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U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D. C. 20555

Serial No. NA3-10-032R
Docket No. 52-017
COL/MWH

DOMINION VIRGINIA POWER
NORTH ANNA UNIT 3 COMBINED LICENSE APPLICATION
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION LETTER 50

On December 2, 2010, the NRC requested additional information to support the review of certain portions of the North Anna Unit 3 Combined License Application (COLA). The responses to the following RAI Questions are provided in Enclosures 1 and 2:

- RAI 5210 Question 02.02.03-8 MCR Chemical Concentration ALOHA Model Inputs and Assumptions
- RAI 5210 Question 02.02.03-9 On-site Chemical Explosions Analysis Inputs and Assumptions

Please contact Regina Borsh at (804) 273-2247 (regina.borsh@dom.com) if you have questions.

Very truly yours,

Eugene S. Grecheck

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NFO

Enclosures:

1. Response to NRC RAI Letter Number 50, RAI 5120 Question 02.02.03-8
2. Response to NRC RAI Letter Number 50, RAI 5120 Question 02.02.03-9

Commitments made by this letter:

None

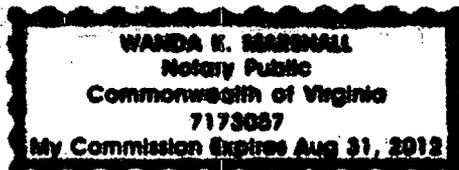
COMMONWEALTH OF VIRGINIA

COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President-Nuclear Development of Virginia Electric and Power Company (Dominion Virginia Power). He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of the Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 10th day of January, 2011
My registration number is 7173057 and my
Commission expires: August 31, 2012

Wanda Marshall
Notary Public



cc: (distribution w/o enclosures except where noted with an *)

U. S. Nuclear Regulatory Commission, Region II *

C. P. Patel, NRC *

J. B. Jessie, NRC

T. S. Dozier, NRC *

J. T. Reece, NRC

ENCLOSURE 1

Response to NRC RAI Letter 50

RAI 5120 Question 02.02.03-8

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**North Anna Unit 3
Dominion
Docket No. 52-017**

RAI NO.: 5210 (RAI Letter 50)

SRP SECTION: 02.02.03 – EVALUATION OF POTENTIAL ACCIDENTS

QUESTIONS for Siting and Accident Conseq Branch (RSAC)

DATE OF RAI ISSUE: 12/02/2010

QUESTION NO.: 02.02.03-8

RG 1.206 provides guidance regarding the information that NRC needs to ensure potential hazards in the site vicinity are identified and evaluated to meet the siting criteria in 10 CFR 100.20 and 10 CFR 100.21. The staff has performed confirmatory calculations which show that carbon dioxide concentrations at the control room air intake could exceed the National Institute for Occupational Safety and Health (NIOSH) immediately dangerous to life or health (IDLH) concentration limit of 40,000 ppm. However, the applicant's calculated concentration is lower than the IDLH concentration (COL FSAR Table 6.4-201). Therefore, the staff requests that the applicant provide the input data it used in ALOHA modeling of this chemical. Please also provide the rationale for using an urban or forest roughness factor selected in ALOHA modeling compared to the open country option used for on-site chemicals stored at Units 1 and 2.

As shown in COL FSAR Table 6.4-201, the applicant showed that calculated distances up to which IDLH concentrations could be exceeded would exceed the distances to the nearest control room air intake for each of the following chemicals: Ammonium Hydroxide (19%), Dimethylamine (40%), Hydrazine (20%), Hydrochloric Acid (30%) for Unit 3, and Ammonium Hydroxide (30%) and Carbon Dioxide for Units 1 and 2. This implies that the concentration of the above chemicals exceed respective IDLH concentrations at the control room air intake. However, the applicant calculated maximum concentrations of these chemicals using ALOHA in Table 6.4-201 are lower than the respective IDLH concentrations inside the control room. Please provide rationale and justification for using ALOHA model instead of HABIT model identified in the guidance provided in RG 1.78. Provide the concentrations of chemicals at the control room air intake along with the concentration in the control room for comparison.

Dominion Response

RAI Question 02.02.03-8 includes two parts –

- (1) The NRC staff requests that the applicant provide the input data it used in ALOHA modeling of carbon dioxide concentrations at the control room air intake and provide the rationale for using an urban or forest roughness factor selected in ALOHA modeling compared to the open country option used for on-site chemicals stored at Units 1 and 2.
- (2) The NRC staff requests that the applicant provide rationale and justifications for using the ALOHA model instead of the HABIT model identified in the guidance provided in RG 1.78, and provide the concentrations of chemicals at the control room air intake along with the concentration in the control room for comparison.

The following provides the response to each part:

- (1) Table 1 below presents a summary of the Areal Locations of Hazardous Atmospheres (ALOHA) model input values and the basis used for each input in the modeling of carbon dioxide. As specified by Regulatory Guide 1.206, *Combined License Applications for Nuclear Power Plants*, for each postulated event, the evaluation should determine a range of concentrations at the site for a spectrum of meteorological conditions. The evaluation conducted used a spectrum of standard meteorological conditions as depicted in Table 2 below for selected stability class, wind speed, time of day, and cloud cover conditions.

The degree of atmospheric turbulence influences how quickly a chemical cloud moving downwind will mix with the air around it and be diluted. Friction between the ground and air passing over it is one cause of atmospheric turbulence. Because the air nearest the ground is slowed the most, eddies can develop. The rougher the ground surface, the greater the ground roughness (Z_0), and the greater the turbulence that develops. "Urban or Forest" ground roughness was selected for the determined worst case meteorological class for the following Unit 3 chemicals stored on-site: acetone, ammonium hydroxide, carbon dioxide, dimethylamine, ethanol, hydrazine, hydrochloric acid, nitrogen and sodium hypochlorite (Access Building only). The selection of "Urban or Forest" is appropriate because the releases at the indicated chemical's storage locations would require a resultant vapor cloud to travel between/around the Unit 3 Ultimate Heat Sink structures (for those chemicals not in the Turbine Building) or around/between structures (e.g., pipes and tanks) within the Turbine Building (for those chemicals stored within the Turbine Building). Figure 1 below shows the storage locations in relation to the Unit 3 Main Control Room HVAC intake.

"Open Country" roughness was selected for the remaining chemicals listed in FSAR Table 6.4-201, including the Units 1 and 2 chemicals, because, as depicted in Figure 1, there are no obstructions or roughness elements between these storage locations and the Unit 3 Main Control Room HVAC intake.

- (2) Regulatory Guide 1.78, *Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release*, does not specify that the

HABIT model be used for control room habitability analysis, only that the dispersion model permits temporal as well as spatial variations in release terms and concentrations. This is indicated in Regulatory Position 3.3 of Regulatory Guide 1.78, which states:

"The atmospheric transport of a released hazardous chemical should be calculated using a dispersion or diffusion model that permits temporal as well as spatial variations in release terms and concentrations. The NRC uses a computer code HABIT, for control room habitability evaluation. The HABIT code is described in NUREG/CR-6210, "Computer Codes for Evaluation of Control Room Habitability (HABIT)" (Ref. 8)...Other atmospheric dispersion models (e.g., ARCON96) with similar capabilities may be used for dispersion calculations."

ALOHA, like HABIT, permits temporal as well as spatial variations in release terms and concentrations. ALOHA is part of the Computer-Aided Management of Emergency Operations (CAMEO) software package developed by the U.S. Environmental Protection Agency and National Oceanic and Atmospheric Administration to provide planning for chemical release emergencies. For example, ALOHA uses a time dependent Gaussian plume model for neutrally buoyant gases and a heavy gas dispersion model for gases with specific gravities greater than 1.0, and generates output in a concentration versus time format for specified receptors.

In addition, ALOHA has been used in other recent COL applications, such as the Comanche Peak US-APWR R-COL Application, the South Texas Project ABWR COL Application, and in previous revisions of the North Anna Unit 3 COL Application.

Table 3 presents a summary of the ALOHA modeling results including the constituent concentrations both at the MCR HVAC intake and inside the MCR.

Proposed COLA Revision

None

Table 1: ALOHA Input Values with Bases

Menu	Parameter	Input	Basis
Site Atmospheric Data			
Site Data	Number of Air Changes	0.771 air exchanges per hour	The number of air exchanges per hour (of outside air) for the Unit 3 main control room is used to estimate indoor concentrations of carbon dioxide.
Site Data	Date and Time	12:00 pm on June 21, 2008 5:00 am on June 21, 2008 was used only for Meteorological Classes E and F, and for Class D with a wind speed of 3 m/s	The date was selected because it coincides with the summer solstice. The time 12:00 pm was selected for those meteorological classes likely to occur during the daytime because solar radiation is highest during mid-day and higher solar radiation leads to a higher evaporation rate and thus a larger vapor cloud. The time 5:00 am on June 21, 2008 was selected to provide a realistic meteorological condition for those meteorological classes likely to occur during the evening or early morning.
Setup / Chemical	Chemical Information	Carbon Dioxide	This chemical exists in the ALOHA chemical library.
Setup / Atmospheric	Wind Speed	A meteorological sensitivity analysis was performed at varying wind speeds and meteorological stability classes to determine the worst case scenario. (see Table 2)	RG 1.206 requires that for each postulated event, the evaluation should determine a range of concentrations at the site for a spectrum of meteorological conditions. The ALOHA model was run over a spectrum of meteorological conditions to determine the worst case Main Control Room (MCR) concentration for each chemical release scenario. The chosen wind speed inputs were based on the meteorological stability classes defined by Pasquill.
Setup / Atmospheric	Wind Direction	S	In the ALOHA modeling runs conducted, the threat at point function was chosen which allows the user to set the receptor location directly downwind from the source for a worst case determination, effectively negating the input for this menu item (i.e., the model ignores the input value for wind direction).
Setup / Atmospheric	Wind Measurement Height	10 meters	ALOHA (ALOHA, 2007) calculates a wind profile based on the height at which the meteorological data is taken. Wind rose data from the onsite meteorological tower, described in ESP Application SSAR Section 2.3.3.1.2, were collected at a height of 10 meters. Additionally, the surface wind speeds for determining the Pasquill stability class are defined at 10 meters.

Table 1: ALOHA Input Values with Bases

Menu	Parameter	Input	Basis
Setup / Atmospheric	Ground Roughness	"Urban or Forest"	See RAI Question 02.02.03-8 response part (1).
Setup / Atmospheric	Cloud Cover	The appropriate selection is chosen to agree with the meteorological stability class (see Table 2).	ALOHA uses this input to estimate the amount of incoming solar radiation at the time of a chemical release. There are defined cloud cover percentages for some of the Pasquill meteorological classes.
Setup / Atmospheric	Air Temperature	91.5°F (mid-day) 71.5°F (night-time)	Air temperature influences ALOHA's estimate of the evaporation rate from a puddle surface. The higher the air temperature, the more the puddle is warmed by the air above it, the higher the liquid's vapor pressure, and the faster the substance evaporates. The highest mean daily maximum temperature in the last three years of available National Weather Service (NWS) data (2007, 2008, 2009) was used for mid-day calculations and the highest mean daily minimum temperature in the last three years of available data was used for night-time calculations.
Setup / Atmospheric	Stability Class	A meteorological sensitivity analysis was performed at varying wind speeds and stability classes (see Table 2).	The atmosphere may be more or less turbulent depending upon the amount of incoming solar radiation as well as other factors. Meteorologists have defined atmospheric stability classes, each representing a different degree of turbulence in the atmosphere. When moderate to strong incoming radiation heats air near the ground, causing it to rise and generate large eddies, the atmosphere is considered unstable (relatively turbulent). When solar radiation is weak or absent, air near the surface has a reduced tendency to rise, and less turbulence develops (stable atmospheres). As required in RG 1.206, a meteorological sensitivity analysis was performed.
Setup / Atmospheric	Humidity	63%	A relative humidity of 63% was selected because it is the average relative humidity over the last three years of available NWS data (2007, 2008, 2009).
Setup / Source	Direct	Direct	In ALOHA, the direct source is the option chosen for modeling a direct release of a gas over a given period of time.
Setup / Source	Direct/source strength units of mass or volume	Pounds	Releasing the quantity in pounds is an accurate representation of the amount of a chemical in a container for a gas.
Setup / Source	Direct/ Instantaneous or Continuous Source	Continuous	Continuous was selected because this allows for modeling a time duration release within ALOHA.

Table 1: ALOHA Input Values with Bases

Menu	Parameter	Input	Basis
Setup / Source	Direct/Amount of Pollutant Entering the Atmosphere	665.4 lb/min	For substances that are normally gases at ambient temperature and handled as a gas, if the released substance is not contained by passive mitigation systems or if the contained pool would have a depth of 1 cm or less, the entire quantity shall be released over 10 minutes and the release rate shall be assumed to be the total quantity divided by 10. (40 CFR 68.25, 2010) In the case of carbon dioxide, the total mass in the container (6,654 pounds) was assumed to be released over a period of 10 minutes.
Setup / Source	Direct/Source Height	0 feet	The source height is the height of a chemical release above ground. Source height is zero if the chemical is released at ground-level. The worst case release of a regulated toxic substance was analyzed assuming a ground-level (0 feet) release (40 CFR 68.22, 2010).

References:

(40 CFR 68.22, 2010) Title 40 Code of Federal Regulations Part 68.22, *Chemical Accident Prevention Provisions: Subpart B-Hazard Assessment: Offsite consequence analysis parameters*, March 2010.

(40 CFR 68.25, 2010) Title 40 Code of Federal Regulations Part 68.25, *Chemical Accident Prevention Provisions: Subpart B-Hazard Assessment: Worst-case release scenario analysis*, March 2010.

(ALOHA, 2007) Areal Locations of Hazardous Atmospheres (ALOHA) User's Manual, EPA and NOAA, February 2007.

Table 2: Meteorological Sensitivity Analysis

Stability Class	Surface Wind Speed (m/s)	Cloud Cover	Date/Time
A	1.5	0%	June 21, 2008/ 12:00 pm
B	1.5	50%	June 21, 2008/ 12:00 pm
C	3	50%	June 21, 2008/ 12:00 pm
C	5.5	0%	June 21, 2008/ 12:00 pm
D	3	50%	June 21, 2008/ 5:00 am
D	5.5	50%	June 21, 2008/ 12:00 pm
E	1	50%	June 21, 2008/ 5:00 am
E	2	50%	June 21, 2008/ 5:00 am
F	1	0%	June 21, 2008/ 5:00 am
F	2	0%	June 21, 2008/ 5:00 am
F	3	0%	June 21, 2008/ 5:00 am

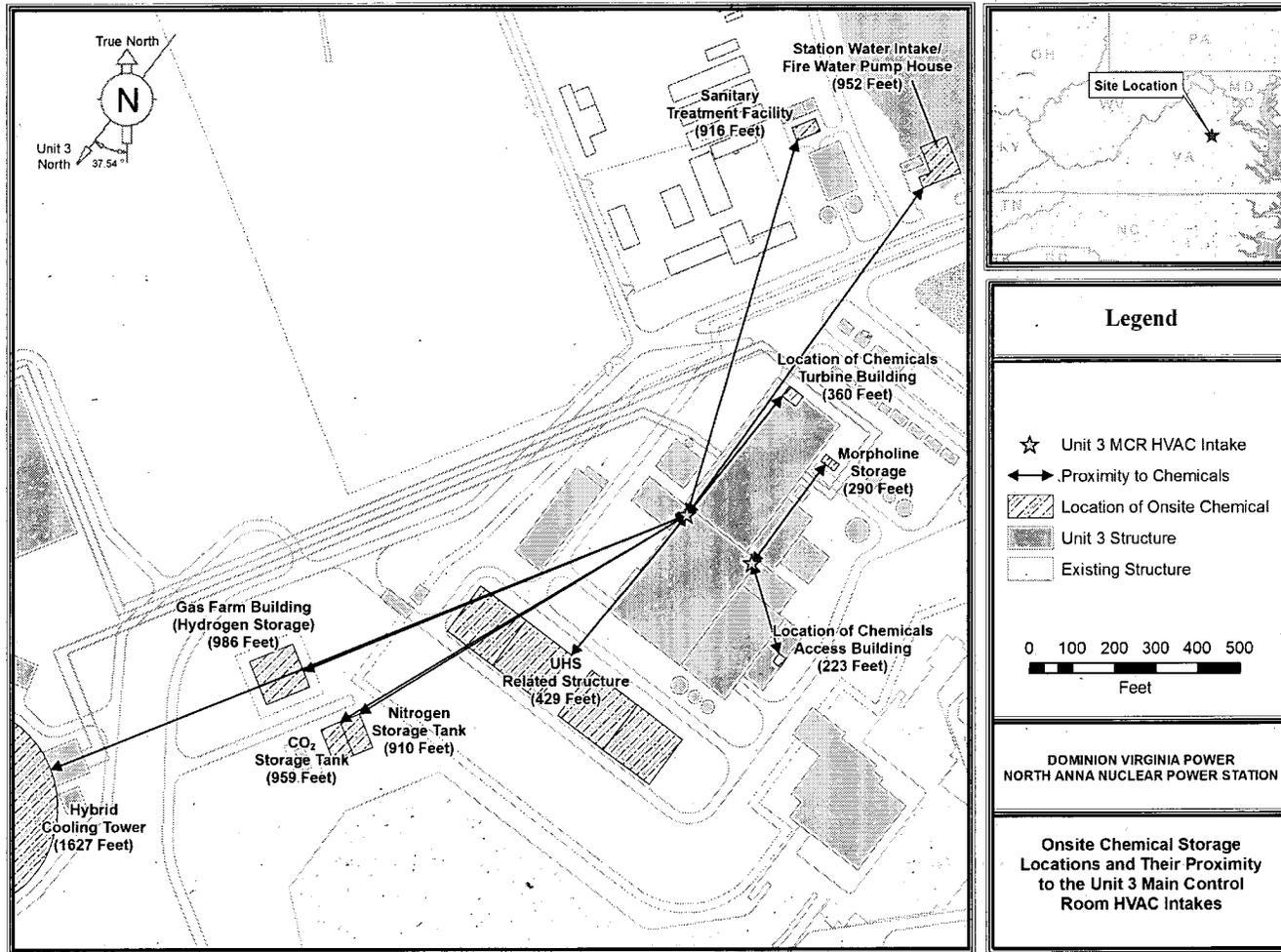


Figure 1: Onsite Chemical Storage Locations in Relation to the Unit 3 Main Control Room HVAC Intake

Table 3: MCR Toxic Gas Concentrations

Chemical/Material	Distance to Nearest MCR HVAC Intake (ft)	Toxicity Limit (ppm)	Distance to IDLH (ft)	Maximum Concentration at the MCR HVAC Intake (ppm)	Maximum MCR Concentration (ppm)
Unit 3					
Acetone ⁽⁶⁾	223	2,500	<33	73.7	28.9
Ammonium Hydroxide (19% wt solution) ⁽⁶⁾	360	300	813	1,130	266
Carbon Dioxide ⁽⁷⁾	959	40,000	423	8,540	995
Dimethylamine (40% wt solution) ⁽⁶⁾	360	500	474	926	216
Dimethylamine (2% wt solution) ⁽⁶⁾	360	500	306	382	52.1
Ethanol ⁽⁶⁾	223	3,300	54	273	127
Hydrazine (20% wt solution) ⁽⁶⁾	360	50	417	59.7	29.3
Hydrazine (85% wt solution) ⁽⁶⁾	223	50	75	7.64	3.79
Hydrochloric Acid (30% solution) ⁽⁶⁾	223	50	234	53.1	22.2
Hydrogen	986	Asphyxiant	NA	24,500	2,880
Morpholine (40% wt solution)	290	1,400	255	1,160	584
NALCO H-130	1,627	3,300 ⁽³⁾	90	58.3	25.2
NALCO H-130	429	3,300 ⁽³⁾	81	437	194
Nitrogen ⁽⁷⁾	910	Asphyxiant	NA	19,500	2,280
NOVEC 1230	0 ⁽⁴⁾	100,000	NA	NA	2,400
Sodium Hypochlorite (12% Solution) - Access Building ^{(1),(6)}	223	10 ⁽⁵⁾	39	No significant concentration ⁽²⁾	No significant concentration ⁽²⁾
Sodium Hypochlorite (12% Solution) - Hybrid Cooling Tower ⁽¹⁾	1627	10 ⁽⁵⁾	168	0.161	0.0754
Sodium Hypochlorite (12% Solution) - Station Water Intake ⁽¹⁾	952	10 ⁽⁵⁾	57	0.0594	0.0294
Sodium Hypochlorite (12% Solution) - UHS ⁽¹⁾	429	10 ⁽⁵⁾	39	0.132	0.0679

Table 3: MCR Toxic Gas Concentrations

Chemical/Material	Distance to Nearest MCR HVAC Intake (ft)	Toxicity Limit (ppm)	Distance to IDLH (ft)	Maximum Concentration at the MCR HVAC Intake (ppm)	Maximum MCR Concentration (ppm)
Units 1 & 2					
Acetone	2,198	2,500	93	14.6	5.65
Ammonium Hydroxide (30% Solution)	1,199	300	1,278	343	48.0
Carbon Dioxide	1,199	40,000	1,902	96,600	11,300
H-130 Microbiocide (Ethanol)	1,437	3,300 ⁽³⁾	177	136	58.9
Halon 1301 (Bromotrifluoromethane)	1,199	40,000	72	83.4	9.71
Hydrazine (35% Solution)	1,199	50	873	28.5	13.0
Hydrochloric Acid (31% Solution)	1,587	50	438	4.47	1.59
Hydrogen	1,199	Asphyxiant	NA	9,080	1,060
Nitrogen, liquid	1,121	Asphyxiant	NA	22,800	2,670
Sodium Hypochlorite (15% Solution) ⁽¹⁾	1,884	10 ⁽⁵⁾	39	No significant concentration ⁽²⁾	No significant concentration ⁽²⁾

Notes:

(1) As Chlorine gas based on a decomposition analysis of sodium hypochlorite

(2) Concentrations under 0.00100 ppm are reported as "No significant concentration"

(3) As ethanol

(4) This chemical is stored inside the MCR

(5) As chlorine

(6) For those chemicals stored inside the Access Building or Turbine Building, an Urban or Forest roughness factor was selected in ALOHA

(7) An Urban or Forest roughness factor was selected in ALOHA when evaluating Nitrogen and Carbon Dioxide to account for the wakes/eddies that would be generated as the formed cloud moves past the UHS structure

ENCLOSURE 2

Response to NRC RAI Letter 50

RAI 5120 Question 02.02.03-9

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**North Anna Unit 3
Dominion
Docket No. 52-017**

RAI NO.: 5210 (RAI Letter 50)

SRP SECTION: 02.02.03 – EVALUATION OF POTENTIAL ACCIDENTS

QUESTIONS for Siting and Accident Conseq Branch (RSAC)

DATE OF RAI ISSUE: 12/02/2010

QUESTION NO.: 02.02.03-9

RG 1.206 provides guidance regarding the information that NRC needs to ensure that potential hazards in the site vicinity are identified and evaluated in order to meet the siting criteria in 10 CFR 100.20 and 10 CFR 100.21. North Anna 3 USAPWR COL FSAR Section 2.2.3.1.3 (Table 2.2-204) addresses vapor cloud explosions and flammable vapor cloud (delayed ignition) explosions due to on-site chemicals. The staff's confirmatory calculation for ethanol resulted in minimum safe distance exceeding the distance to nearest SSC for unit 3 of 94 ft. Therefore, the staff requests that the applicant provide the methodology, assumptions and data used in its calculations.

Dominion Response

Two methods were used to determine the impacts of explosive vapor clouds: the Areal Locations of Hazardous Atmospheres (ALOHA) air dispersion model for traveling vapor clouds and a modification of the trinitrotoluene (TNT) equivalency method in Regulatory Guide (RG) 1.91, Revision 1, *Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants*, for confined vapor explosions. The assumptions and data used for both methods are provided below.

For ethanol, the ALOHA method showed that a vapor cloud would not detonate. The TNT equivalency method resulted in a safe distance of 71 feet.

ALOHA Analysis of Impacts from Traveling Vapor Clouds Method

The ALOHA results show that there is insufficient ethanol vapor formed to cause an explosion. Tables 1 and 2 provide the input values and justifications used for the ALOHA analysis.

Table 1: ALOHA Input Parameters

Menu	Parameter	Input	Basis
Site Atmospheric Data			
Site Data	Date and Time	12:00 pm on June 21, 2008 5:00 am on June 21, 2008 was used only for Meteorological Classes E and F, and for Class D with a wind speed of 3 m/s	The date was selected because it coincides with the summer solstice. The time 12:00 pm was selected for those meteorological classes likely to occur during the daytime because solar radiation is highest during midday and higher solar radiation leads to a higher evaporation rate and thus a larger vapor cloud. The time 5:00 am on June 21, 2008 was selected to provide a realistic meteorological condition for those meteorological classes likely to occur during the evening or early morning.
Setup / Chemical	Chemical Information	Ethanol	This chemical exists in the ALOHA (ALOHA, 2007) chemical library.
Setup / Atmospheric	Wind Speed	A meteorological sensitivity analysis was performed at varying wind speeds and meteorological stability classes to determine the worst case scenario. (see Table 2)	RG 1.206 requires that for each postulated event, the evaluation should determine a range of concentrations at the site for a spectrum of meteorological conditions. The ALOHA model was run over a spectrum of meteorological conditions to determine the Main Control Room (MCR) impact for each chemical release scenario. The chosen wind speed inputs were based on the meteorological stability classes defined by Pasquill.

Table 1: ALOHA Input Parameters

Menu	Parameter	Input	Basis
Setup / Atmospheric	Wind Direction	S	In the ALOHA modeling runs conducted, the threat at point function was chosen which allows the user to set the receptor location directly downwind from the source for a worst case determination, effectively negating the input for this menu item (i.e., the model ignores the input value for wind direction).
Setup / Atmospheric	Wind Measurement Height	10 meters	ALOHA calculates a wind profile based on the height at which the meteorological data is taken. Wind rose data from the onsite meteorological tower, described in ESP Application SSAR Section 2.3.3.1.2, were collected at a height of 10 meters. Additionally, the surface wind speeds for determining the Pasquill stability class are defined at 10 meters.
Setup / Atmospheric	Ground Roughness	"Urban or Forest"	The degree of atmospheric turbulence influences how quickly a pollutant cloud moving downwind will mix with the air around it and be diluted. Friction between the ground and the air passing over it is one cause of atmospheric turbulence. Because the air nearest the ground is slowed the most, eddies can develop. The rougher the ground surface, the greater the ground roughness (Z_0), and the greater the turbulence that develops. Due to the site layout and the location of ethanol, "Urban or Forest" ground roughness was selected. This selection is appropriate because a release from inside the access building would require that the formed vapor cloud travel through many roughness elements (e.g., HVAC system, structures).
Setup / Atmospheric	Cloud Cover	The appropriate selection is chosen to agree with the meteorological stability class (see Table 2).	ALOHA uses this input to estimate the amount of incoming solar radiation at the time of a chemical release. There are defined cloud cover percentages for some of the Pasquill meteorological classes.

Table 1: ALOHA Input Parameters

Menu	Parameter	Input	Basis
Setup / Atmospheric	Air Temperature	91.5°F (mid-day) 71.5°F (night-time)	Air temperature influences ALOHA's estimate of the evaporation rate from a puddle surface. The higher the air temperature, the more the puddle is warmed by the air above it, the higher the liquid's vapor pressure, and the faster the substance evaporates. The highest mean daily maximum temperature in the last three years of available National Weather Service (NWS) data (2007,2008, 2009) was used for mid-day calculations and the highest mean daily minimum temperature in the last three years of available data was used for night-time calculations.
Setup / Atmospheric	Stability Class	A meteorological sensitivity analysis was performed at varying wind speeds and stability classes (see Table 2).	The atmosphere may be more or less turbulent depending upon the amount of incoming solar radiation as well as other factors. Meteorologists have defined atmospheric stability classes, each representing a different degree of turbulence in the atmosphere. When moderate to strong incoming radiation heats air near the ground, causing it to rise and generate large eddies, the atmosphere is considered unstable (relatively turbulent). When solar radiation is weak or absent, air near the surface has a reduced tendency to rise, and less turbulence develops (stable atmospheres). As required in RG 1.206, a meteorological sensitivity analysis was performed for each postulated chemical release scenario.
Setup / Atmospheric	Humidity	63%	A relative humidity of 63% was selected because it is the average relative humidity over the last three years of available NWS data (2007, 2008, 2009).
Puddle Source			
Setup / Source	Puddle	Puddle	The puddle source option was chosen for ethanol because the chemical would be stored as a liquid under ambient conditions.
Setup / Source	Puddle / Direct	Area	It was assumed that the entire equivalent volume of the tank was released and instantaneously formed a puddle with a depth of 1 cm. The area of the puddle was selected such that this can be achieved with the given volume or mass of chemical released.

Table 1: ALOHA Input Parameters

Menu	Parameter	Input	Basis
Setup / Source	Puddle	Volume of Puddle or Mass of Puddle	200 gallons
Setup / Source	Puddle / Ground Type	Default Soil	ALOHA expects heat to be transferred most readily from default ground and concrete surfaces into a puddle.
Setup / Source	Puddle / Ground Temperature	Use air temperature	ALOHA uses ground temperature to predict the amount of heat transferred from the ground to an evaporating puddle. The value for ground temperature should be the temperature of the ground below the surface, rather than at the surface. The ground temperature was assumed to be the same as the air temperature if the ground temperature was unknown. The air temperature inputs were based on the meteorological classes (see Table 2).
Setup / Source	Puddle / Initial Puddle Temperature	Use ground temperature	To predict the rate of evaporation from a puddle of spilled liquid, ALOHA must know the initial temperature of the puddle. It assumes the initial temperature to be the same throughout the depth and width of the puddle. The initial puddle temperature was assumed to be the same as the ground temperature (i.e., the air temperature).

Reference:

(ALOHA, 2007) Areal Locations of Hazardous Atmospheres (ALOHA) User's Manual, EPA and NOAA, February 2007.

Table 2: Meteorological Sensitivity Analysis

Stability Class	Surface Wind Speed (m/s)	Cloud Cover	Date/Time
A	1.5	0%	June 21, 2008/ 12:00 pm
B	1.5	50%	June 21, 2008/ 12:00 pm
C	3	50%	June 21, 2008/ 12:00 pm
C	5.5	0%	June 21, 2008/ 12:00 pm
D	3	50%	June 21, 2008/ 5:00 am
D	5.5	50%	June 21, 2008/ 12:00 pm
E	1	50%	June 21, 2008/ 5:00 am
E	2	50%	June 21, 2008/ 5:00 am
F	1	0%	June 21, 2008/ 5:00 am
F	2	0%	June 21, 2008/ 5:00 am
F	3	0%	June 21, 2008/ 5:00 am

Equivalent TNT Explosion Methodology

In addition to performing an analysis for a traveling vapor cloud explosion using the ALOHA program, an additional scenario was analyzed to account for a confined explosion at the location of the storage of the chemical, where it was postulated that a tank failure occurred resulting in an immediate detonation of the material. An equivalent TNT methodology was used.

Whether an explosion is possible depends in large measure on the physical state of a chemical. In the case of liquids, such as ethanol, flammable and combustible liquids often appear to ignite as liquids. However, it is actually the vapors above the liquid source that ignite. For flammable liquids at atmospheric pressure, an explosion will occur only if the non-oxidized, energized fluid is in the gas or vapor form at correct concentrations in air. The concentrations of formed vapors or gases have an upper and lower bound known as the upper flammable limit (UFL) and the lower flammable limit (LFL). Below the LFL, the percentage volume of fuel is too low to sustain propagation. Above the UFL, the percentage volume of oxygen is too low to sustain propagation.

For atmospheric liquids, the allowable and actual distances of hazardous chemicals transported or stored were determined in accordance with RG 1.91, Revision 1. RG 1.91 cites 1 psi (6.9 kPa) as a conservative value of positive incident overpressure below which no significant damage would be expected. RG 1.91 defines this safe distance by the Hopkinson Scaling Law Relationship:

$$R \geq k \cdot \sqrt[3]{W}$$

Where R is the distance in feet from an exploding charge of W pounds of equivalent TNT and k is the scaled ground distance constant at a given overpressure (for 1 psi, the value of the constant k is 45 feet-pounds³).

Because RG 1.91 is "*limited to solid explosives and hydrocarbons liquefied under pressure*," the guidance provided in determining W, the mass of the substance that will produce the same blast effect as a unit mass of TNT, is specific to solids.

In the case of atmospheric liquids, where only that portion in the vapor phase between the UFL and LFL is available to sustain an explosion, the guidance for determining the TNT equivalent, W, in RG 1.91 is not appropriate. That is, when determining the equivalent mass of TNT available for detonation, the mass of a chemical in the vapor phase cannot occupy the same volume under atmospheric conditions as the same mass of the chemical in its liquid phase. Further, upon release of the full contents of a vessel filled with liquid, vaporization of the total mass of the liquid release would not occur instantaneously. Therefore, the methodology employed considers the maximum gas or vapor within the storage container as explosive. Thus, for atmospheric liquid storage, this maximum gas or vapor would involve the container to be completely empty of liquid and filled only with air and fuel vapor at UFL conditions per NUREG-1805, *Fire Dynamics Tools (FDT) Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program*, December 2004. Therefore, for atmospheric liquids, the TNT mass equivalent, W, was determined following guidance in NUREG-1805, where

$$W = \left(\frac{M_{\text{vapor}} \cdot \Delta H_c \cdot Y_f}{2000} \right)$$

Where M_{vapor} is the flammable vapor mass (lbs), ΔH_c is the heat of combustion (Btu/lb), and Y_f is the explosion yield factor. Specifically, for ethanol, the calculation would be:

$$W = \left(\frac{0.67 \text{ lb} \cdot 11,570 \text{ btu/lb} \cdot 1}{2000} \right)$$

$$W = 3.88 \text{ lb TNT}$$

$$R = 45 \cdot \sqrt[3]{3.88 \text{ lb TNT}}$$

$$R = 71 \text{ feet}$$

Therefore, the TNT equivalency method resulted in a safe distance of 71 feet.

Proposed COLA Revision

None