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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING APPEAL BOARD

Jerome E. Sharfman, Chairman
Richard S. Salzman
Dr. W. Reed Johnson

In the Matter of PUBLIC SERVICE ELECTRIC AND GAS COMPANY and ATLANTIC CITY ELECTRIC COMPANY (Hope Creek Generating Station, Units 1 and 2)	Docket Nos. 50-354 50-355

Mr. Troy B. Conner, Jr., Washington, D. C., for Public Service Electric and Gas Company and Atlantic City Electric Company, applicants.

Mr. Peter A. Buchsbaum, Trenton, New Jersey, (with whom Mr. Robert Westreich was on the brief) for the Concerned Citizens on Logan Township Safety, the boroughs of Paulsboro and Swedesboro, Stanley C. Van Ness, Public Advocate of the State of New Jersey, and David A. Caccia, intervenors.

Mr. Richard L. Black for the Nuclear Regulatory Commission staff.

DECISION

January 12, 1979

(ALAB-518)

We have before us for the second time the issue of the likelihood that a cloud of flammable vapor might reach

the Hope Creek Generating Station as a result of the accidental release of liquefied natural gas (LNG) or a similar highly flammable gas, following a tanker accident on the Delaware River. The two unit Hope Creek nuclear power plant would be situated on the New Jersey shore of the Delaware, about one mile from its deepwater channel.

The history of this issue is fully presented in our earlier decision in this matter -- ALAB-429, 6 NRC 229 (1977). We there described the accident being considered in the following way:

> The evidence shows that the hypothetical series of events resulting from LNG traffic which would present the most serious threat to the Hope Creek Station is as follows: A tanker accident would occur. One or more LNG tanks would rupture. A vapor cloud composed of methane gas would be formed but would not immediately ignite. The cloud would then be carried to the plant by the wind where flammable concentrations of the gas would ignite, producing a fire of great turbulence and intensity. [Footnote omitted]. 1/

We accepted, in the absence of a challenge to them from any of the parties, "the guideline probability values set forth in NUREG-75/087 (10^{-7} for a realistic calculation

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1/ Id. at 232.

and 10^{-6} for a conservative calculation) which would permit an applicant not to design a plant to withstand a particular accident due to its low probability."[2/] However, we held that the applicants and the staff had not shown that those standards had been met with respect to potential LNG tanker accidents which might affect the plant.[3/] We found further that the Licensing Board had not adequately considered the threat posed to the Hope Creek plant by accidents involving tankers carrying liquefied petroleum gas (LPG) and butane.[4/] We therefore remanded the case to the Licensing Board for a further evidentiary hearing and a determination of the scope of these hazards.[5/]

In a second supplemental initial decision, issued on April 13, 1978,[6/] the Licensing Board again found that the combined likelihood of an LNG or LPG[7/] tanker accident

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2/ Id. at 234. 10^{-7} is a mathematical notation meaning one chance in ten million; 10^{-6} means one chance in one million.

3/ Ibid.

4/ Id. at 243-45.

5/ Id. at 234, 245-46 and 247.

6/ LBP-78-15, 7 NRC 642.

7/ It defined LPG to include propane, butane and butadiene. Id. at 677.

that would affect the Hope Creek Station was so small that such an event need not be considered in the design of the plant. It concluded:[8/]

> On the basis of the evidence before us, and for the foregoing reasons, we have found that a conservative calculation of the probability that a flammable gas cloud resulting from an accident involving an LNG or LPG tanker could reach the Hope Creek plant is 2.4×10^{-7} occurrences per year. This value is less than 1×10^{-6}, the guideline probability for a conservative calculation set forth in NUREG-75/087. Events which are expected to occur with probabilities less than 1×10^{-6}, based on a conservative calculation, may be disregarded in the design basis of a facility. We therefore conclude, as stated in our Order dated January 26, 1978, that the Hope Creek Generating Station, Units 1 and 2, need not be designed so as to protect against flammable gas cloud accidents.[9/]

Joint intervenors[10/] and David A. Caccia appeal from the Licensing Board's decision on remand, as they did from

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8/ Id. at 698-99.

9/ The Board also considered the threat to the plant posed by an accident involving a tanker carrying vinyl chloride but found it to be negligible. Id. at 697-98.

10/ Concerned Citizens on Logan Township Safety, Stanley C. Van Ness (Public Advocate of the State of New Jersey) and the Boroughs of Paulsboro and Swedesboro.

its prior one. They take the position that the decision is erroneous in three major respects: (1) the Board's finding about the probability of a flammable vapor cloud reaching the plant rests on insufficient evidence; (2) the record is barren of evidence about riverborne traffic in hazardous cargoes other than LNG; and (3) the value found by the Licensing Board to be the probability that a flammable gas cloud will reach the plant is sufficiently close to the 10^{-6} per year standard calculations that design changes which would eliminate or minimize that risk should have been explored. They also argue that a supplemental environmental impact statement, dealing with the risk to the plant from hazardous river traffic, must be filed.[11/]

As we explain in detail in Part I of this opinion, we affirm the Licensing Board's acceptance of the applicants' determination as to three of the five factors which govern the probability of a flammable vapor cloud reaching the Hope Creek plant as the result of an LNG or LPG tanker accident. We

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11/ We wish to acknowledge the participation of the Office of the New Jersey Public Advocate, which has represented the joint intervenors throughout and also Mr. Caccia on this appeal. Its efforts have contributed substantially to the development of the record on an important public issue and were appreciated by this Board.

hold that the evidence does not support the value found by the Licensing Board for the spills per collision factor and we adopt a higher, more conservative value. However, for reasons given below, we are now satisfied that the LNG traffic, which under our decision in ALAB-429 the Licensing Board was constrained to consider, is unlikely to develop. We are, therefore, able to approve the construction of the plant as proposed -- but with the addition of license conditions designed to ensure that the staff will be promptly alerted should circumstances arise which suggest that either LNG traffic or a significant increase in LPG traffic will materialize or that other factors which govern the probability calculation will change. We caution the applicants that, if this occurs, they will either have to (1) demonstrate that the plant nevertheless meets the prescribed probability standard under an improved probability analysis, (2) achieve a strengthening of the Coast Guard's rules for flammable gas tanker traffic in the vicinity of the plant or (3) adapt the plant so that it is able to withstand an LNG or LPG fire or explosion without endangering the public health and safety.

In Part II, we reject the intervenors' legal position that a supplemental environmental impact statement on the flammable gas cloud hazard must be filed.

I. THE SAFETY ISSUE

In ALAB-429,[12/] we stated:

> The method used by the applicant to determine the probability that an LNG accident would affect the plant was to consider the chain of events that would have to occur in order for that to happen. Each event in the chain was assigned a numerical value, or conditional probability, and the combined probability was obtained by multiplying together all of these values. [Footnote omitted.] The factors considered in the calculation were: (a) number of ships per year; (b) accident rate (accidents per mile); (c) probability of an LNG spill in the event of an accident (spills per accident); (d) probability that, if an LNG spill did occur, the natural gas vapor (methane) would not ignite at the site of the accident but instead form a flammable cloud (vapor clouds per spill); and (e) probability that the vapor cloud produced as a result of a spill along the Delaware River would reach the plant site with a methane concentration in the flammable range, i.e., 5-15% by volume (the meteorological factor).[*/]

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*/ The calculation of the meteorological factor is illustrated in Applicant's Exhibit 11, at pp. 23-27. It consists of the sum of probabilities that a vapor cloud produced in each one-mile stretch of the Delaware River channel will reach the plant site. These individual probabilities are based on actual meteorological data for the Hope Creek site. For a one-tank spill, the probability that a flammable cloud would reach the site from distances of greater than 12 miles in either direction on the river was taken by the applicant to be zero. Id. at 26.

This methodology would apply as well to LPG vapor clouds, with appropriate changes in the individual factors.

12/ 6 NRC at 235.

The conclusion which prompted our remand of the flammable vapor cloud issue in ALAB-429 was that some of the conditional probability factors accepted by the Licensing Board were not supported by substantial evidence of record. Those were the accident rate per mile, the spills per accident, and the vapor clouds per spill.[13/] Their inadequacy applied to both LNG and LPG traffic.[14/] We did find applicants' meteorological factor for LNG vapor to be reasonable and conservative[15/] but were unable to accept the use of the same meteorological factor for LPG vapor.[16/]

With regard to ships per year, we stated that we were obliged to assume that construction of the proposed LNG terminal at West Deptford would be approved by the Federal Energy Regulatory Commission ("FERC").[17/] We also ordered that further information be elicited as to the expected magnitude of river traffic in the various LPG materials in future years.[18/]

13/ Id. at 236-41.

14/ Id. at 244.

15/ Id. at 241-42.

16/ Id. at 244-45.

17/ Id. at 236. In ALAB-429, we spoke of FERC's predecessor agency -- the Federal Power Commission ("FPC"). See n.111, infra.

18/ Id. at 243.

A matter that was raised for the first time at the remanded hearings was the disclosure of the existence of a "rammable object" in the Delaware River close enough to the plant that a flammable vapor cloud resulting from an accident there could reach the plant.[19/] The object, the base of a transmission tower numbered 97, was found by the Board to be 8.8 nautical miles up-river from the plant.[20/] Evidence was taken at the hearings concerning the probability that a flammable vapor cloud caused by an LNG or LPG ship ramming "Tower 97" might reach the plant.

The hearings on remand have materially increased the information in the record concerning the factors from which the probability of the hypothesized accident may be calculated. As in our first decision, we shall address each of these factors individually.

19/ LBP-78-15, *supra* at 686-95.

20/ *Id.* at 686-87.

1. Ships Per Year

The Licensing Board decided to use, for the purpose of calculating probability, a value of 360 LNG tankers passing the plant each year.[21/] This number is based on a staff estimate of expected traffic from both the proposed West Deptford LNG Terminal (292 ships per year) and the previously proposed Raccoon Island Terminal, a project which was cancelled (68 ships per year).[22/] Clearly, it was error to include projected traffic from the cancelled terminal. However, the whole matter of LNG ship traffic is the subject of more detailed discussion later in this opinion (pp. 41-46, infra), and thus we defer further comment on the number of LNG ships per year until then.

The Licensing Board adopted the following values for traffic in the various types of LPG: propane -- 40 ships per year; butane -- 10 ships per year; butadiene -- 10 ships per year; propylene -- none.[23/]

The Board based its projection of propane traffic on the maximum number of propane shipments that could be

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21/ Id. at 644-45 and Table II at 676.

22/ See id. at 644.

23/ Id., Table II at 676 and 677-79.

received at an existing Sun Oil Company LPG terminal at Marcus Hook, Pennsylvania, up-river from the Hope Creek site.[24/] Current propane traffic is reported to be about 12 ships per year.[25/]

For butane, the Board accepted a value of 10 ships per year proposed by the staff, rather than the applicants' figure of 2 per year.[26/] The record indicates that there has been only one butane shipment up the Delaware since 1974.[27/] Butane shipped up the Delaware is used by refineries as a gasoline additive, and the most likely cause for an increase in butane traffic would be an increase in gasoline output by up-river refineries.[28/] While there was no indication that such an increase would materialize, the Board nevertheless used the staff's larger value.

The figure of 10 ships per year for butadiene was based on applicants' estimate of current traffic. There was no figure for butadiene traffic proposed by the staff, nor were any projections of future traffic made.[29/]

24/ J. Read, Supplemental Testimony, p. 9.

25/ Ibid.

26/ LBP-78-15, supra, at 678.

27/ Kalelkar Supplemental Testimony, pp.59-60.

28/ LBP-78-15, supra, at 678.

29/ See id. at 678-79.

Intervenors assert that the LPG traffic estimates accepted by the Board do not adequately reflect increases in such traffic that may occur during the life of the plant. In this regard, the note that the number of propane and butadiene shipments has increased significantly in the recent past. Intervenors also complain that the efforts of the applicants and staff to make a quantitative assessment of future LPG traffic were not substantial.

As we see it, the 40 per year propane tanker figure, established on the basis of a yet unfinished terminal facility and more than three times the current traffic, seems to be a reasonable estimate. Moreover, the use of this value does involve a projection into the future. While the applicants and staff might conceivably have done better in trying to predict future traffic, the fact remains that, notwithstanding intervenors' speculation that additional terminal facilities may be built, evidence of plans to build any such facilities is lacking. In light of the low current magnitude of butane traffic and unestablished potential for its future growth, we

find the Board's acceptance of 10 butane ships per year conservative, perhaps overly so. On the other hand, the butadiene figure (10 ships per year) is clearly based on current traffic without any serious consideration having been given to future prospects for the shipment of this material.[30/]

However, the per ship risk to the Hope Creek plant is about the same for vessels carrying butane or butadiene[31/] and the potential for future propane traffic was accounted for. On balance, therefore, we accept as reasonable the estimate of total LPG traffic which was adopted by the Licensing Board to assess the potential for hazard at Hope Creek.

2. Accidents Per Mile

The applicants and staff both propose 1.5×10^{-6} per mile as the accident rate for LNG and LPG ships in

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30/ See ibid; Kalelkar Supplemental Testimony, p. 59.

31/ LBP-78-15, supra, Table II at 676.

that portion of the Delaware River appropriate for the analyses of the vapor cloud hazards at Hope Creek.[32/] The Board accepted this value and undertook an extensive review of the record to explain its reasons for so doing.[33/]

The applicants' accident data base was determined by taking all the collisions which occurred on the Delaware River for a seven year period (fiscal years 1969-75) and eliminating those accidents not likely to take place in the part of the river near Hope Creek (e.g., collisions involving an anchored or moored vessel) and those involving a vessel not large enough to damage an LNG or LPG tanker. An explanation was provided for rejecting particular collisions or groups of collisions. This process yielded ten relevant collisions out of a total of 67 for the period.[34/] The applicants' accident rate was determined by dividing the average number of relevant collisions per year by the average number of ship miles per year traveled on the river, during that same period, by the types of vessels large enough to be considered.[35/]

32/ Kalelkar Supplemental Testimony, pp. 21 and 55; J. Read, Supplemental Testimony, p. 21.

33/ LBP-78-15, supra, at 645-63 and 681.

34/ Kalelkar Supplemental Testimony, pp. 13-18.

35/ Id., pp. 19-21.

The collision rate obtained using actual shipping data was characterized by the applicants as being a conservative reflection of the collision rate to be expected for ships following the Coast Guard's "rules of the road" for LNG and LPG ships and having the design features of LNG ships.[36/] Testimony indicated that the Coast Guard chose not to rely on the alleged impenetrability of LNG and LPG tankers, but rather instituted traffic regulations for these ships designed to prevent accidents.[37/] One of the Coast Guard witnesses testified that, in his opinion, the penalties for violation and the Coast Guard presence will ensure that these regulations are observed.[38/] On the other side, intervenors' witness, Dr. Fisher, pointed out that some of the collision data were obtained during periods in which some of the same rules of the road now contained in the Coast Guard regulations were already being utilized.[39/] He also disputed the efficacy of certain design features of LNG tankers which are supposed to improve safety.[40/] Worldwide experience to date is not very helpful on this question, as there have been no LNG tanker collisions and only a statistically valid upper limit to the collision rate

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36/ Id. at 19-20 and Appendix C.

37/ J. Read, Supplemental Testimony, p. 25.

38/ Tr. 3482-83.

39/ Fisher Testimony, following Tr. 3411, pp. 19-20.

40/ Id. at 12-17, 21-23, 28-29.

(e.g., 95% confidence) can be assigned.[41/]

Despite the conflicting testimony by seemingly well qualified experts on the conservatism of the collision rate, we are persuaded that all of the special precautions being taken to reduce the likelihood of an LNG accident will have a beneficial effect. We therefore concur with the Board below that applicants' collision rate, determined from conventional ship accident data, is a conservative value to apply to ships following the LNG rules. We are unable to assign a specific magnitude to this conservatism, however, for only with additional LNG experience can the effectiveness of the safety measures be quantified.

We, as did the Licensing Board, accept as reasonable the applicants' assertion that a collision between an LNG or LPG tanker and another vessel of substantial size represent the prevalent type of accident which could lead to the spillage of LNG or LPG.[42/] We believe that the record fairly supports the exclusion of grounding accidents[43/] from the data base because the bottom of the Delaware River in the

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41/ Kalelkar Supplemental Testimony, Appendix D, pp. D-3 and D-5.

42/ [illegible]-7[illegible]-15, supra, at 652 and 659. The applicants excluded collisions between an LNG or LPG tanker and a tug or barge on the ground that such a collision could not cause a spill. Id. at 652.

43/ I.e., the situation where a vessel proceeds into waters insufficiently deep for its draft and runs aground.

region of Hope Creek is not rocky but silty and sandy.[44/] Thus, a grounding would be unlikely to cause loss of cargo from a double hulled or pressure vessel type of tanker.[45/]

Rammings (other than at Tower 97 which was treated separately) were excluded from the accident data base because, in the region of the river within the 24 mile catchment distance of Hope Creek,[46/] there are no rammable objects. Intervenors suggest that this might not be the case throughout the 40-year life of the plant, but did not adduce evidence that any objects of this type are proposed for construction on this segment of the river. An assessment of the increase in the flammable vapor hazard due to the construction of additional rammable objects would therefore be an exercise in uninformed speculation in which we are unwilling to engage.

44/ Tr. 3059; see Appendix A to Kalelkar Supplemental Testimony.

45/ It is quite true, as intervenors argue, that a grounding on an uncharted rock or at high speed on a hard spot on the river bottom could cause a cargo spill. But the Delaware is a well-traveled waterway and there is no showing that the likelihood of a grounding of this type is so large that it should reasonably be included in the accident data base.

46/ As we stated in ALAB-429, supra, at 242, applicants' meteorological data showed that "a vapor cloud formed from a one-tank (10,000-ton) spill could reach the site in a flammable concentration from a distance of up to 12 miles in either direction on the river." Applicants have referred to this zone in which a tanker accident could impact the plant as the "catchment distance."

3. Spills Per Collision

The spills per collision factor is in effect a measure of the severity of a collision, for it quantifies the likelihood that LNG or LPG will be released once a collision has occurred. The applicants determined this factor by means of an empirical analytical technique developed by V. U. Minorsky, a naval architect.[47/] This method predicts the depth to which a colliding ship will penetrate the vessel it strikes by evaluating the vessels' size, their relative speeds, their structure and the angle of collision. When, for a given set of data, the penetration depth equals or exceeds the outermost boundary of an LNG or LPG tank, the method assumes that the tank's contents are spilled.[48/]

The method, as used by the applicants, is best outlined in Applicants' Exhibit 10 (Answer to Question 1). The main assumptions used to calculate the spills

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47/ Minorsky, An Analysis of Ship Collisions with Reference to Protection of Nuclear Power Plants, JOURNAL OF SHIP RESEARCH (October 1959)(Applicants' Exhibit 13).

48/ Appl. Exh. 10, p. 2.

per collision factor are there stated to be: (a) that the relative velocities of colliding ships are uniformly distributed from 0 to 12 knots; and (b) that the angles at which the ships collided are distributed uniformly from 0° to 45°.[49/] Applicants also assume that all of the collision energy is absorbed by the struck ship and that the striking ship suffers no damage.[50/] (This is, of course, a conservatism because inevitably some of the force will be absorbed by the striking vessel).

49/ At the confluence of the Chesapeake & Delaware Canal and the Delaware River, an angular distribution of 0° to 90° was assumed in recognition of the fact that at this location collisions at all angles up to 90° (beam-on) were likely, as a colliding ship coming from the canal may strike an LNG or LPG ship plying the Delaware. ALAB-429, supra, at 239; Kalelkar Supplemental Testimony, p. 35.

In ALAB-429, supra, at 239 (see n. 58), we followed Minorsky's convention of calling the impact angle 0° when the ships are moving perpendicularly to each other and 90° when they are moving on parallel courses. On remand, the applicants' testimony abandoned that convention and so did the Licensing Board. LBP-78-15, supra, at 664 n. 27. As should be obvious from the preceding paragraph, we do so as well. We now call the perpendicular relationship 90° and the parallel configuration 0°.

50/ Tr. 2681.

Although the depth of penetration also depends upon the mass of the striking ship,[51/] applicants did not specify what ship size spectrum they used to calculate spill probabilities. Their calculations yielded spills per collision values of 0.0067 for the membrane type LNG ship and 0.0034 for ships of the spherical, or free standing, tank design.[52/] Applicants adopted an average value of 0.005 spills per collision in the analysis for LNG ships.[53/] However, they calculated a spills per collision value of 0.05 for the area adjacent to the Delaware River Ship Canal, where collisions at all angles were deemed possible (i.e., 0° - 90°).[54/]

On the ground that late model propane tankers, though smaller, are similar to LNG tankers in structural design, applicants adopted the same spills per collision factor for propane tankers.[55/] A spills per collision figure of

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51/ See Appl. Exh. 10, pp. 2-3.

52/ Id. , p. 1.

53/ Id., p. 2.

54/ Appl. Exh. 11, p. 24.

55/ Kalelkar Supplemental Testimony, pp. 54-56.

0.1 was estimated by the applicants for ships transporting butane and butadiene -- twice as large as the "all angles" value for LNG and LPG ships.[56/]

In ALAB-429, we expressed concern that there was little basis established for the applicants' assumptions regarding the angle (0-45°) and speed (0-12 knots) of collisions.[57/] We also pointed out that there were apparent discrepancies between the magnitude of collision effects predicted by the applicants' analysis and those reported elsewhere.[58/]

On remand, applicants' witness failed to take up our suggestion[59/] that a study of accidents which had occurred under analogous situations might yield information applicable to liquefied gas tanker collisions on the Delaware River. At least with respect to collision angles, Dr. Kalelkar stated that the only relevant data would

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56/ Id. at 59 and 60.

57/ ALAB-429, supra, at 240.

58/ Ibid.

59/ Id. at 234.

be that collected within the 24-mile segment of the river adjacent to Hope Creek. At present, there are no such data.[60/] Thus, the speed and angle of collision assumptions were accepted by the Licensing Board primarily on the basis of their reasonableness for ships traveling in narrow waters under rigid Coast Guard speed regulations and with an escort vessel.[61/]

We are unable to perceive why data on angle and speed of collision gathered from other narrow shipping channels generally comparable in conformation to the stretch of the Delaware River near Hope Creek could not be used to establish a statistically valid and applicable frequency distribution for these two critical collision parameters. Indeed, we have recently endorsed a procedure used by the staff and applicants in another case for the calculation of aircraft crash probability in the vicinity of a particular airport from data as to crashes near all commercial airports where, as here, the small likelihood of occurrence renders it impossible to glean meaningful probability data from accidents at the location in question

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60/ Kalelkar Supplemental Testimony, pp. 35-36.

61/ LBP-78-15, *supra*, at 669.

alone. Metropolitan Edison Co. (Three Mile Island Nuclear Station, Unit No. 2), ALAB-486, 8 NRC 9, 36 (1978). As for Dr. Kalelkar's statements about the lack of collision angle data, we note that one collection of data in the record for 12 tanker collisions which took place in rivers and harbors[62/] includes an angle of collision value in degrees for 8 of the 12 accidents and the notation "glancing" or "raking" for two others.[63/]

Intervenors' witness (Dr. Fisher) took issue with the angle and speed assumptions, suggesting that a conservative analysis would assume either all angles of collision or speeds near the top of the allowable 12 knot range.[64/] He also testified that Minorsky, in a telephone conversation with him, agreed with his view that the Minorsky technique may not be properly applied to collisions involving double-

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62/ SAI Draft (described at pp. 26-27, supra), pp. 3-13 to 3-15.

63/ The angle data there presented does not support a 0-45° assumption for collision angles but there is no specific information given for the exact channel configuration in each case.

64/ Fisher Direct Testimony, p. 33.

hulled vessels where the angles of collision are less than 60 or 70 degrees.[65/] In this regard, the Licensing Board's own review of Minorsky's paper led it to conclude that the accuracy of the correlation declines as the collision angle decreases below 90°.[66/] This is probably due to the fact that the smaller collision angles were not included in the data base upon which the correlation was established.[67/] The Licensing Board accepted the correlation, however, because there was nothing in Minorsky's published paper (Appl. Exh. 13) to suggest that the "method is invalid when applied to oblique collisions."[68/]

Dr. Kalelkar, on rebuttal, also relied on a privately expressed opinion of Minorsky, obtained during a visit with that gentleman. He stated that Minorsky agreed that the analysis could be used for small collision angles[69/] and that the values derived in applicants' analysis were in

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65/ Tr. 3629-30.

66/ LBP-78-15, supra, at 666.

67/ Ibid.

68/ Ibid. (Emphasis in original).

69/ Tr. 3698.

the same range as those arrived at by Minorsky himself in a study he had made using his own depth of penetration method to analyze LNG tanker collisions.[70/] However, that study was not introduced into evidence.[71/]

The document in question, Collision Study for LNG Tankers -- for Marathon Oil Company, presents a series of calculations performed using Minorsky's correlation to determine the critical collision speed for a variety of ships colliding with an LNG tanker of a particular design. The critical speed is the lowest speed of the striking ship which will result in penetration of the LNG tank, hence causing a spill. The collision angle, though not specified, is presumably 90°, in order to have the minimum critical speed value for each colliding ship.

70/ Ibid. Unlike the Licensing Board (see LBP-78-15 at 665-66 and 668-69), we believe that it is impossible to resolve the conflict between the hearsay testimony of Drs. Fisher and Kalelkar as to Minorsky's opinion of applicants' use of his methodology. Hearsay evidence may be admitted in proceedings before this Commission only if it is reliable. 10 C.F.R. §2.743(c). In view of the contradictory testimony of Dr. Fisher, Dr. Kalelkar's testimony was, in our judgment, not sufficiently reliable to meet this standard.

71/ See Tr. 3703-06.

Although, as stated above, this study was not offered into evidence, it was made available to us after oral argument, along with two other documents, at our request. In response to our inquiry, the parties stated that they did not object to our supplementation of the record to include these three documents, although the staff and intervenors did say that our reference to or reliance upon the documents should be restricted to "specific facts and data . . . referred to or relied on by any of the witnesses in this proceeding." Staff's letter to Appeal Board of October 18, 1978; intervenors' letter to Appeal Board of October 24, 1978. We found the contents of the Marathon oil study interesting but without value for our purposes. However, because it may have been implied from Dr. Kalelkar's testimony on rebuttal that this document shows that Minorsky's method may be used for small angle collisions, we note the fact that such use is not mentioned in the report. Indeed, its ultimate conclusions are stated as applying to 90 degree (i.e., beam-on) collisions.

One of the other documents placed into the record by us with the agreement of the parties, and which also relates

to spill probability, is a report prepared for the Federal Power Commission by Science Applications, Inc. ("SAI") entitled Risk Assessment of LNG Marine Operations for Raccoon Island, New Jersey. It comes in two versions -- draft and final (hereinafter "SAI Draft" and "SAI Final").[72/] It was referred to by witness Arvedlund of the Federal Energy Regulatory Commission[73/] and Dr. Kalelkar.[74/]

In SAI Final, there is presented an analysis of LNG tanker accident risks which is performed in a manner similar to that done by the applicants.[75/] However, SAI finds it reasonable to assume that collisions at all angles (0 to 90°) are possible in the Delaware River.[76/] And SAI apparently calculates spills per collision factors of 0.20, 0.13 and 0.10, depending upon the segment of the river being considered.[77/]

72/ Intervenors objected to our "utilization" of the SAI Draft on the issue of ignition probability because the intervenors were not able to cross-examine with respect to it.

73/ See his prepared testimony fol. Tr. 3310 at p. 6; Tr. 3319-32.

74/ See his Supplemental Testimony, pp. 45-46 and 64 (item 6).

75/ Dr. Kalelkar cites the results of the collision rate calculation presented in this document (slightly corrected) as a source of independent support for his 1.5×10^{-6} accidents per mile rate. Supplemental Testimony, p. 26.

76/ SAI Final, pp. 2-21 and 2-24.

77/ The SAI Final report does not present a spills per collision factor *per se*. However, for each of three river segments, Table 2.8 contains values of collision probability (per transit) and tank rupture probability (per transit). Dividing the latter of these two by the former must yield the number of tank ruptures (*i.e.*, spills) per collision, the three values of which are cited above.

The value for the Wilmington-Delaware Bay segment, which includes Hope Creek, is the largest -- 0.2. Although (FOOTNOTE CONTINUED ON NEXT PAGE).

These factors are substantially higher than applicants' value of 0.005.[78/] Counsel for intervenors brought this discrepancy to the attention of applicants' witness Kalelkar but did not press the matter sufficiently to get a definitive explanation for it into the record.[79/]

The staff's contribution to the spills per collision issue was nil. The staff rejected Minorsky's method and that of Bovet and Comstock and Robertson.[80/] Indeed, it

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77/ (FOOTNOTE CONTINUED FROM PREVIOUS PAGE) it is not clear why the values differ from one segment of the river to another, a possible explanation is that some segments contain open water, in which collision near 90° are much more probable. (See SAI Final, pp. 2-23 to 2-24). The Wilmington - Delaware Bay segment, including the open bay, would thus have a higher spill probability. The lower values would be appropriate for narrow channels, such as the river segment near Hope Creek.

78/ See p. 20, supra.

79/ Tr. 3025-27. Intervenors' counsel asked the witness to explain a discrepancy between a value of spills per mile derived from the SAI report (about 2×10^{-7}) and the value used by the applicants (about 10^{-8}). In his answer, Dr. Kalelkar appeared to assign the discrepancy to a difference in collision rate. However, he already had shown that the SAI collision rate and that derived by the applicants were in close agreement (n. 75, supra). Our review of the report leads us to conclude that the difference between the two values is due to SAI's higher spills per collision factor, arrived at using a Minorsky analysis, under the assumption of 0-90 degree angles of collision. SAI Final, pp. 2-17 to 2-24.

80/ J. Read, Supplemental Testimony, pp. 23-28. The reference is to D. M. Bovet Preliminary Analysis of Tanker Groundings and Collisions, (U.S. Coast Guard 1973) and Comstock & Robertson, Survival of Collision Damage Versus the 1960 Convention on Safety of Life at Sea, 69 SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS TRANSACTIONS 461 (1961). We had asked that these studies be addressed on remand. ALAB-429, supra, at 240 and 246.

of the process which it itself had promulgated. Implicit in the requirement that the probability of an accident be ascertained is the obligation to determine numerical probability values for each individual event in the accident sequence. When the validity of that determination is subjected to test in an adjudicatory hearing, a reasoned basis must be found for each proposed figure. The decision-making process is not aided when the staff deprecates the basis used by the applicants to support their spills per collision factor, and then accepts applicants' value for that factor because it is "reasonably conservative." Although it is certainly possible to conclude in a given case that either the data or the analytical methodology are not sufficient to make one confident of any specific value, it is hardly responsible in such a case to accept the lowest value presented in the record or referenced literature, which the staff did here by accepting the 0.005 figure.

The applicants' spills per collision factor was determined by the use of the Minorsky analysis, under the assumptions that ship collisions will be uniformly distributed in angle between 0 and 45 degrees and in relative speed between 0 and 12 knots. There is no indication of

concluded "that there was no rational method of deriving the required spill-per-accident estimate by a posteriori means."[81/] Although the staff said it would derive the estimate by "a priori techniques",[82/] it did not make any estimate at all. Instead, it accepted the applicants' spills per collision factor

> not because it was likely to be correct, but because there was no basis to believe that any accident that was predictable near Artificial Island would cause the rapid release of LNG gas necessary to endanger the nuclear power plants which are located about one mile from the river's deepwater channel. Such a rapid release, however, is not precluded by physical law, and it was therefore determined that 0.005 represented a reasonably conservative estimate of its probability if an accident should occur.[83/]

That explanation is unacceptable. The use of numerical probability criteria to determine whether a nuclear plant must be designed to withstand certain postulated accidents is required by the staff's own Standard Review Plan (NUREG-75/087, §2.2.3). (See pp. 2-3, supra). It is not legitimate for the staff, in a hearing on the application of those criteria to a particular problem, to base its position on a denigration

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81/ J. Read, Supplemental Testimony, p. 24.

82/ Ibid.

83/ Id. at 28-29.

the assumed size of colliding ships, although collisions involving certain types of ships, such as tugs and barges, were excluded from the data base because they would not rupture the tanks of an LNG vessel (see p. 14, supra). The value of this factor, 0.005, has a significant effect on the resultant yearly probability that a flammable gaseous cloud will reach the Hope Creek site. Stated another way, it reflects the analytical prediction that, of 200 postulated major collisions involving laden LNG or LPG ships on the Delaware River near Hope Creek, only one would be sufficiently severe to cause an LNG or LPG cargo spill.

The validity of the Minorsky analysis itself was questioned by both intervenors and the Licensing Board because, although it is an empirical technique based on collision data for more or less beam-on situations, it has been employed to compute depth of penetration in accidents occurring at oblique angles. While the correlation as it is formulated clearly accounts for the angle of collision,[84/] there is no body of data to indicate that

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84/ Appl. Exh. 13, p. 2.

the empirical correlation will correctly predict penetration at angles far less than 90°.[85/]

The extreme effect of the 0-45 degree angle-of-collision assumption on the results of the analysis is evidenced by the fact that a spills per collision factor 10 times greater was calculated by the applicants when collision in the range 0-90 degrees was assumed.[86/] Moreover, the calculations relied on in the SAI Final report apparently yield an even larger spills per collision factor, 0.1, when all angles of collision are considered.[87/]

85/ We do not mean to suggest that the correlation yields erroneous or nonconservative results for acute angles of collision, only that its performance is untested, hence uncertain, in this domain. The inclusion of angle of collision in the formula merely reduces the total kinetic energy of the two ship system to that kinetic energy associated with motion of the colliding ship in the direction normal (perpendicular) to the axis of the struck ship. Otherwise, there is no account made of the degree to which the energy absorbing resistance of a struck ship might change with the angle of collision. Since the correlation was based on a fit to near 90° collisions, there are no data which indicate how well the inclusion of smaller angles in the mathematical formulation is reflected by experience.

Admittedly, those collisions in the 0-45 degree range which could cause deep penetration are most likely to be those in which the collision angle approaches 45°. Thus, the collision angles of interest would be those nearest to the range of angles for which the correlation was established.

86/ P. 20, *supra*.

87/ Pp. 27-28 and n.77, *supra*.

The record is silent regarding the sensitivity of the spills per collision factor to the 0-12 knot relative speed assumption. Both the applicants and SAI used this range, and both cite Bovet[88/] to indicate that it is reasonable to assume a uniform distribution of impact velocity, from 0 to the maximum allowable speed, in this case 12 knots. Dr. Kalelkar includes in his testimony Figure 17 of Bovet's paper which plots depth of penetration by a striking ship against the striking ship's energy (energy is proportional to velocity squared) for a number of collisions.[89/] The distribution depicted there is skewed in favor of lower velocities. Moreover, in his study for Marathon Oil Company (supra, p.25), Minorsky calculated the speed at which the bow of a wide variety of striking ships, colliding with an LNG tanker at a 90° angle, would reach the inner hull of the LNG tanker without penetrating it. For a variety of heavy ships (we exclude his findings for small vessels because, as he stated at p. 12, there is no danger to an LNG tanker from them), Minorsky found that this "critical speed" ranges from 3.33 to 6.85 knots.

88/ Supra, p. 28 n. 80.

89/ Kalelkar Supplemental Testimony, Fig. 2, p. 41.

Taking into consideration all of this evidence, we find that the 0-12 knot assumption is reasonable.

On the basis of the foregoing discussion, we conclude that the spills per collision factor calculated by the applicants for LNG and propane tankers (0.005) cannot be accepted as valid or conservative because of the unproven nature of the Minorsky correlation for small collision angles and the lack of verification provided in the record for the assumption that collision angles will lie in the 0-45° range.

Applicants used a spills per collision factor of 0.1 for butane and butadiene ships.[90/] Although they did not provide any supporting analysis for it, the value is twice as large as for LNG tanker collisions at all angles. Under cross-examination, it was brought out that the ships carrying these products were of the double bottom design and would thus have a spill resistance comparable to that of the LNG ships.[91/] This spills per collision value also

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90/ Kalelkar Supplemental Testimony, pp. 59-60.

91/ See Tr. 3045, 3060-61.

is equal to approximately one half of that obtained from world wide experience with conventional, single hull tankers.[92/]

Despite the fact that no specific analysis was performed to obtain a spills per collision factor for butane and butadiene tankers, we believe that the extrapolation from the applicants' all angles results was conservative[93/] and we therefore accept it.

4. Vapor Clouds per Spill[94/]

There is apparently no adequate body of experience upon which to base a prediction of the likelihood that LNG or LPG liquid spilled as a result of a tank ship collision will ignite at the site of the accident. Applicants' witness took the position that, because of the large amount of energy that must accompany a collision of sufficient magnitude to cause a spill, there will be numerous ignition sources at the accident site and the

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92/ See Kalelkar Supplemental Testimony, p. 43.

93/ The major uncertainties in the use of Minorsky's technique are far less significant when all angles of collision are assumed.

94/ The meaning of this factor is stated in the quotation from ALAB-429 at p. 7, supra.

vapor cloud will "almost always ignite immediately."[95/] The "almost always" likelihood of ignition is translated into an estimate of 90%, and hence into a non-ignition or vapor cloud per spill, probability of 0.10 (i.e., 10%).[96/] Applicant cites four other analyses of LNG maritime hazards which use this value.[97/] The Licensing Board found this value acceptable and, for the reasons they assign, so do we.[98/]

In supporting applicants' probability value for vapor clouds per spill, the staff relied upon a review of vapor-cloud explosions by Strehlow.[99/] The paper was concerned with land-based events, and it cited cases in which vapor clouds were formed and traveled some distance before ignition. An inspection of the accidents discussed there reveals, however, that in most cases in which

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95/ Kalelkar Supplemental Testimony, pp. 49-50.

96/ Id. at 50.

97/ Id. at 50-51.

98/ LBP-78-15, supra, at 669-71.

99/ Strehlow, Unconfined Vapor-Cloud Explosions -- An Overview, presented at the Fourteenth Symposium on Combustion, Pennsylvania State University (August 20-25, 1972).

ignition was delayed, the event resulting in the release of flammable material was relatively minor (e.g., a burst pipe, a large leak or an open valve). This information is consistent with the thesis that, when ignition sources are provided by the accident itself, as in a severe ship collision, the vapor will most probably ignite at the collision site. It does not, however, provide any basis for quantification of that proposition.

5. The Meteorological Factor

We found in ALAB-429 that the meteorological factor calculated by the applicants for LNG vapor was reasonable and appropriately conservative.[100/] However, we questioned their meteorological factor for LPG because LPG is flammable in much lower concentrations than LNG -- 2 to 6%, as against 5 to 15% for LNG.[101/] This matter was resolved at the remanded hearing, as the Licensing

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100/ Supra, at 242.

101/ Id. at 244-45.

Board explained:[102/]

> Evidence presented in the remanded proceeding demonstrates that flammable limits for gases, when expressed in percentages, are mole-percentages (Kalelkar Supplemental Testimony at 56). In terms of molecular weight, propane is 2.75 times "heavier" than methane (ibid.). When the flammable limits of the two are converted from mole-percent to pounds per cubic feet, the lower flammable limits of the two are approximately the same: 2.59×10^{-3} lb/ft^3 for propane and $2.24 \times 10^{-3} lb/ft^3$ for methane (id. at 57). The distance that a vapor cloud remains flammable is a direct function of the flammable limit expressed in units of mass. Since in mass units the lower flammable limits of the gases are about the same, the maximum hazard distances for them are about the same (ibid.)

6. Tower 97 and Vinyl Chloride Traffic

During the course of the proceedings on remand, the presence of Tower 97 up-river from Hope Creek was disclosed and the question of how much the possibility of a tanker ramming this object adds to the total probability of a flammable vapor cloud reaching the Hope Creek site was the subject of testimony. Using traffic levels of

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102/ LBP-78-15, supra, at 683.

360 LNG ships and 60 LPG ships, and other probability factors developed for this particular incident, the Licensing Board found that the likelihood of a vapor cloud reaching Hope Creek as the result of an LNG or LPG tanker ramming Tower 97 is 3.16×10^{-8} per year.[103/] We accept the Board's findings, noting that the spills per ramming incident factor used, 0.1, was determined using the upper limit of an estimated range of probability that the rammed transmission tower will fall on the tanker and cause a spill.[104/] .

The Board also found that the probability of a flammable vapor cloud reaching the Hope Creek plant as a result of an accident involving a vinyl chloride tanker on the Delaware River is $.9 \times 10^{-8}$ per year.[105/] All of this gas is shipped on one vessel, in which the vinyl chloride tanks are 26 feet inboard from the hull and are surrounded by cofferdams and tanks containing nonflammable materials.[106/] Furthermore,

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103/ See id. at 686-95.

104/ Id. at 691.

105/ Id. at 698.

106/ Id. at 697.

vinyl chloride tankers must obey the same Coast Guard regulations which govern LNG and LPG traffic.[107/] We accept the Board's findings for this type of accident and agree that its contribution to the cumulative probability of a flammable vapor cloud reaching the Hope Creek plant is negligible.

DISCUSSION

With the exception of the spills per collision factor and the number of ships per year, we have accepted the Licensing Board's determinations of the values for the five factors used to calculate the probability of a flammable vapor cloud reaching the plant. The spills per collision factor is of critical importance. If we were to accept the Licensing Board's figure of 360 LNG ships per year and to assume arbitrarily that the spills per collision factor for LNG ships applicable to the entire catchment distance should be 0.05 (i.e., accept applicants' Minorsky method calculation but use a 0-90 degree collision angle distribution), LNG traffic alone would result in a vapor cloud probability which exceeds the 10^{-6} per year standard for a conservative calculation. Moreover, another

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107/ Ibid.

remand is not likely to yield much better evidence on spills per collision. It could only refine the theoretical models because "no LNG tanker has ever lost its cargo in a marine casualty" or even "been involved in a collision with another ship while underway".[108/]

We turn, therefore, to the Licensing Board's value of 360 LNG ships per year. We have already held (supra, p. 10) that it was error to include traffic from the proposed Raccoon Island Terminal, which was cancelled. This reduces the LNG traffic to 292 ships per year calling at the proposed West Deptford LNG Terminal. We noted in ALAB-429 that the Federal Power Commission staff had recommended that construction of this terminal not be approved because the transportation of LNG on the Delaware River "would result in an unacceptable risk to the public."[109/] Nevertheless, we said:[110/]

> Since it is our obligation to be conservative on matters of safety, we must assume that it [the application to construct and operate the West Deptford terminal] will be approved and that the tanker traffic will therefore materialize.

108/ Appendix D to Kalelkar Supplemental Testimony at p. D-3.
109/ Supra, at 236, quoting from Board Exh. 2, p. 158.
110/ Id. at 236.

We now question whether it is still wise to make that assumption. A year and a half has passed and the Federal Energy Regulatory Commission ("FERC"), which has inherited the approval responsibilities for the West Deptford plant from the Federal Power Commission,[111/] has yet to act on the matter. As of the time of the oral argument of this appeal last August, the FERC proceeding was in limbo.[112/] Tenneco (the applicant) "did not want to go ahead with the hearing but neither did they want to dismiss the case".[113/] The FERC staff did not want to go forward with its review of the application until Tenneco submitted information as to the source of the LNG and the price to be charged for it.[114/] Tenneco did not have any LNG under contract for this terminal at that time.[115/] Lieutenant Stanton of the Coast Guard in Philadelphia testified that "the prospects of receiving LNG [on the Delaware River] at this point are rather remote . . . ."[116/] And FERC staff witness Arvedlund gave the following testimony:[117/]

111/ See App. Tr., pp. 11-12 and 86; Natural Gas Act §3, 15 U.S.C. §717b; DOE Organization Act §§301(b) and 402(f), 42 U.S.C. §§7151(b) and 7172(f); DOE Delegation Order No. 0204-26, 43 Fed. Reg. 47769, 47772 (October 17, 1978).

112/ Id., p. 86.

113/ Id., p. 12.

114/ Id., p. 86.

115/ Ibid.

116/ Tr. 3443.

117/ Tr. 3365-66.

Q. In the case of the West Deptford site, you suggested alternate sites. Could you list what these alternate sites were?

A. For purposes of the draft impact statement, if memory serves me correctly, the recommendation was that there were possibly better sites in the Chesapeake Bay and other such places.

For the final environmental statement, we are proposing to look at specific sites in detail and perhaps come up with a site, if such is warranted. That has not been completed to date.

Q. Would it be a fair characterization to say that the chances of a site located in a populated area in an inland waterway would have a small chance of being approved?

A. I certainly think that is the trend. I wouldn't want to assign a probability number to it, but there has certainly been a large number of interventions, a large amount of time and money spent by people promoting that idea, that they not be located in populated areas, one of which includes Mr. Buchsbaum.

I would not be shocked to see down the road that the criteria or a standard like that could in fact be applied. I wouldn't say that is going to be applied in every case, because there may be cases which warrant locating near populated areas.

But I do believe the trend is that way. That trend is certainly very active on the West Coast, where they have in fact passed a law in California which prohibits the location of LNG sites, and they relate to some populated [sic] density criteria.

The West Deptford site is directly across the river from Philadelphia International Airport. It is seven miles from Philadelphia itself, even closer to Camden, New Jersey, and adjacent to industrial and residential areas.[118/] The FPC staff found that the transportation of LNG on the Delaware River to the West Deptford Terminal "would result in an unacceptable risk to the public" and therefore recommended that the terminal site not be approved.[119/] We therefore deem it unlikely that the FERC will approve that location for an LNG terminal.

But safety considerations are not the only ones which make the building of an LNG terminal at West Deptford unlikely. A recent decision by the Department of Energy's Economic Regulatory Administration ("ERA"), indicates that ERA approval of further imports of LNG, at least in the foreseeable future, is unlikely for reasons of energy policy. Tenneco Atlantic Pipeline Co., DOE/ERA Opinion Number Three (December 18, 1978).[120/] In that case, the ERA rejected a

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118/ See Board Exh. 2, pp. 2, 58 and 96 and Figures 1 and 2 at pp. 4 and 5.

119/ Id. at 158.

120/ Under Sections 301(b) and 402(f) of the DOE Organization Act, 42 U.S.C. §§7151(b) and 7172(f), the Secretary of Energy must authorize the importation of natural gas pursuant to Section 3 of the Natural Gas Act, 15 U.S.C. §717b. He has delegated this responsibility to the Administrator of ERA. DOE Delegation Order 0204-25, 43 Fed. Reg. 47769, 47772 (October 17, 1978).

a proposal by a Tenneco subsidiary to import LNG from Algeria to a terminal in New Brunswick, Canada, there to reconstitute it as gas and bring it into this country by pipeline. Some of the main reasons given for the rejection were (1) that sufficient gas supplies are available from domestic sources in the short term, that long term needs can be met by domestic, Mexican and Canadian natural and synthetic gas, and that these sources are preferable to overseas sources; (2) that a real need for the importation of the gas does not exist; (3) that the LNG would be too costly and (4) that there was no contingency plan covering possible interruptions of consumers' supply.[121/] Another decision rejecting an application to import Algerian LNG was rendered three days later by the ERA, for similar reasons. El Paso Eastern Co., DOE/ERA Opinion Number Four (December 21, 1978). Although each proposal is treated individually, the ERA said in Tenneco: "In the case of proposed LNG import projects, however, national policy dictates the

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121/ See pp. 66-67 of the opinion. Another major reason was that the purchase proposed was not a direct one by distribution utilities from the producer. The West Deptford project also contemplates a purchase by the pipeline company. See Board Exh. 2, p. 1.

most cautious -- even skeptical -- assessment of each gas import project on its overall merits, since LNG generally represents a marginal natural gas supply for the U.S.A. at the present time."[122/] In our judgment, these two cases reflect an Administration policy which is generally unfavorable to LNG imports.

For all these reasons, we are unable to persist in our decision of last year that the LNG traffic projected for West Deptford must be assumed to exist. It is our practice to be conservative in assessing safety problems, but it is unreasonable to postulate hazards which neither exist at present nor are likely to come into being.

We therefore conclude that the value for LNG traffic in the Delaware River should be zero. Thus, the likelihood of a flammable vapor cloud from this source will be zero as well. Further, for the purpose of assessing LPG tanker accident hazards, we accept what we consider to be a conservative spills per collision factor for all LPG

122/ DOE/ERA Opinion Number Three, pp. 37-38.

ships of 0.1.[123] Because we have already accepted those values for the other terms in the probability calculation which the Licensing Board found to be reasonable, we can summarize the flammable vapor cloud probability from all remaining sources, using a table similar to the Licensing Board's table VI:[124]

Revised Flammable Vapor Cloud Probability

LNG Traffic[125]	0.0
LPG Traffic	
Propane	1.87×10^{-7}/yr.
Butane	$.48 \times 10^{-7}$/yr.
Butadiene	$.38 \times 10^{-7}$/yr.
LNG Traffic at Tower 97	0.0
LPG Traffic at Tower 97	$.05 \times 10^{-7}$/yr.
Vinyl Chloride Traffic[126]	$.09 \times 10^{-7}$/yr.
	2.97×10^{-7}/yr.

123/ This is the factor that was proposed by the applicants and accepted by the Licensing Board for butane and butadiene ships, which do not have the same safety features as LNG and propane tankers. LBP-78-15, supra, at 682-83. For the liquid propane carriers, 0.1 is twenty times the value assigned to it by the Licensing Board for points other than at the C&D Canal (id. at 681-82), twice the value that would be obtained using applicants' all angles Minorsky method analysis, and is apparently the same value used by SAI for narrow channels. See pp. 27-28 n. 77, supra.

124/ LBP-78-15, supra, at 697.

125/ Id., Table II at p. 676, with spills per collision modified as noted above.

126/ See id. at 698.

The resulting total probability of approximately 3 X 10^{-7} per year, which we believe to be based on conservative factors, is well within the guideline value of 10^{-6} per year for a conservative calculation. On this basis we find that the construction of the Hope Creek units may continue, without any modification in their design to accommodate the flammable vapor cloud hazard.

However, the construction permit we sanction today "does not make automatic the later issuance of a license to operate". Power Reactor Co. v. Electricians, 367 U.S. 396, 411 (1961). We direct that this issue be reassessed by the applicants and staff at the operating license review stage. At that time, it will be known for sure whether the West Deptford terminal will be built and there may be more data available on LNG/LPG accident rates, LNG/LPG tanker spill resistance and the behavior of flammable liquefied gases in maritime accident situations. If, by then, hazardous gas traffic has increased significantly or experience teaches that the probability factors used in these analyses are too low, that will have to be weighed very carefully

in deciding whether the Hope Creek plant may be licensed to operate. And in making that judgment, the need for power from the plant and the cost of its construction will not influence the decision. Rather, as the Commission has stressed, the obligation will be "to ascertain whether, irrespective of how great or small might be the benefits flowing from the operation of this particular facility, the record established that the health and safety of the public would be adequately protected and that the licensing of the facility would not be inimical to it". Maine Yankee Atomic Power Co. (Maine Yankee Atomic Power Station), CLI-74-2, 7 AEC 2, 4 (quoting ALAB-161, 6 AEC 1003, at 1008), aff'd sub nom. Citizens for Safe Power v. NRC, 524 F.2d 1291 (D.C. Cir. 1975).

As it is possible that applicants may eventually be faced with the need to modify the plant to accommodate the flammable vapor cloud hazard, it would be best for them to know of such a need at the earliest possible time. We therefore believe that the prudent course is to have those factors which might affect the probability monitored throughout the pendency of the construction

permit. In the event that this monitoring indicates a change in the factors which has a significant adverse effect on the probability[127/] (e.g., approval of construction of the West Deptford LNG Terminal), the applicants should report it to the staff and within a reasonable time period indicate how they propose to demonstrate the plant's acceptability in light of it.[128/]

127/ In the context of the monitoring conditions which we now impose on the construction permits, a change in one or more probability factors is deemed "significant" if its effect is to increase the total flammable vapor probability by a factor of two or more.

128/ See p. 56 and n.130, *infra*.

Cir. 1974):

> An EIS need not discuss remote and highly speculative consequences. * * * A reasonably thorough discussion of the significant aspects of the probable environmental consequences is all that is required by an EIS.

Accord, Environmental Defense Fund v. Hoffman, 566 F.2d 1060, 1067 (8th Cir. 1977); Concerned About Trident v. Rumsfeld, 555 F.2d 817, 828 (D.C. Cir. 1977); Sierra Club v. Hodel, 544 F.2d 1036, 1039 (9th Cir. 1976); Carolina Environmental Study Group v. United States, 510 F.2d 796, 799 (D.C. Cir. 1975).

We have found that the likelihood of the accident about which intervenors are concerned is so low that the plant does not have to be designed to withstand it. We can think of no logical reason why NEPA should require so much more than the safety provisions of the Atomic Energy Act and this Commission's safety regulations. See Carolina Environmental Study Group v. United States, loc cit. supra. Intervenors rely on Hanly v. Kleindienst, 471 F.2d 823, 830-31 (2d Cir. 1972), but that reliance is misplaced. Hanly dealt with the question of whether the environmental impact that will occur by reason of the

II. THE NEPA ISSUE

Intervenors contend that the National Environmental Policy Act ("NEPA")[129/] requires that the staff issue and circulate a supplemental environmental impact statement which discusses alternative methods of protecting the Hope Creek plant from accidents involving vessels on the river. In view of our findings on the probability of such an accident producing a flammable vapor cloud that would reach the nuclear plant, we find no merit in that position.

The Supreme Court has embraced the doctrine, first enunciated in Natural Resources Defense Council v. Morton, 458 F.2d 827, 837-38 (D.C. Cir. 1972), that environmental impact statements need not discuss the environmental effects of alternatives which are "deemed only remote and speculative possibilities." Vermont Yankee Nuclear Power Corp. v. Natural Resources Defense Council, 435 U.S. 519, 551 (1978). And the same has been held with respect to remote and speculative environmental impacts of the proposed project itself. As was stated by the Court of Appeals in Trout Unlimited v. Morton, 509 F.2d 1276, at 1283 (9th

129/ Specifically, 42 U.S.C. §4332.

proposed action is significant enough to require an impact statement, not with whether an impact whose occurrence is highly improbable must be dealt with in an environmental statement.

However, even if intervenors were correct in their position that the environmental statement must deal with the flammable vapor cloud accident, a supplemental statement would not have to be issued in this case. When the original statement was issued, the staff did not know enough about the accident's likelihood or its nature to warrant including a discussion of it. However, the probability of this type of accident has now been considered by the staff, has been the subject of two sets of hearings and has been discussed exhaustively in two decisions of the Licensing Board and in two decisions of this Board. Under 10 C.F.R. §51.52(b)(3), the environmental impact statement is deemed modified by the second decision of the Licensing Board (LBP-78-15, supra) and by this decision to show that this event is so unlikely that its environmental impact need not be considered. New England Coalition on Nuclear Pollution v. NRC, 582 F.2d 87, 93-94 (1st Cir. 1978); see Citizens for Safe Power v. NRC, 524 F.2d 1291, 1294 (D.C. Cir. 1975).

CONCLUSION

For the reasons stated in Part I of this opinion, the construction permits shall be modified by the addition of the following conditions:

1. Applicants shall monitor all forms of LNG and LPG traffic on the Delaware River. They shall also monitor those activities along the waterway which might lead to significant traffic of that kind in the future. A yearly report of actual LNG and LPG traffic projections for future traffic shall be made to the staff. However, major changes in either actual or projected traffic, such as approval by the FERC of the proposed West Deptford Terminal, shall be reported within 30 days.

2. The applicants shall monitor existing and planned construction of facilities in or along the Delaware river, within the 24 mile catchment distance and report yearly to the NRC staff as to the existence or planned construction of additional

rammable objects, mooring or docking sites, or any other facility that might cause a significant change in the probability of a flammable vapor cloud reaching the plant.

3. At intervals of not more than two years, the applicants shall submit to the staff a summary of LNG and LPG shipping experience, similar to that contained in Kalelkar Supplemental Testimony, Appendix D. To the extent possible, the data collected should be related to the various pertinent probability factors and their effect on those factors should be indicated.

   This review should include the results of pertinent experimental programs and the development of new or existing analytical methods which might similarly be related to those factors and the effect of their application on the probability factors considered in this case.

4. In the event that the monitoring programs disclose a change or changes that might have a significant adverse effect on the flammable vapor cloud probability, the applicants should prepare and submit

to the staff an analysis of whether the 1×10^{-6} standard will be met. If it is not, applicants should submit within 3 months a proposed method by which the changed circumstances will be countered to re-establish a sufficiently low probability factor.[130] Copies of all reports and proposals submitted by the applicants to the staff under these four paragraphs shall be sent to the Office of the Public Advocate of the State of New Jersey.

There remains open an issue raised by the Commission in this and other cases concerning the environmental effects of radon emissions attributable to the mining and milling of uranium. 43 Fed. Reg. 15613, 15615-16 (April 14, 1978). Final disposition of that question

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130/ This might be done by an improved probability analysis or by a proposed redesign of the plant. It might also be accomplished by a modification of the Coast Guard's regulations to prevent LNG or LPG tankers from meeting or being overtaken by other ships in that portion of the river near Artificial Island. These regulations already prevent LNG and LPG ships from overtaking, or being overtaken, and from meeting other ships at "bends in the river channel". (Kalelkar Supplemental Testimony, Appendix B, p. 2).

The prevention of meeting situations within 3 miles of the plant would reduce the likelihood of collisions in this stretch of the river to near zero. An inspection of Applicants' Exhibit 11, at p. 28, indicates that consideration of only those collisions more than 3 miles from the plant would reduce the meterological factor to 25% of its current value, and thus cause a similar four-fold reduction in the probability of a flammable vapor cloud reaching the plant.
(FOOTNOTE CONTINUED ON NEXT PAGE)

must await the completion of separate proceedings. See ALAB-480, 7 NRC 796 (May 30, 1978), ALAB-509, 8 NRC___ (December 1, 1978) and ALAB-512, 8 NRC___(December 21, 1978).

Except for the radon issue, the Licensing Board's authorization for the issuance of construction permits is AFFIRMED, subject to the modifications to the construction permits required herein.

It is so ORDERED.

FOR THE APPEAL BOARD

Margaret E. Du Flo
Secretary to the
Appeal Board

130/ (FOOTNOTE CONTINUED FROM PREVIOUS PAGE)
The record indicates that the NRC and Coast Guard are in the process of generating a memorandum of understanding on LNG tanker-nuclear plant interactions. (App. Tr. 126-27). That might be an occasion for considering a regulatory change of this nature.