider the impact of such an occurrence on the implementation of protective actions. Indirectly, such events may have fallen under the category of events that led the Reactor Safety Study authors to assign a 30% probability of an effective evacuation speed of zero miles per hour. On the other hand, however, WASH-1400 also included the assumption that persons within the contaminated area within 25 miles were removed from that area after a four-hour exposure to ground-deposited radionuclides [WASH-1400, Appendix VI, Section 11].

Q.15 Why are hurricanes, earthquakes, and area-wide power failures significant in terms of modeling protective actions?

A.15 The PRA Procedures Guide [NUREG/CR-2300, page 10-3] generally indicates that consequence analyses for risk studies which include "external events" should reflect the effects of such events on the environment. In addition, the Sandia siting study recommends that when consequence models are applied to evaluate risk at specific sites, consideration should be given to characteristics of the site that could influence the effectiveness of emergency response [NUREG/CR-2239, page 2-9].

Hurricanes, earthquakes, and area-wide power failures are capable of both initiating an accident at Indian Point and impairing the ability of offsite authorities to implement one or more protective action strategies. All three of these events can involve area-wide loss of electrical power. Since the sirens that are intended to be used for prompt alerting of the offsite population are dependent upon the electrical grid, failure of the electrical grid causes failure of the siren alerting system. Earthquakes and hurricanes pose additional constraints to the implementation of protective actions depending upon their severity [DAVIS, 1982, page 6].

Q.16 How can earthquakes, hurricanes, and area-wide power failures impair protective response?

A.16 In the event of an area-wide power failure, the sirens intended for use in promptly notifying the public within the Plume EPZ to tune to an Emergency Broadcast System (EBS) station will not function. The effect of this failure will be to extend the time required for notification of the public of the need to take protective actions, which time is a component of the delay time before evacuation. This extended delay time will always occur in the event of an area-wide power failure, independent of the degree of planning and preparation for emergencies of offsite agencies and authorities. Thus, this scenario represents an exception to the CRACIT probabilistic model of delay time. Delay time can be significant in terms of its impact on consequence estimates; the PRA Procedures Guide notes that the choice of a delay time can cause "orders of magnitude" differences in estimates of "mean public risk" [NUREG/CR-2300, page 9-52].

Alerting the public in the event of an area-wide power failure will occur by chance (assuming that an EBS broadcast can be made, some fraction of the population will be listening on battery-powered radios and televisions), by route alerting (the use of vehicles mounted with loudspeakers to alert the offsite population), and by notifications involving friends, neighbors, and relatives (the effectiveness of the latter alerting method will be limited if the telephone system fails due to causes associated with earthquakes and hurricanes). The effect of the extended delay times associated with an area-wide power failure will be to give a wider range of delay times and also a different distribution of the delay times than assumed in the CRACIT model.

In addition to causing area-wide power failures, hurricanes and earthquakes can impose additional constraints on the implementation of protective response depending upon the severity of the event. For earthquakes, the loss of power could be compounded by the disruption of communications and the degradation of evacuation routes by debris and/or physical damage. For particularly severe earthquakes, evacuation may prove to be infeasible. Moreover, the availability of sheltering in basements may be limited. In typical consequence modeling practice, an average shielding factor is assumed. While sensitivity calculations have shown that the assumption of an average shielding factor introduces only small errors [NUREG/CR-2300, page E-14], in the specific application for modeling consequences of accidents that can be initiated by earthquakes, this assumption may not be justified. A prudent procedure might be to model a distribution of shielding factors (for accidents initiated by earthquakes) to account for the severity of the seismic event and its likely impact on shelter availability.

According to IPPSS [IPPSS, page 7.2-2], the maximum historical earthquake corresponds to Modified Mercalli Intensity Level VII, and the study conservatively raised this to Intensity Level VII. According to the updated FSAR for Indian Point 3 [FSAR UPDATE, Figure 2.8-1], MM-VIII intensity corresponds to the following description:

> "Damage slight in specially built structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars."

For seismic events of greater intensity, the effects become more severe than depicted above.

The range of delay times experienced in the event of an earthquake will be greater and the distribution different than assumed in the CRACIT model in IPPSS. For scenarios involving hurricanes, area-wide power failures could be accompanied by local flooding, high winds, and blockage of evacuation routes by debris, all of which could degrade the ability of offsite authorities to implement an evacuation.

Q. 17 How might the consequence estimates presented in IPPSS be affected by the omission of consideration of the impact of hurricanes, earthquakes, and area-wide power failures on protective response options?

A.17 Inasmuch as CRACIT is a proprietary code and not freely available (I am unaware of a model description or user's guide, other than information provided in IPPSS, which is in the public domain), it is difficult to be very precise about the impact of hurricanes, earthquakes, and area-wide power failures on the consequences calculated using CRACIT. One area which should be explored is the impact of delay times in excess of those modeled in IPPSS and/or the inability to implement evacuation at all (in the event of severe earthquakes or hurricanes) on the consequences estimated by CRACIT for Release Category 2RW.

Release Category 2RW involves a late overpressure failure of the containment as a result of a loss of heat sink and the consequent buildup of steam (perhaps exacerbated by long-term non-condensible gas buildup). The containment sprays are inoperable in this scenario. IPPSS concluded that Release Category 2RW made no contribution to early fatality risk for Indian Point [IPPSS, Section 5].

In the NRC Staff testimony on Question One, however, the Staff evaluated (using CRAC) Release Category C which they asserted was analogous to Release Category 2RW in IPPSS [MEYER & PRATT, page III.B-25]. The Staff concluded that Release Category C for Indian Point Unit 2 contributed 25% to the total site early fatality risk and that the same release category for Unit 3 contributed 14% to the total site early fatality risk. The Staff analysis assumes no evacuation and early relocation within 10 miles and later relocation outside 10 miles, with the availability of supportive medical treatment.

In addition, IPPSS presents CCDF data in Section 8 for Release Category 2RW if the source term for this release is arbitrarily doubled [IPPSS, page 8.5.8-4]. In this case, Release Category 2RW (with a doubled source term) is found to cause early fatalities. This result and the NRC Staff's independent consequence calculations suggest that the absence of early fatalities for Release Category 2RW in IPPSS is sensitive to modeling assumptions. The IPPSS analysis assumes that evacuation always occurs for Release Category 2RW due to the long "warning time" of 11 hours for this release [IPPSS, page 6.2-54]. Consideration of the impact of hurricanes, earthquakes, and area-wide power failures could impact contradict this assumption.

The CRACIT consequence estimates in IPPSS take credit for the beneficial aspects of a long warning time (11 hours) for Release Category 2RW, a delay time before evacuation not exceeding four hours (except for a fraction of the population in the weekday-school-in-session scenario), and an evacuation transit time not exceeding eight hours. IPPSS should have examined the detrimental aspects of the effect that hurricanes, earthquakes, and area-wide power failures could have on the implementation of protective actions. The quantitative difference in consequence estimates resulting from considering this factor should be evaluated using the CRACIT model in order to compare the results directly with those presented in IPPSS. Consideration of the impact of hurricanes, earthquakes, and area-wide power failures on the consequence estimates would be expected to have the greatest impact on acute (early) fatalities and early injuries.

Q.18 Moving to the next area of criticism of CRACIT and IPPSS that you hve identified, what are your criticisms of the modeling assumptions made in IPPSS?

A.18 I have identified the following modeling assumptions in CRACIT (as applied in IPPSS) that I believe to be questionable:

1. Use of evacuation transit times in IPPSS that are significantly shorter than those provided uncer some scenarios in the November 1981 Parsons Brinckerhoff estimates;
2. Use of the "supportive treatment" dose-response curve for acute (early) fatalities without comparing the potential need for this type of treatment with the resources available to implement the treatment;
3. Use of an optimistic "warning time" for Release Category 2RW;
4. Use of an unspecified dose reduction factor for inhalation doses by taking credit for a "ventilation

model" without justifying its use;

5. Use of 30-year plateau period for cancer induction, contrary to BEIR III recommendations and the cancer induction model in CRAC2;
6. Use of 1980 population data without assessing the impact on consequences of future population growth and possible changes in population distribution during the remaining operating lifetime of the plant; and
7. An assumption that a single year of meteorological data is adequate for consequence estimates.

Q.19 How are the evacuation transit times in IPPSS different from the November 1981 Parsons Brinckerhoff evacuation transit time estimates?

A.19 IPPSS modeled a range of evacuation transit times from two to eight hours. In contrast, the November 1981 Parsons Brinckerhoff [PBQD] report showed a much wider range of evacuation transit times under a variety of circumstances. The Parsons Brinckerhoff report presents both "lower bound" and "upper bound" transit time estimates. According to the report [PBQD, page 45], upper bound times are representative of a situation where:

1. "Capacity restrictions adversely affect traffic flow, but not to the point where a breakdown in traffic flow would result";
2. "A low state of operational readiness results from minimal mobilization of the emergency workforce"; and
3. "A low degree of cooperation from the public occurs".

Evacuation transit times for the 10-mile radius around Indian Point are presented for four 90-degree sectors, and for several population groups: (a) resident population with autos; (b) resident population without autos; (c) special facilities; and (d) transients. The evacuation transit times estimated by Parsons Brinckerhoff in the November 1981 report are:

A. SCHOOL IN SESSION, NORMAL WEATHER (Table 13)

SECTOR	RESIDENT POPULATION WITH AUTOS	WITHOUT	SPECIAL FACILITIES	TRANSIENTS
I	6:05-10:15	6:50-10:15	8:20-12:40	6:05-10:15
J	5:10- 8:15	7:40-10:40	7:15- 9:45	5:10- 8:15
K	6:55-11:40	7:15-12:00	7:55-12:15	6:55-11:40
L	5:30- 9:25	6:00- 9:50	5:50- 9:40	5:45- 9:40

B. SCHOOL IN SESSION, ADVERSE WEATHER (Table 14)

SECTOR	RESIDENT POPULATION WITH AUTOS	WITHOUT	SPECIAL FACILITIES	TRANSIENTS
I	12:40	12:40	15:25	12:40
J	10:15	12:55	11:55	14:30
K	14:30	14:50	15:10	14:40
L	11:40	12:05	11:55	11:50

(Adverse weather defined as a slippery roadway surface and/or reduced visibility.)

It is not clear that these evacuation transit times have been taken into account in the IPPSS estimates of accident consequences. IPPSS appears to have used a range of evacuation transit times which corresponds to the lower-bound results, while modeling the impact of adverse weather in terms of a maximum two-hour additional delay time. From the above, it is clear that this is a somewhat optimistic assumption. To the extent that actual transit times are longer than modeled. the early consequences (acute fatalities and early injuries) would be expected to increase. While UCS/NYPIRG does not necessarily subscribe to the above evacuation transit time estimates, they do call into question the much narrower range of transit times modeled in IPPSS (namely 2-8 hours) [IPPSS, page 0-62].

Q.20 What is the nature of the dose-response curves for early fatalities used in WASH-1400?

A.20 WASH-1400 postulated three different dose-response curves for early fatalities, based on varying levels of medical treatment that might be provided. WASH-1400 [WASH-1400, Appendix VI, Section 9 and Appendix F] describes three levels of treatment: (a) minimal treatment; (b) supportive treatment: and (c) heroic treatment.

For minimal treatment (treatment less comprehensive in nature than supportive treatment), the mean lethal dose (LD_{50}) is 340 Rads, with an LD_{10} at 250 Rads.

Supportive treatment includes the following steps: (a) use of laxatives to accelerate the transit of radionuclides through the gastrointestinal tract; (b) strict reverse-isolation procedures; (c) major antibiotic therapy with microbiological laboratory support; and (d) use of transfusions of blood and blood products. WASH-1400 estimated that the entire U.S. could provide 2,500-5,000 patients with supportive treatment. The LD_{50} dose for supportive treatment is 510 Rads.

Heroic treatment includes, in addition to the therapy outlined above for supportive treatment, the use of extraordinary procedures such as bone marrow transplantation. WASH-1400 estimated a capability within the entire U.S. for treating 50-150 persons at this level of treatment. The LD_{50} for heroic treatment is estimated to be 1,050 Rads.

Q.21 What dose-response curve did IPPSS utilize?

A.21 IPPSS assumed that the supportive treatment curve would apply. There is no indication in IPPSS that the availability of such treatment versus the expected numbers of victims requiring such treatment was considered. Moreover, the Risk Assessment Review Group, in its review of WASH-1400, noted that "the ability to carry out such intervention [supportive treatment] not only has not been demonstrated, but isn't even well planned at this time". The Review Group also noted a wide range of uncertainty in scientific opinion which supported a range of 400-600 Rads for the LD_{50} for supportive treatment [NUREG/CR-0400, pages 18-19].

Q.22 Have other accident consequence studies used dose-response assumptions for early fatalities that differ from those modeled in WASH-1400 and IPPSS?

A.22 Yes. A study of the consequences of accidents for underground nuclear plants prepared for the California Energy Resources Conservation and Development Commission used a different curve [JOHNSON, 1979, pages 360-366]. Citing discrepancies between the data in WASH-1400 and the data in the references cited in WASH-1400 as the basis for the curves in WASH-1400, the authors of the underground siting report recommended the use of two dose-response curves for early fatalities as follows: (a) for minimal treatment, an LD_{10} of 220 Rads, an LD_{50} of 286 Rads, and an LD_{90} of 352 Rads; (b) for supportive treatment, an LD_{10} of 410 Rads, an LD_{50} of 429 Rads, and an LD_{90} of 448 Rads.

In addition, the Accident Evaluation Code (AEC), used in the risk assessment of the Clinch River Breeder Reactor, assumes that only minimal treatment is available, and uses an LD_{50} for minimal treatment as being 350 Rads. This LD_{50} is based on whole-body exposure, whereas the WASH-1400 curves are based on bone marrow exposure [SAI, pages 3-5 through 3-10].

Q.23 What would be the result of using the minimal treatment dose-response curve for early fatalities instead of the supportive treatment curve for Indian Point consequence calculations?

A.23 It is well recognized that the early fatality estimates are quite sensitive to the dose-response curve modeled [NUREG/CR-2300, page 9-58]. The NRC Staff testimony on accident consequences and risks by Dr. Sarbeswar Acharya contains several tables for early fatalities with calculations carried out using both the minimal treatment and supportive treatment curves. If comparisons are made of the difference in early fatality estimates on a per reactor-year basis, the differences range between a factor of 2.4 to a factor of 3.0 [ACHARYA, 1983, pages III.C-8 through III.C-10]. These results are consistent with estimates in NUREG-0340 which concluded that using the minimal treatment curve instead of the supportive treatment curve in the WASH-1400 consequence calculations would increase the early fatality estimate by a factor of 3 or 4 [NUREG-0340, page 28].

It is reasonable to conclude that acute fatality calculations using the CRACIT code would also be sensitive to the nature of the dose-response curve used. It may be, given the modeling of plume trajectory and other model features in CRACIT which serve to reduce calculated doses, that CRACIT could be more sensitive than CRAC to the assumption of the availability of supportive treatment.

Q.24 Are there any available estimates of the number of persons who might require supportive treatment for accidents at Indian Point in order to take credit for the supportive treatment dose-response curve in the CRACIT and CRAC models?

A.24 Approximate results are available in the NRC Staff's testimony. The LD_{10} for the minimal treatment dose-response curve is 250 Rads to the bone marrow. The Staff's testimony contains several consequence curves which portray the number of persons receiving whole-body doses of 200 Rem or higher. These calculations, while not precisely what might be desired for the purpose of calculating the number of persons requiring supportive treatment, serve adequately for providing a ballpark estimate. For the scenario that the Staff describes as "after fix" with evacuation within 10 miles and relocation outside 10 miles for Indian Point Unit 2 [ACHARYA, 1983, Figure III.C.2], at a probability level of about 10^{-6} the number of persons receiving whole-body doses of 200 Rems and higher is 10,000 persons. The PRA Procedures Guide suggests that if the number of persons receiving acute bone-marrow doses of 200 Rems or more exceeds 5,000, "it is likely that some individuals wouldd receive less than supportive treatment" [NUREG/CR-2300, page 9-59].

It should also be noted from the Staff's analysis [ACHARYA, 1983, Figure III.C.2] that the probability level for which one person receives an acute bone-marrow dose of 200 Rems or greater is between 8×10^{-5} and 9×10^{-5}. Thus, based on the NRC Staff's analysis, there is about an order of magnitude difference in probability between the chance of one person receiving 200 Rem whole-body (or higher) and the chance of 10,000 persons receiving such a dose. The Staff testimony describes a "potentially lethal dose to the total bone marrow" of 175 Rem [ACHARYA, 1983, page III.C.A-4]. From the above considerations, it would appear that for some accidents at Indian Point, the available level of supportive treatment will be exceeded. This issue deserves closer attention than it has received from the Staff and the authors of IPPSS.

Q.25 How is "warning time" defined in IPPSS?

A.25 IPPSS defines "warning time before evacuation" as "the interval between awareness of impending core melt and the release of radioactive material to the atmosphere" [IPPSS, page 6.2-13]. This definition is consistent with that used in WASH-1400 [WASH-1400, Appendix VI, page 2-1] and the PRA Procedures Guide [NUREG/CR-2300, page 9-69]. The definition is subtly different from that used in the Sandia siting study, however, which defines warning time as the time from notification by plant personnel (presumably to offsite emergency response officials) to the release of radioactivity due to containment failure [NUREG/CR-2239, page 2-39].

Q.26 What warning time is assigned by IPPSS to Release Category 2RW?

A.26 IPPSS assigns an 11-hour warning time value to Release Category 2RW [IPPSS, page 6.2-54].

Q.27 Why do you believe the warning time value assigned by IPPSS to Release Category 2RW is incorrect?

A.27 I believe that an 11-hour warning time for Release Category 2RW in IPPSS is overly optimistic. Release Category 2RW in IPPSS is classified as a "late overpressure failure" with failure of the containment predicted to occur at 12 hours after the start of the accident. MARCH code calculations for transient initiated core melts (presumably including those contributing to Release Category 2RW) show that core uncovery does not occur until 188 minutes (just over three hours into the sequence). The same set of MARCH calculations show core melt occurring between 212-253 minutes (about 3.5 to 4.25 hours into the sequence) and reactor vessel failure at 259 minutes [IPPSS, pages 5.8.2-10 and 5.8.2-16].

It is difficult to believe that operators will recognize one hour into such a sequence of events that core melt and containment failure will necessarily ensue. Even if the operators are capable of doing so, it is not clear that they would immediately recommend evacuation. Thus, the 11-hour warning time would appear to be optimistic. It would appear more reasonable to assume that operators might recommend evacuation once they get a clear indication of impending core melt. This would probably not occur until core damage indications begin to be annunciated in the control room, and these indications would be delayed until core uncovery begins. As depicted in Figure 5.8.2.3-1 of IPPSS [IPPSS, page 5.8.2-16], core uncovery does not begin until 1.37 hours. The "gap release" (indicative of core damage) does not occur until 3.133 hours (times based on MARCH-COCO calculations).

It would appear to be more realistic to assign a warning time of 9 hours to Release Category 2RW. A more conservative approach would be to assign a warning time of 8 hours to Release Category 2RW (the approximate time of reactor vessel failure).

The PRA Procedures Guide [NUREG/CR-2300, page 9-69] recommends that warning times be obtained by comparing the emergency plan implementing procedures with the output of a code such as MARCH. IPPSS gives no indication of how the warning time for Release Category 2RW was determined.

Q.23 What would be the impact on the calculated consequences of the 2RW Release Category of changing the warning time from 11 hours to 8-9 hours?

A.23 In qualitative terms, this would reduce the amount of time available for implementation of protective actions prior to containment failure. In quantitative terms, an answer at this time is difficult because of lack of access to the CRACIT code; if the conditional consequence calculations for Release Category 2RW were re-calculated using CRACIT and the changed warning time assumptions, a more specific response could be obtained. The PRA Procedures Guide, in a discussion of sensitivities and uncertainties in consequence analysis, concludes that warning time is an important source of uncertainty that can have a "major" impact on uncertainties in early fatalities and early injuries (except for peak results which are determined by scenarios for which evacuation within 10 miles has little or no effect) [NUREG/CR-2300, pages 9-99 and 9-102].

For those scenarios contributing to Release Category 2RW involving earthquakes, hurricanes, and area-wide power failures, reduced warning time would tend to exacerbate the situation described above in response to Q.15 through Q.17, and contribute to a limited extent to an increase in early consequences.

Q.29 What credit does IPPSS take for a so-called "ventilation model" in reducing inhalation doses?

A.29 IPPSS concludes [IPPSS, page 6.1-12] that the quantity of radionuclides inhaled may be reduce by remaining indoors during passage of the plume. WASH-1400 described this phenomenon, but took no credit for it, concluding that average over a large population, "little reduction in inhaled radionuclides would be expected" [WASH-1400, Appendix VI, page 11-8]. Three reasons were given: (a) since a reactor accident would be a "once-in-a-lifetime experience", it would be unreasonable to expect the public to be prepared to take "sophisticated" protective measures; (b) in many geographical regions and for several months of the year, residents live and sleep with windows open and no reduction is possible without "positive action"; and (c) it would be difficult to persuade the public to close their windows and, once done, would be even more difficult to persuade the public to reopen the windows at the right time.

IPPSS notes that WASH-1400 did not take credit for this potential reduction, but did not cite the reasons therefor. In taking credit for this reduction in IPPSS, no explanation is given which addresses the points made in WASH-1400 regarding why no credit should be taken for this reduction. Moreover, no specific quantitative information is given in IPPSS which indicates the amount of reduction assumed and under what conditions the reduction is justified (i.e., sheltering on the first floor of structures or in basements). In addition, Figure VI 11-4 in WASH-1400 [WASH-1400, Appendix VI, page 11-9] displays a wide range of doses with time for different ventilation rates; this is also not addressed in IPPSS.

Q.30 Has the potential reduction in inhaled radionuclides been examined in other reports?

A.30 Yes. In SAND77-1555, Aldrich and Ericson examined a "multicompartment ventilation model" for shelters. Their report concluded that using "best estimate" values for model parameters, a reduction of 35% in the dose from inhaled radionuclides could be achieved [SAND77-1555, page 42]. Aldrich and Ericson also noted that this reduction would not significantly affect early fatalities since this health effect is due primarily to bone marrow damage. Reductions in inhalation doses would thus affect latent health effects moreso than early health effects [SAND77-1555, page 8].

In addition, a review of the infiltration of particulate matter into buildings undertaken for Sandia Laboratories by A.F. Cohen and B.L. Cohen at the University of Pittsburgh. Their report suggested that a protection factor of two could be used with "some degree of conservatism" for sheltered individuals for reduction in inhaled radionuclides [NUREG/CR-1151, page 6]. The PRA Procedures Guide also appears to recognize a potential factor of two reduction in doses due to inhalation [NUREG/CR-2300, page E-16].

The Staff's testimony of Dr. Acharya indicates that IPPSS took a factor of two credit for reduction in inhaled radionuclides for the sheltered population [ACHARYA, 1983, page III.C.A-37]. Dr. Acharya noted that this was an optimisttic assumption that did not correspond to an existing offsite emergency response strategy.

Q.31 What is your conclusion regarding the use of the inhalation dose reduction factor in IPPSS?

A.31 Inasmuch as IPPSS has not justified its "ventilation model", I conclude that its use was inappropriate. The impact of eliminating this dose reduction factor would be limited to an increase in latent effects, the magnitude of which is unclear due to a lack of relevant information in IPPSS.

Q.32 What is a "plateau period" as used in discussing cancer induction due to exposure to ionizing radiation?

A.32 The WASH-1400 model for cancer risk assumed a latency period during which the risk was zero, followed by a "plateau period" where exposed individuals were assumed to be at a constant risk. Thus, the plateau period is the time in which cancers were assumed to appear following the latency period.

Q.33 How do the CRAC and CRACIT consequence models depict this plateau period?

A.33 WASH-1400 assumed a 10- to 30-year plateau period for cancers. CRAC and CRACIT reflect this model.

Q.34 How does CRAC2 model the plateau period?

A.34 The BEIR III report recommended the adoption of a lifetime risk model in which the "plateau period" is assumed to extend to the end of the life of the exposed individual. CRAC2, developed after the release of the BEIR III report, is responsive to this recommendation, and models a lifetime plateau period. This results in an increase in the estimated number of cancers per million man-rem (except for leukemia) [NUREG/CR-2239, Appendix E]. The calculated numbers of latent cancer deaths per million person-rem of external exposure for CRAC (with a 30-year plateau) and CRAC2 (with a lifetime plateau) are shown below [NUREG/CR-2300, page 9-61]:

TYPE OF CANCER	CRAC ESTIMATE	CRAC2 ESTIMATE
Leukemia	28.4	28.4
Lung	22.2	27.5
Stomach	10.2	12.7
Alimentary Canal	3.4	4.2
Pancreas	3.4	4.2
Breast	25.6	31.7
Bone	6.9	10.1
"Other"	21.6	28.0
TOTAL	121.7	146.8

Q.35 What impact would result in the calculated cancer consequences for Indian Point if the lifetime plateau model were used in CRAC and CRACIT?

A.35 The result would be a slight increase in the number of cancers estimated. The magnitude of the increase is different for the various types of cancers modeled, as reflected above.

Q.36 What population data did IPPSS use in calculating the consequences of accidents at Indian Point?

A.36 IPPSS used 1970 Census data which was modified using growth rate estimates to reflect an estimated 1980 population [IPPSS, page 6.2-5].

Q.37 What population did the NRC Staff testimony use in calculating the consequences of accidents at Indian Point?

A.37 The Staff used an estimated 1990 population to reflect the approximate "mid-life" of the Indian Point site [SOFFER, 1983].

Q.38 What approach do you recommend?

A.38 Neither the approach used in IPPSS nor by the Staff completely reflects the uncertainties involved. The IPPSS estimates are already out of date by three years; in addition, 1980 Census data should be available. The Staff's use of an estimated 1990 population is more realistic in comparison.

However, not only will the magnitude of the population change between the present and the end of the operating lifetime of the Indian Point reactors, it is possible that the spatial distribution of the population will also change. It is not clear that this latter phenomenon is reflected in the Staff's estimates.

Inasmuch as releases of radioactive materials due to accidents at Indian Point are assumed to occur at random throughout the operating lifetime of the facilities, a more appropriate approach would be to perform a sensitivity study of the impact of population magnitude and distribution changes between the present and the estimated end of the operating lifetime of the Indian Point reactors. It is reasonable to expect that early consequences would be more sensitive to population magnitude and distribution changes than would be latent consequences.

A set of projections for the population in the region surrounding Indian Point is found in the Indian Point Unit 3 "FSAR Update" [FSAR UPDATE, page 2.4.P-5, and Figures 2.4-3 and 2.4-4]. Cumulative ring totals as well as estimates by grid location are provided through the year 2010 (the nominal end of operating lifetime for the Indian Point reactors). These estimates (Attachments 1 through 3) show that substantial changes in both magnitude and distribution are expected between 1980 and 2010. The impact of these changes on consequence estimates requires further investigation.

Q.39 Moving to the last area of criticism under modeling assumptions, what meteorological data was used in IPPSS?

A.39 IPPSS made use of a single year of meteorological data, covering the period from August 1978 through July 1979 [IPPSS, page 6.2-1].

Q.40 What meteorological data was used by the NRC Staff in their consequence calculations?

A.40 The NRC Staff used meteorological data from the same time period as IPPSS [ACHARYA, 1983, page III.C.A-5].

Q.41 How do the approaches used by IPPSS and the NRC Staff differ in terms of their use of meteorological data?

A.41 IPPSS uses meteorological data from the Indian Point site and fourteen "satellite" stations throughout the region, and models the influence of meteorology as the plume moves from one region to another. The meteorological regions used in IPPSS are depicted on page 6.2-56 of IPPSS.

IPPSS used a random sample of 288 start hours from the 8,760 hours of data available. The plume behavior for 15 of these start times were "edited" as described in IPPSS [IPPSS, pages 6.2-10 to 6.2-11]. Each start time is considered as one scenario with meteorological behavior determined by the data. In addition, IPPSS used a separate procedure for defining the "tails" of the probability distributions [IPPSS, pages 6.3-5 through 6.3-6].

The NRC Staff uses the meteorological sampling technique in CRAC which begins at a chosen hour and selects 91 start hours by progressing through the year's worth of meteorological data by a uniform four days and thirteen hours as discussed in NUREG-0340 [NUREG-0340, pages 5-6]. The four day cycle is intended to account for "predominant weather cycles" and the thirteen hour cycle is intended to accomodate diurnal cycles. Each of the start times is used to establish the meteorological data which is then used to calculate consequences in each of the sixteen direction sectors used in CRAC. Thus, CRAC generates 1,456 samples from which the probability distributions for consequences are generated.

Q.42 What is the impact of using only a single year of meteorological data and how do the meteorological sampling schemes used by IPPSS and the NRC Staff affect this consideration?

A.42 The consequence analyses developed in IPPSS and by the NRC Staff have as one goal the definition of risk for the remainder of the operating lifetime of the Indian Point reactors. About 30 years remain in the projected operational lifetimes of these reactors.

IPPSS and the Staff both rely on the same 12-month period of meteorological data. It is not clear whether this period of time was chosen at random, or whether it was evaluated and determined to be a "typical" year for the Indian Point region. Since meteorological conditions at the time of a release can have a substantial impact on the estimated consequences of a release of radioactive material [NUREG/CR-2239, page 1-3], it is important that the year of meteorological data chosen by IPPSS and the NRC Staff not be atypical (such as unusually dry or wet). It is also important for the definition of the "tails" portion of the probability distributions for early consequences that the frequency, intensity, and spatial variability of precipitation be accurately modeled [NUREG/CR-2239, page 2-9].

The Sandia siting study concluded that using a single year of meteorological data should not have a significant impact on predicted consequences to a conditional consequence probability of 1:100 [NUREG/CR-2239, page 2-29]. This study was conducted using the CRAC2 code, which has a different meteorological sampling scheme than used in CRAC. Sensitivity studies conducted using the meteorological sampling scheme in CRAC showed that considerable variations in predicted consequences result from the CRAC sampling scheme, with differences in the magnitude of peak consequence estimates not uncommonly differing by an order of magnitude using different sets of data from the same year of meteorological data [NUREG/CR-2239, page E-3]. These differences result because large consequences are typically associated with relatively low probability meteorological conditions such as rainfall within a few tens of kilometers of the site, windspeed slowdowns following a release, and stable weather conditions with moderate windspeeds. Due to the nature of the meteorological sampling technique used in CRAC, such conditions will not necessarily be accurately sampled.

The CRAC2 code implements an improved sampling scheme which takes the entire year of meteorologial data and sorts it into 29 weather "bins". Probabilities are established for each bin based on the number of sequences placed into each. Meteorological sequences are then sampled from the bins accounting for each bin's probability [NUREG/CR-2239, page E-3 to E-4]. Despite this improvement, however, the Sandia siting study concluded that further refinement was required, and recommended consideration of utilizing more than one year of meteorological data [NRUEG/CR-2239, page 2-31]. An alternative to this might be the creation of a "Typical Meteorological Year" to represent the long-term average behavior of weather as discussed in the Sandia siting study [NUREG/CR-2239, pages A-9 through A-10].

Based on the above considerations, uncertainties are associated with the use of a single year of weather data. In addition, the sampling technique used by CRAC carries with it additional uncertainties. Whether the CRACIT procedure in IPPSS avoids the latter difficulty remains to be proven.

Q.43 Moving from the general area of modeling assumptions, are there consequences of accidents at Indian Point which IPPSS has omitted?

A.43 Yes. IPPSS omitted genetic effects and financial consequences. IPPSS notes, however, that genetic effects could be estimated by applying a constant multiplier to the total man-rem exposure risk curve to obtain a genetic risk estimate that would be consistent with the WASH-1400 approach. Financial consequences, however, are entirely absent from IPPSS.

Q.44 What is the significance of the omission of financial consequence estimates from IPPSS?

A.44 WASH-1400 and later studies have demonstrated that the financial consequences of reactor accidents could be substantial. Moreover, the TMI-2 accident experience vividly demonstrates that even where core melt is prevented and the containment functions to prevent large releases of radioactivity, the financial consequences to society can be large [NUREG/CR-2300, page 9-64]. Costs associated with the TMI-2 accident include an estimated cleanup cost of approximately $1 billion, plus replacement power costs, the possible loss of TMI-2 as a generating facility, and, to some extent, the costs incurred at other reactors of implementing the "lessons learned" from the TMI-2 accident (although inclusion of this latter category of costs is somewhat arbitrary to the extent that these "lessons learned" represent changes that should have been made independent of the accident).

For accidents involving containment failure and a substantial release of radioactive materials to the environment, the financial impact could be quite large. WASH-1400 approached this issue by modeling the direct offsite costs of measures taken to mitigate the effects of a reactor accident. The specific cost components modeled in CRAC are [CRAC]:

1. The cost of evacuation;
2. The value of crops condemned as a result of contamination by radioactive materials;
3. The value of milk condemned as a result of

contamination by radioactive materials;

4. The loss in value of private and public property (real estate);

5. The loss of income during a period of relocation and temporary unemployment for residents of the interdiction areas;

6. The costs of decontamination of property to regain use of that property; and

7. The costs of relocation.

Table 5-4 in the WASH-1400 Main Report provides the study's conclusions regarding the offsite financial consequences of reactor accidents [WASH-1400, Main Report, page 83]. The estimated financial consequences reported there ranged from \$0.9 billion at an estimated probability of $1:10^5$ per reactor-year to \$14 billion at an estimated probability of $1:10^9$ per reactor-year. These economic consequence estimates, of course, are now out of date due to inflation, do not reflect estimates of the consequences at actual reactor sites, and, as discussed below, are incomplete estimators of financial consequences of reactor accidents.

Q.45 What financial consequences are omitted from the CRAC and CRAC2 codes?

A.45 Several financial cost components are missing from the CRAC and CRAC2 codes. I have recently obtained (through the Freedom of Information Act) an undated draft proposal from Pacific Northwest Laboratories for review and revise the financial consequence model in CRAC. This paper notes a number of omissions in the CRAC financial consequences model [PNL]:

1. Loss of value in real property other than real estate due to contamination by radioactivity;

2. Costs associated with monitoring and decontaminating the evacuated population;

3. Incomplete treatment of compensation for loss of income due to disruption of economic activity;

4. Indirect costs such as compensation for health damages;

5. Incremental costs of replacement power;

6. Indirect effects associated with possible reduction in productive capacity of industries located outside the area directly affected by the accident; and

7. Aggregation of state level economic data which may be insensitive to site conditions such as how the concentration of population and centers of production and economic activity vary in different directions from the site.

A second report which discusses financial consequences of reactor accidents not included in the CRAC and CRAC2 models is NUREG/CR-2591. This report was prepared for the NRC by the Bureau of Economic Analysis in the Department of Commerce, and sets forth a methodology and uses the methodology to analyze three case studies. The consequences estimated by the procedure set forth in the report are limited to the first year following the release. Regional industry-specific job losses are reported as output from the model [NUREG/CR-2591].

A third report is a draft Sandia National Laboratories report on the financial consequences of reactor accidents [NUREG/CR-2723] which utilizes mean consequence results from the Sandia siting study to calculate conditional mean financial consequence estimates for accidents of three levels of severity. The methodology set forth in this report uses a discounting procedure to assign financial costs to the loss of the generating facility, replacement power costs, and cleanup from the accident. The report also assigns financial costs of $1 million per early fatality and $0.1 million per early injury and latent cancer fatality [NUREG/CR-2723, page 7]. Onsite as well as offsite health effects costs are included in the reported results. The conditional fiancial costs are estimated for three release categories (designated SST1, SST2, and SST3) and are calculated for 91 approved reactor sites in the U.S.

The draft Sandia report cautions against the use of the absolute financial consequence values due to uncertainties, but concludes that comparisons on a relative basis are "fairly accurate" [NUREG/CR-2723, page 11]. I have reviewed the draft results and have found that the estimated conditional financial consequence results for Indian Point Units 2 and 3 are larger than for any other site evaluated in the report. It is worth noting that onsite costs are a substantial component of the total financial consequences as estimated in the report, and that the onsite financial consequences vary very little if a core melt accident occurs, regardless of the offsite consequences. This is an important conclusion, and challenges the assertion that core melt frequency is a poor risk estimator at least insofar as financial consequences are concerned.

Finally, an August 1982 report prepared by a former member of the ACRS Staff and two ACRS Fellows also contains a discussion of the financial consequences of reactor accidents. The report notes that under the present risk management framework established by the NRC's regulations and practices, the principal aim of this risk management framework is the limitation of health consequences of reactor accidents. The report lists among the resources that might be lost due to contamination with radioactive material arising from a reactor accident: (a) farmland; (b) crops and livestock; (c) water resources such as reservoirs; (d) mineral resources; (e) forest product reserves; (f) industrial facilities; (g) transportation and communications centers; (h) health care facilities; (i) storage facilities for commodities; (j) power production and distribution facilities; and (k) urban areas [GRIESMEYER, 1982, pages 4-6]. Some of these factors are addressed in varying degrees by the CRAC and CRAC2 models, but others are not.

Q.46 What financial consequence components are calculated in the NRC Staff's testimony?

A.46 The Staff's testimony appears to be limited to the calculation of the financial costs associated with offsite mitigation measures. As such, these financial consequence estimates must be taken as underestimates of the total financial consequencese to society of accidents at Indian Point. Considering that onsite financial consequences are not included in the Staff's estimates, the financial risk curves are biased toward lower financial risk.

Q.47 Moving to the next area of your evaluation of CRACIT as applied in IPPSS, how did IPPSS model uncertainty in in the "site matrix"?

A.47 There are two components to the consideration of the uncertainty in the "site matrix" in IPPSS, those being the uncertainty in the source terms for the release categories and the uncertainty in the consequence estimates from CRACIT. To model uncertainties in the source terms, IPPSS assigned a subjective probability distribution to the chances that the source terms were: (a) underestimated by a factor of two; (b) properly estimated; (c) overestimated by a factor of two; and (d) overestimated by a factor of ten [IPPSS, Section 5.6.2]. To model uncertainties in the consequence estimates themselves, IPPSS again assigned a sujective probability distribution to the chances of over- and under-estimation, this time of the doses calculated using the CRACIT model [IPPSS, Section 6.3.2.3].

Q.48 What justification is given in IPPSS for the procedure used to model source term uncertainties?

A.48 In Section 5.5, IPPSS discusses source term technology. In concluding this discussion, IPPSS states [IPPSS, page 5.5-1]:

> "The study team and other investigators who were consulted (References 5 and 6) judge that the data available today does not yet provide a sufficient foundation for altering the basis and assumptions of the RSS source term estimates. It is important to recognize however, that the available data does indicate that the point estimate source term values used in this study (and derived from the RSS) are conservatively high."

The references in the above quote from IPPSS are to discussions that the IPPSS study team had with R. Ritzman (SAI), H.K. Hilliard (Westinghouse), D.O. Campbell (ORNL), R. Lorentz (ORNL), A.P. Malinauskas (ORNL), G.W. Parker (ORNL), and D.H. Walker (Offshore Power Systems). Notwithstanding this conclusion, IPPSS goes on to assign subjective probability distributions (in the form of histograms on pages 5.6-5 and 8.5.8-2 of IPPSS). These distributions are justified on the basis of "engineering judgment" [IPPSS, page 5.6-2]:

> "The probability distribution histograms area based on engineering judgment regarding the effects of accident phenomenology, core melt progression, and containment processes (including safeguards systems) on the source term in the containment atmosphere available for release from containment."

One might expect that if these judgments were so clear as to lead to such specific probability distributions that the IPPSS authors would have had little difficulty in setting forth with some particularity the basis for their judgments. This was not done, however, nor was any mention made of the detailed information on source terms set forth in so-called "technica bases" report by the NRC [NUREG-0772], much less a discussion of that information in terms of how the IPPSS study team arrived at its source term probability distributions. It is worth noting, in addition, that whatever consideration was given to the chance that the source terms could have been underestimated by a factor of two, the subjective probability of this occurrence was zero in each case. Indeed, the study assigned a higher probability of the source term being a factor of two less than the "point estimate" source terms in nearly all cases [IPPSS, page 8.5.8-2].

No specific justification is given for either the magnitude of the assumed source term reductions or for the uniformity of the reduction across the radionuclide groups considered in establishing the release fractions for each Release Category. Indeed, a "sensitivity study" presented in Section 5.8.2.6 reaches a different conclusion on the uniformity issue, concluding that for the particular scenario evaluated that iodine would be reduced by a factor or 8 while the Te, Ru, and La groups would be reduced by only a factor of 2 [IPPSS, page 5.8.2-8]. It is difficult to accept the uniformity in reduction posited in IPPSS absent some considerable justification which addresses the chemical and physical parameters which control source term determinations.

Q.49 What justification is given in IPPSS for its approach in modeling uncertainty in consequences estimated using CRACIT?

A.49 After a brief qualitative discussion of consequence uncertainties (most of which is devoted to extolling the virtues of CRACIT in terms of reductions of uncertainties compared to CRAC). IPPSS concludes that uncertainties in consequence modeling can be simulated by assigning a subjective probability distribution to the chance that the doses calculated using CRACIT are: (a) low by a factor of 2; (b) correctly calculated; (c) high by a factor of 2; and (d) high by a factor of 10. This distribution is assigned "(a)fter a quantitative consideration of the net effect of uncertainties in many aspects of the dose calculations, such as mitigation measures, rainfall washout, and release durations". It is noted, however, that the uncertainties estimated quantitatively in the analysis are those resulting from uncertainties in model parameters, and that the uncertainties "do not fully address trajectory uncertainties" [IPPSS, pages 6.3-6 through 6.3-7]. The probability distributions for the uncertainties are different for early and latent effects and vary depending with the Release Category in the early effects histogram [IPPSS, page 8.5.6-[illegible]].

Again, as in the source term discussion above, no detailed justification is given for the approach. Despite a passing reference to a "quantitative consideration of the net effect of uncertainties in many aspects of the dose calculations" [IPPSS, page 6.3-7], no such information is presented in the IPPSS report. The reader is left to speculate as to which variables were considered, the ranges over which they were considered, and how the results calculated using CRACIT differ from those calculated using other risk codes such as CRAC or CRAC2. In this case, the lack of information is more troubling to the consequence modeler than is the case with the source terms above simply because so much more is known about how the uncertainties in the consequence models affect the results. Sensitivity studies performed using CRAC and CRAC2 abound, yet not one of these is even referenced by IPPSS, much less discussed. Further, the PRA Procedures Guide [NUREG/CR-2300, Chapter 9] contains an extensive discussion on assumptions, sensitivities, and uncertainties wherein the contribution to uncertainties in risk curves are discussed for literally dozens of parameters used in consequence models. The IPPSS study team could hardly have been unaware of this discussion inasmuch as Keith Woodard of Pickard, Lowe, and Garrick, Inc., is on the peer review panel for NUREG/CR-2300 on "Environmental Transport and Consequences".

Rather than discuss the areas of uncertainty in consequence analysis and describe how each contributed to the study team's subjective assessment of uncertainty, IPPSS simply gives the reviewer the study team's conclusion that the procedure utilized adequately represents the uncertainties. Nothing could be more unscrutable, unreproducible, and open to the possibility of arbitrariness. Indeed, the PRA Procedures Guide describes an analogous treatment in the Zion Probabilistic Safety Study as "extremely subjective" [NUREG/CR-2300, page 9-113].

Q.50 Moving to the final area of your review of CRACIT as applied in IPPSS, what is the nature of the sensitivity studies using CRACIT and reported in IPPSS?

A.50 The limited sensitivity studies performed using CRACIT were apparently directed a model testing and are discussed in Section 6.3.1 of IPPSS. Unfortunately, these sensitivity studies were performed using a BWR-1 release category from WASH-1400 and modeled a 1,930 MWt BWR core inventory rather than a PWR core inventory. IPPSS asserts that the BWR-1 release category from WASH-1400 is "very similar" to the PWR-2 release category from the same study. A quick comparison of the release fractions for these two release categories calls into question this assumption [WASH-1400, Appendix VI, page 2-5]:

RADIONUCLIDE GROUP	RELEASE FRACTIONS FOR BWR-1	PWR-2
Xe-Kr	1.0	0.9
Org-I	7×10^{-3}	7×10^{-3}
I	0.4	0.7
Cs-Rb	0.4	0.5
Te-Sb	0.7	0.3
Ba-Sr	0.05	0.06
Ru	0.5	0.02
La	5×10^{-3}	4×10^{-3}

Moreover, the time of release for BWR-1 is 30 minutes shorter than for PWR-2, the release elevation is different (25 meters versus ground level), the warning time for evacuation is longer (1.5 hours versus 1 hour), and the energy content is slightly less (130 million BTU/hr versus 170 million BTU/hr). Thus, there are considerable differences between the BWR-1 and PWR-2 release categories in WASH-1400. In addition, CRAC code calculations for these two release categories in WASH-1400 [NUREG-0340, page 38] show that BWR-1 caused only half the early fatalities caused by PWR-2 for a low probability accident (i.e., about 1×10^{-9} per reactor-year.

The difference in core inventory for a 1,930 MWt BWR and a 3,025 MWt PWR are substantial, and due not only to the difference in power level but due to differences in fuel management practices. Given these differences, some analysis demonstrating the applicability of these results to estimates of consequences for Indian Point is clearly needed.

Q.51 Does this conclude your testimony.

A.51 Yes.

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ATTACHMENT ~~1~~

Table I

SUMMARY OF CUMULATIVE RING POPULATION ESTIMATES

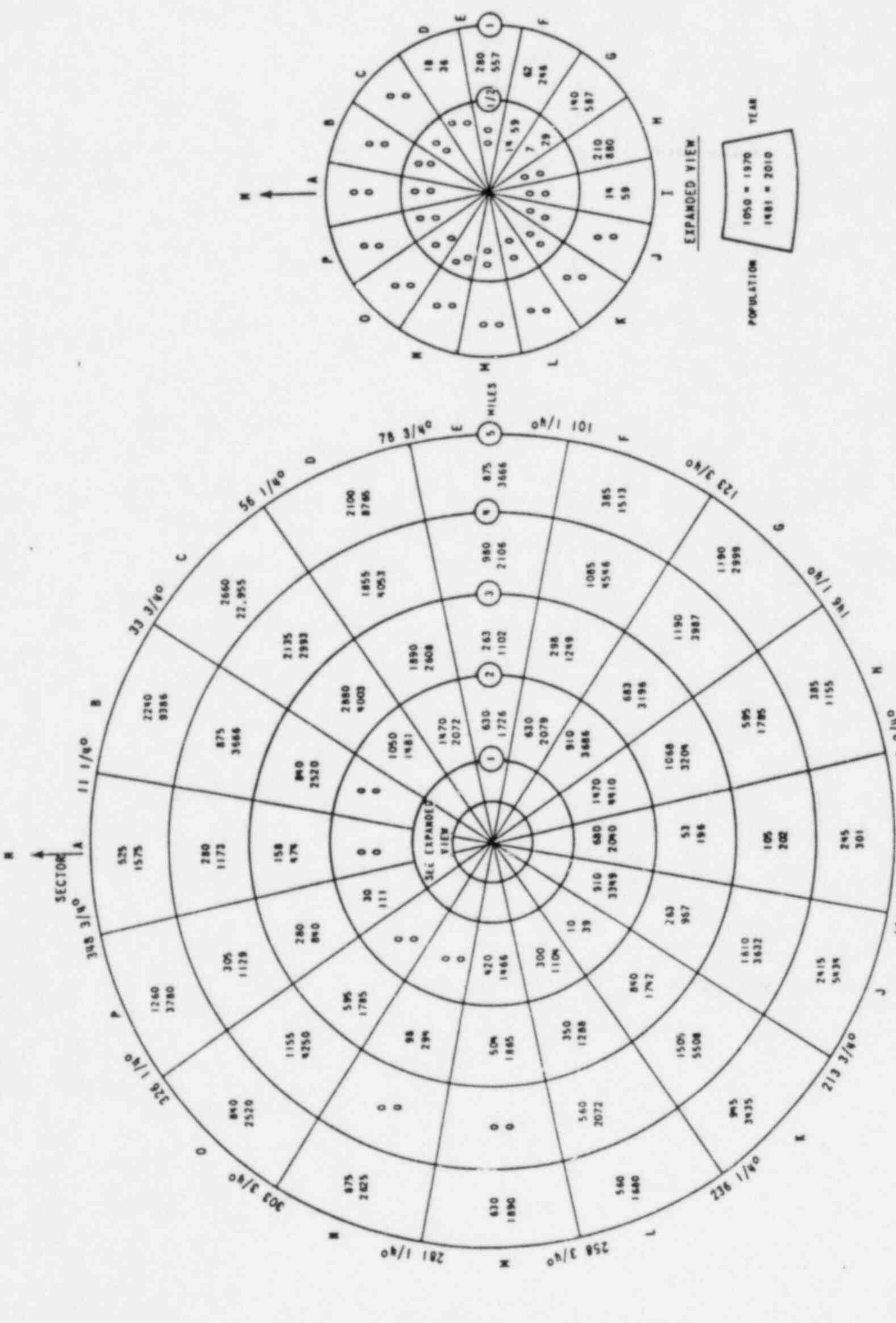
RADIUS OF THE RING IN MILES	CUMULATIVE RING POPULATION ESTIMATES				
	1970	1980	1990	2000	2010
Half	21	31	45	65	88
One	745	1,008	1,375	1,891	2,453
Two	9,255	11,981	15,673	20,698	26,016
Three	20,318	25,747	33,045	42,926	53,349
Four	34,553	44,338	57,544	75,482	94,451
Five	52,683	70,053	94,512	129,397	168,164
Ten	218,398	297,459	408,198	564,220	734,682
Fifteen	450,207	603,035	814,078	1,107,195	1,423,387
Twenty	888,163	1,179,611	1,577,851	2,125,429	2,711,048
Thirty	3,984,844	4,637,627	5,480,207	6,584,630	7,724,505
Forty	11,659,574	12,882,240	14,403,268	16,333,563	18,276,655
Fifty	17,471,479	18,991,980	20,923,966	23,400,331	25,899,727
Sixty	19,510,656	21,383,172	23,821,556	26,997,743	30,235,074

ATTACHMENT 2

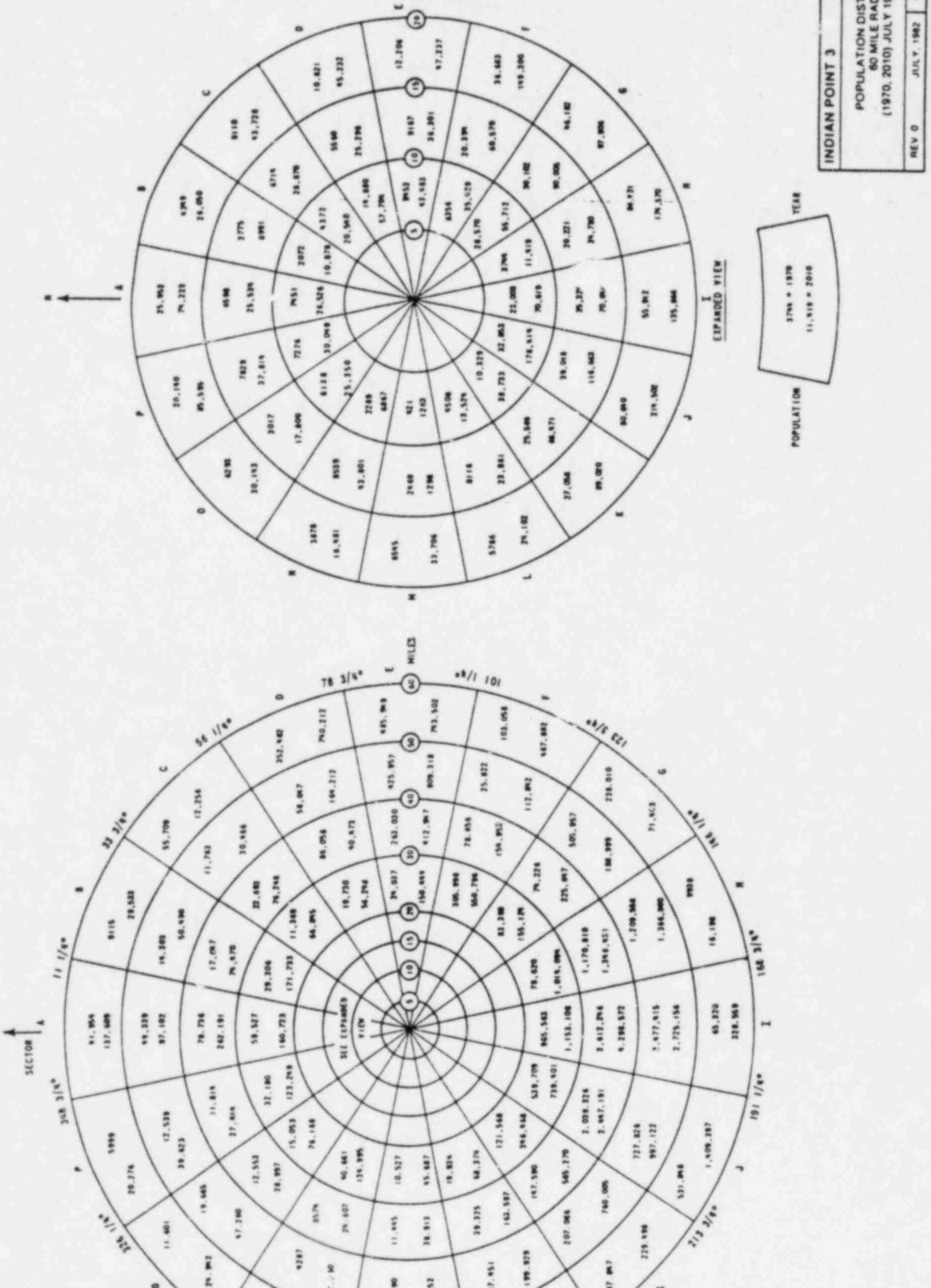
INDIAN POINT 3 — FSAR UPDATE

POPULATION DISTRIBUTION
5 MILE RADIUS
BASED ON JUNE 1972 REPORT

REV 0 | JULY, 1982 | FIGURE NO. 2.4-3



ATTACHMENT 3



STATEMENT OF PROFESSIONAL QUALIFICATIONS - STEVEN C. SHOLLY

My name is Steven C. Sholly. I am a Technical Research Associate with the Union of Concerned Scientists (UCS), 1346 Connecticut Avenue, N.W., Suite 1101, Washington, D.C., 20036. I joined the UCS staff in February 1981. My responsibilities at UCS include monitoring technical developments in a number of fields related to nuclear reactor safety, including radiological emergency planning, severe accident research, probabilistic risk assessment and accident consequence analysis, accident mitigation systems, and systems interaction. My responsibilities at UCS also include writing articles for UCS's quarterly report Nucleus. responding to inquiries from the media and from citizens groups, and researching NRC and other technical literature on a variety of topics related to nuclear reactor safety. My most recent articles published in Nucleus include "The Probability of a Core Melt Accident" [Vol. 4, No. 3, Fall 1982], and "The Consequences of a Nuclear Reactor Accident" [Vol. 4, No. 4, Winter 1983].

Prior to joining the UCS staff, I served as Research Coordinator and later as Project Director of the TMI Public Interest Research Center (TMIPIRC), 1037 Maclay Street, Harrisburg, PA, 17103. At TMIPIRC, I was responsible for directing research and public education activities. I also attended the TMI-1 Restart proceeding before the Atomic Safety and Licensing Board and kept TMIPIRC member groups and the public informed on the hearings through press conferences and periodic reports. While at TMIPIRC, I authored a report on the then-proposed venting of Krypton-85 gas from the containment of the damaged TMI-2 reactor. I was also responsible for monitoring the progress of the cleanup of the TMI-2 reactor.

I was awarded a Bachelor of Science degree in Education from Shippensburg State College, Shippensburg, PA, in August 1975. My majors were Earth and Space Science and General Science, and I took a minor in Environmental Education. I have also completed graduate courses at Shippensburg State College in land use planning.

In addition to the work job experience detailed above, I taught Earth and Space Science and Environmental Science for two years at the junior high school level, and operated wastewater treatment facilities for two years. In the latter capacity, I served as Chief Process Operator at the Derry Township Municipal Authority's treatment facility in Hershey, PA, where I was responsible for directing and monitoring the biological performance of a 5-MGD tertiary wastewater treatment plant.

I have published several articles in Nucleus and have also published an article in the Journal of Geological Education on determining Mercalli earthquake intensities from media accounts of historical earthquakes ["Determining Mercalli Intensities from Newpaper Reports", Journal of Geological Education, Vol. 25, pages 105-106, 1977]. I have testified in several Congressional hearings, most recently in December 1982 before the Subcommittee on Oversight and Investigation of the House Interior and Insular Affairs Committee on steam generator operating experience and accident hazards. I have also testified on filtered vented containment systems and compartment venting systems in the Indian Point special investigation proceeding.

Updated 7 February 1983