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10 CFR 50.4
10 CFR 52.79

October 6, 2008

UN#08-043

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: UniStar Nuclear Energy, NRC Docket No. 52-016
Submittal of Response to Requests for Additional Information for the
Calvert Cliffs Nuclear Power Plant, Unit 3 – RAI No. 9 RSAC 946

Reference: John Rycyna (NRC) to George Wrobel (UniStar), "RAI No. 9 RSAC 946.doc," email dated September 5, 2008

The purpose of this letter is to respond to a portion of requests for additional information (RAIs) identified in the NRC e-mail correspondence to UniStar Nuclear, dated September 5, 2008 (Reference). UniStar will respond to the remaining RAIs in Set 9 within 60 days of the original request as agreed upon during RAI issuance, on or before November 4, 2008. These RAIs address hazards in the site vicinity as discussed in Section 2.2.3 of the Final Safety Analysis Report as submitted in Part 2 of the CCNPP Unit 3 Combined License Application (COLA).

The enclosure provides responses to the RAIs.

If there are any questions regarding this transmittal, please contact me or Mr. George Wrobel at (585) 771-3535.

D079
NRO

I declare under penalty of perjury that the foregoing is true and correct.

Executed on October 6, 2008

Greg Gibson

Enclosure: Response to RAI Set Number 9 RSAC 946

cc: U.S. NRC Region I
U.S. NRC Resident Inspector, Calvert Cliffs Nuclear Power Plant, Units 1 and 2
NRC Environmental Project Manager, U.S. EPR Combined License Application
NRC Project Manager, U.S. EPR Combined License Application
NRC Project Manager, U.S. EPR Design Certification Application (w/o enclosure)

Enclosure

Response to RAI Set Number 9 RSAC 946

RAI Number 02.02.03-2: FSAR Section 2.2.3

RG 1.206 provides guidance regarding the information that is needed 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 FSAR Section 2.2.3 referenced study conflicts with an earlier report. That section's referenced study on LNG hazards due to the DCPLNG, describes the capacity of the facility as one 850,000 barrel and four 230,000 barrel LNG storage tanks, with future expansion to consist of two additional LNG tanks of 1,000,000 barrels each. A June 7, 1993, Arthur D. Little study of hazards associated with the DCPLNG facility, for the licensee of CCNPP Units 1 and 2 described the DCPLNG in terms of four 375,000 barrel LNG tanks. At that time, two proposed additional LNG storage tanks of 600,000 barrels each were considered in the analysis. Please resolve the discrepancy regarding the DCPLNG capacity.

UniStar Response:

The referenced study in FSAR Section 2.2.3, *Cove Point Liquid Natural Gas (LNG) Terminal Expansion Project Risk Study*, prepared for the Maryland Department of Natural Resources, Maryland Power Plant Research Program, provided the following description of the capacity of the Dominion Cove Point LNG facility:

- There exists one 850,000 barrel and four 230,000 barrel LNG storage tanks; and
- Two additional LNG tanks of 1,000,000 barrels each to be added during the expansion. (MDNR, 2006)

The NRC indicates that an earlier June 7, 1993 study conducted by Arthur D. Little, described the capacity of the Dominion Cove Point LNG facility, as follows:

- Four 375,000 barrel LNG tanks; and, at the time of the study
- Two proposed additional LNG storage tanks of 600,000 barrels each were considered.

A resolution to this discrepancy is provided as follows:

- In a letter received September 4, 2008 from Michael Gardner, Manager LNG Operations, Dominion Cove Point LNG, to Mary Richmond, Bechtel Power, Dominion Cove Point LNG provided the following information in reference to the LNG capacity at their facility
    - There exists one 850,000 barrel and four 375,000 barrel LNG tanks; and
    - Two additional LNG tanks of 1,000,000 barrels each to be added by December 2008. (DCPLNG, 2008)
- In a memorandum dated September 5, 2007 from M. J. Yox, Calvert Cliffs Nuclear Power Plant, detailing a phone conversation with Rich McLean, Maryland Department of the Environment, the following explanation was provided regarding the discrepancy:

  Rich McLean verified that the information in question--concerning the existing tank capacity in the Maryland Department of Natural Resources Cove Point LNG Terminal

Expansion Project Risk Study--was a typographical error. However, the conclusions made in the report were based on the correct capacities of 375,000 for the four small tanks. (CCNPP, 2007)

FSAR Impact:

The following changes will be included in Revision 4 of the CCNPP, Unit 3 COLA.

Paragraph 2 in Section 2.2.2.2.2 of CCNPP, Unit 3 COL FSAR, will be revised as shown below:

> The DCPLNG facility includes an offshore pier; and five double-walled, insulated LNG storage tanks that are maintained at -260°F (-162°C) and 2 psig (14 kPa-gauge). One tank has a capacity of 850,000 barrels (35.7 million gallons, or 135,000 m3), and the remaining four tanks have a capacity of ~~230,000 barrels (9.8 million gallons, or 37,000 m3)~~ 375,000 barrels (15.75 million gallons, or 59,600 m^3). The pipeline, known as the Cove Point pipeline, extends approximately 88 mi (142 km) from the LNG terminal to connections with several interstate pipelines (Dominion, 2007) (MDNR, 2006). The pipeline and offshore pier are described in more detail in Section 2.2.2.3 and Section 2.2.2.4.2.

Paragraph 2 in Section 2.2.2.4.2 of CCNPP, Unit 3 COL FSAR, will be revised as shown below:

> The Federal Energy Regulatory Commission (FERC) has approved an application for expansion of the DCPLNG facility. The FERC has authorized an expansion of the DCPLNG facilities that would add two new storage tanks, bringing the total number at the site to seven. Each of the new tanks will be capable of storing or 1.0 million barrels (42~~.3~~ million gallons, or 160,000 m^3) of LNG, increasing the storage capacity at the terminal to approximately ~~14.6 billion ft^3 (413 million m^3)~~ 4,350,000 barrels (182.7 million gallons, or 691,600m^3) of LNG (MDNR, 2006).

References:

(CCNPP, 2007) Calvert Cliffs Nuclear Power Plant, Memorandum from M.J.Yox to file, September 5, 2007.

(DCPLNG, 2008) Dominion Cove Point LNG, LP, Letter from Michael Gardner, Dominion Cove Point LNG, Manager LNG Operations, to Mary Richmond, Bechtel Power, received September 4, 2008.

(MDNR, 2006) Cove Point LNG Terminal Expansion Project Risk Study, Maryland Power Plant Research Program Report PPRP-CPT-01/DNR 12-7312006-147, Maryland Department of Natural Resources, June 28, 2006.

RAI Number 02.02.03-3: FSAR Section 2.2.3

RG 1.206 provides guidance regarding the information that is needed 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. FSAR Section 2.2.3.1.2 does not seem to follow the referenced regulatory guide methodology. The section references Regulatory Guide 1.91, Revision 1 methodology as being used in determining the minimum safe distances. However, for the liquid chemicals stored (i.e., gasoline, toluene, etc), the applicant considered only the in-vessel confined vapor amount for potential for explosion, and the amount of vapor in the air is determined based on the equivalent of the upper flammability limit. The applicant stated that this is consistent with the NUREG-1805 methodology. NRC staff's determination of safe distance conservatively based on RG 1.91, Rev. 1 gave different results. Please provide details of the approach and methodology with a sample analyses for independent review and comparison of results.

UniStar Response:

Regulatory Guide 1.206 requires COL applicants to determine, on the basis of the information provided in FSAR Sections 2.2.1 and 2.2.2, the potential accidents to be considered as design-basis events and to identify the potential effects of those accidents on the nuclear plant in terms of design parameters (e.g., overpressure) or physical phenomena (e.g., concentration of flammable or toxic cloud outside building structures). Design-basis events internal and external to the nuclear plant are defined as those accidents that have a probability of occurrence on the order of magnitude of 10^{-7} per year or greater; and potential consequences serious enough to affect the safety of the plant to the extent that the guidelines in 10 CFR Part 100 could be exceeded. One of the accident categories considered in selecting design-basis events is explosions. Accidents involving detonations of high explosives, munitions, chemicals, or liquid and gaseous fuels for facilities and activities in the vicinity of the plant or on-site, where such materials are processed, stored, used, or transported in quantity are considered.

An explosion is defined as a sudden and violent release of high-pressure gases into the environment. The release must be sufficiently fast so that energy contained in the high-pressure gas dissipates in a shock wave. (NUREG-1805, 2004) The strength of the wave is measured in terms of overpressures (maximum pressure in the wave in excess of normal atmospheric pressure). Explosions come in the form of detonations or deflagrations. A detonation is the propagation of a combustion zone at a velocity that is greater than the speed of sound in the un-reacted medium. A deflagration is the propagation of a combustion zone at a velocity that is less than the speed of sound in the un-reacted medium. (NFPA 68, 2002) For an explosion to occur, the following elements must exist simultaneously:

- a flammable mixture (components are thoroughly mixed and are present at a concentration that falls within a flammable composition boundary) consisting of a fuel and oxidant, usually air
- a means of ignition
- an enclosure or confinement (NUREG-1805, 2004)

Whether an explosion is possible depends in large measure on the physical state of a chemical. In the case of liquids, flammable and combustible liquids often appear to ignite as liquids. However, it is actually the vapors above the liquid source that ignite. (NFPA 921, 2004) 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. Physical explosions may also occur with super-heated liquids that flash-evaporate upon the sudden release of the liquid. (NUREG-1805, 2004) 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. (NFPA 921, 2004)

Two explosion scenarios are evaluated for each flammable chemical capable of sustaining an explosion. The first scenario involves the rupture of a vessel in which the entire contents of the vessel are released and an immediate deflagration/detonation ensues. That is, upon immediate release, the contents of the vessel are assumed to be capable of supporting an explosion upon detonation (For flammable liquids this is only possible when part or all of the container is filled with the chemical in the gas/vapor phase between the UFL and LFL). The second scenario involves the release of the entire contents of the vessel where the gas (or vapors formed from a liquid spill) travel toward the nearest safety-related system, structure, or component and mix sufficiently with oxygen for the vapor cloud to reach concentrations between the UFL and LFL creating the conditions necessary for a vapor cloud explosion whereby detonation occurs. The methodology presented below is representative of the first scenario. (A separate methodology using the Areal Locations of Hazardous Atmospheres (ALOHA) model is used for the second scenario.) Figure 1 summarizes the decision making process/methodologies employed for the two scenarios.

In formulating the methodology for the first scenario, RG 1.91, NUREG-1805, National Fire Protection Association Code, and pertinent research papers were analyzed. While RG 1.91 was chosen as the starting point, it has limited applicability—RG 1.91 is applicable to:

- solid explosives;
- hydrocarbons liquefied under pressure; and
- airblasts on highway, rail, and water routes.

And, RG 1.91 specifically excludes:

- cryogenically liquefied hydrocarbons, e.g., LNG;
- fixed facilities; and
- pipelines.

Therefore, when devising an appropriate, yet conservative, methodology for atmospheric liquids and gases, other technical guidance and research must be considered to account for the limited applicability of RG 1.91. Presented below is a methodology that is based upon the TNT equivalence and standard safe distance concepts presented in RG 1.91, but also includes the compilation of guidance and research necessary to devise a valid and sensible approach to explosions where RG 1.91 is not applicable.

METHODOLOGY FOR EXPLOSION (TNT EQUIVALENCE CALCULATION):

An explanation of the methodology developed is broken up into three sections based on the phase of the chemical during storage/transportation: atmospheric liquids; liquefied gases; and gases.

I. Atmospheric liquids

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

$$R \geq kW^{1/3}$$

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/lbs$^{1/3}$). (RG 1.91, 1978)

> Because RG 1.91 is *"limited to solid explosives and hydrocarbons liquefied under pressure"* (RG 1.91, 1978), 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. RG 1.91 states *"for solid substances more efficient in producing blast effects than TNT, equivalents are known by the manufacturers. For solid substances not intended for use as explosives but subject to accidental detonation, it is conservative to use a TNT equivalence of one in establishing safe standoff distances, i.e., use the cargo mass in Equation (1)"*—the Hopkinson Scaling Law Relationship.

The full adaptation of this guidance-- where the entire mass of the solid substance is potentially immediately available for detonation-- is not applicable to atmospheric liquids. 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 in the case of liquids stored at atmospheric pressure or below their boiling points. During this phase change, dispersion and mixing would occur—the ALOHA dispersion model is used to model this phenomenon (Scenario 2). Therefore, the methodology employed considers the maximum gas or vapor within the storage 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. (Note, Scenario 2 conservatively assumes that the entire contents of the vessel are spilled in a 1 cm thick puddle under very stable atmospheric conditions to maximize volatilization—a vapor cloud explosion is then modeled using the ALOHA model).

Therefore, for atmospheric liquids, the TNT mass equivalent, W, was determined following guidance in NUREG-1805, where

$$W = (M_{vapor} * \Delta H_c * Y_f)/2000$$

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.

<u>Example of Atmospheric Liquid and Vapor Mass Calculation—Gasoline</u>

Chemical Properties of Automotive Gasoline (CHRIS, 1998)

Lower Flammability Limit	1.4%
Upper Flammability Limit	7.4%
Vapor Specific Gravity	3.4

To determine the flammable mass:

V_{vap} = Vvessel * UFL

Where:

V_{vap}= flammable vapor volume at UFL, ft^3
Vvessel = liquid (tank) volume, ft^3
UFL= upper flammability limit

$\rho_{vap} = \rho_{air} * SG_{vap}$

Where:

ρ_{air}=air density, lb/ft^3 ($0.074\ lb/ft^3$) (FLOW, 1988)
ρ_{vap}=vapor density, lb/ft^3
SG_{vap}=vapor specific gravity

$M_{vap} = V_{vap} * \rho_{vap}$

Where:

M_{vap}= flammable vapor mass, lbs

And:

Vvessel= 8,500 gal = 8,500gal * 0.13368 ft^3/gal = 1,136.28 ft^3
V_{vap}= 1,136.28 ft^3 * 7.4%= 84.085 ft^3

ρ_{vap}= (0.074 lb/ft^3) * 3.4 = 0.2516 lb/ft^3

M_{vap}= 84.085 ft^3 * 0.2516 lb/ft^3 = 21.16 lbs.

Therefore:
W_{TNT}=(21.16 * 18,720 * 100%) / 2,000 (NUREG-1805, 2004)

(Note: A 100% yield factor will be attributed to the explosion—this is very conservative because 100% yield cannot be achieved) (FMGLOBAL, 2006)

W=198.02 lbs

$R \geq kW^{1/3}$ (RG 1.91, 1978)

$R \geq 45\ (198.02)^{1/3}$

$R \geq 262.29$ ft

Presented below is a comparison to the methods presented in RG 1.91, three assessment cases for hydrocarbons liquefied under pressure and one method for solids. One must keep in mind that the RG 1.91 methodology is only applicable to hydrocarbons liquefied under pressure and solids and unrealistic assumptions must be made to present this comparison. Therefore, the following cases are offered only as a comparison to the calculation above. The values obtained below do not represent observations seen in real world conditions.

There are three cases presented regarding hydrocarbons liquefied under pressure. The methodology presented in RG 1.91 assumes that upon an accidental release of a hydrocarbon liquefied under pressure, the entire contents would immediately undergo extremely turbulent mixing while returning to its gas phase under atmospheric conditions. For the purposes of this comparison, gasoline, an atmospheric liquid is used—therefore, for this comparison it is assumed that the mass is the mass of the vapor that can occupy the container. While, if one was evaluating a liquefied hydrocarbon, one would consider the entire weight of the liquefied hydrocarbon as the mass for the reasons stated above.

Likewise, when formulating the comparison to the solid methodology presented in RG 1.91, because gasoline is used as a comparison, one must make the following unrealistic assumptions:

- that gasoline is a solid;
- that the mass of the liquid is the entire mass of the liquid that can occupy the container; and
- that this liquid mass is capable of supporting an explosion.

HYDROCARBONS LIQUEFIED UNDER PRESSURE ASSESSMENT COMPARISON

Comparison with RG 1.91 application of TNT equivalence concept to detonations of confined vapor clouds

- *"the ratios of heat of combustion of hydrocarbons to that of TNT are typically about 10"* (RG 1.91, 1978)

  (Note: There is no formula provided in RG 1.91 for W, the equivalent mass of TNT; therefore, this interpretation is applied to the formula presented in NUREG-1805)

  $W=M_{vapor}*(\Delta H_c/\Delta H_{c(TNT)})*Y_f$ (NUREG-1805, 2004)

  $\Delta H_c/\Delta H_{c(TNT)}=10$

  $W= M_{vapor}*(10)*Y_f$

- *"Most assessments...have led to estimates that less than one percent of calorific energy of the substance was released in blast effects"* (RG 1.91, 1978)

  $Y_f=0.01$

  $W=M_{vapor}*(10)*(0.01)=M_{vapor}*(0.10)$

  "...this corresponds to an equivalence on a mass basis of 10%."

- *"However, there have been accidents in which estimates of the calorific energy released were as high as 10 percent. "* (RG 1.91, 1978)

  $Y_f=0.10$

  $W = M_{vapor}*(10)*(0.10)= M_{vapor}*(1.0)$

- *"The blast energy realized depends, in great measure, on phenomena that are accident specific... A reasonable upper bound to the blast energy potentially available based on experimental detonations of confined vapor clouds is a mass equivalence of 240 percent."* (RG 1.91, 1978)

  (Utilizing the formula presented in NUREG-1805, an interpretation leads to the following values for the explosion yield factor, Y_f,--a measure of the portion of the flammable material participating in the explosion)

  $E=M_{vapor}*(240\%) = M_{vapor}*(10)*(Y_f)$ Where, E is the explosive energy released (NUREG-1805, 2004)

  $(10)*Y_f=2.4$

  $Y_f=0.24=24\%$

- Most Assessments:

  Gasoline used as an example:

  $W=M_{vapor}*10\%=$ (21.16 lbs) (10%) =2.116 lbs.
  $R \geq 45(2.116 \text{ lbs})^{1/3} = 57.72$ ft

- Worst Accidents:
  $W=M_{vapor}*100\% =$ (21.16 lbs) (100%)=21.16 lbs.
  $R \geq 45\ (21.16 \text{ lbs})^{1/3} = 124.47$ ft

- Enveloping Case:
  $W=M_{vapor}*240\%=$ (21.16 lbs) (240%)=50.784 lbs
  $R \geq 45\ (50.78)^{1/3} = 166.64$ ft

SOLID ASSESSMENT COMPARISON

Comparison with RG 1.91 application of TNT equivalence to solids:

As a point of contrast to the methods discussed above, the comparison presented below assumes the full liquid mass of gasoline is a solid with the same blast effect as TNT. One must assume this as RG 1.91 specifically states "*This guide is limited to solid explosives and hydrocarbons liquefied under pressure...*"

$R \geq kW^{1/3}$ (RG 1.91, 1978)

W=50,000 lbs—from *RG 1.91 "for solid substances not intended to be used as explosives but subject to accidental detonation, it is conservative to use a TNT equivalence of one in establishing a safe standoff distance, i.e., use the cargo mass in Equation (1)."* (the Hopkinson Scaling Law Relationship)

$R \geq (45)\ (50,000)^{1/3}$

$R \geq 1,658$ feet

(Note that for the solid methodology presented in RG 1.91, the safe-distance determination does not take into account the heats of combustions for a particular substance, therefore, by assuming that a liquid or gas is a solid and proceeding with this method, it would not matter what the flammable chemical was under consideration—for 50,000 pounds of a flammable material, regardless of the material, the safe distance will be 1,658 feet)

II. Liquefied Gases

For liquefied gases, the entire mass is considered as a flammable gas/vapor because a sudden tank rupture would entail the release of a majority of the contents in the vapor/aerosol form and a confined explosion could possibly ensue (i.e., the liquid would violently expand and mix with air while changing states from the liquid phase to a vapor/aerosol phase).

Again, for liquefied gases, the allowable and actual distances of hazardous chemicals transported or stored were determined in accordance with RG 1.91.

In this case the entire mass is conservatively considered available for detonation, the equivalent mass of TNT, W, is calculated as follows:

W=E/2000 lb (NUREG-1805, where E is the blast wave energy)
E= $M_{flammable} * \Delta H_c * Y_f$ (NUREG-1805, where Y_f is the explosion yield factor)

Example of Liquefied Gases Calculation--Liquid Propane:

- Quantity: 50,000 lb (RG 1.91-maximum probable hazardous solid cargo for a single highway truck)

- Flammable mass ($M_{flammable}$): 50,000 lb
- Heat of combustion (ΔH_c) (Btu/lb): 19,782 (CHRIS, 1998)

E=(50,000 lbs) * (19,782) *(100%) (NUREG-1805, 2004)
E= 9.891E8

W= (9.891E8) / 2000
W=494,550 lbs.

$R \geq (45)(494{,}550)^{1/3}$

R≥ 3,559 ft

Comparison with RG 1.91 application of TNT equivalence concept to possible detonation of confined vapor clouds formed after an accidental release of hydrocarbons:

- Taking the Enveloping Case:
  $W = M_{vapor} * 240\%$
  W= (50,000 lbs) (240%)
  W= 120,000 lbs

  $R \geq (45)(120{,}000)^{1/3}$

  R≥ 2,219.6 feet

Comparison with RG 1.91 application of TNT equivalence to solids:

Note: Utilizing this methodology, one would have to make an unrealistic assumption that the propane is a solid with the same blast effect as TNT.

$R \geq kW^{1/3}$ (RG 1.91, 1978)

W=50,000 lbs—from RG 1.91 *"for solid substances not intended for use as explosives but subject to accidental detonation, it is conservative to use a TNT equivalence of one in establishing safe standoff distances, i.e., use the cargo mass in Equation (1)."* (the Hopkinson Scaling Law Relationship)

$R \geq (45)(50{,}000)^{1/3}$

$R \geq 1{,}658$ feet

(As noted before, the solid methodology presented in RG 1.91, the safe-distance determination does not take into account the heats of combustions for a particular substance, therefore, by assuming that a liquid or gas is a solid and proceeding with this method, it would not matter what the flammable chemical was under consideration—for 50,000 pounds of a flammable solid material, regardless of the material, the safe distance will be 1,658 feet)

III. Gases

For pressurized gases, the allowable and actual distances of hazardous chemicals transported or stored were determined in accordance with RG 1.91.

As in the evaluation of liquefied gases, the entire mass is conservatively considered as a flammable gas and available for detonation because a sudden tank rupture would entail the rapid release of a majority of the contents in the vapor/gas phase and a confined explosion could possibly ensue. Therefore, the M_{TNT}, is calculated as follows:

$W=E/2000$ lb (NUREG-1805, where E is the blast wave energy)
$E= M_{flammable} * \Delta H_c * Y_f$ (NUREG-1805, where Y_f is the explosion yield factor)

Example of Pressurized Gas—Hydrogen:

- Quantity: 278 scf
- Vapor Specific Gravity: 0.067 (CHRIS, 1998)
- Heat of Combustion: 50,080 Btu/lb (CHRIS, 1998)

$\rho_{vap}=\rho_{air} * SG_{vap}$

Where:

ρ_{air}=air density, lb/ft^3 (0.074 lb/ft^3) (FLOW, 1988)
ρ_{vap}=vapor density, lb/ft^3

SG_{vap}=vapor specific gravity

$M_{vap}=V_{vap} * \rho_{vap}$

Where:

M_{vap}= flammable vapor mass, lbs

ρ_{vap}= (0.074 lb/ft^3) * 0.067= 0.004958 lb/ft^3

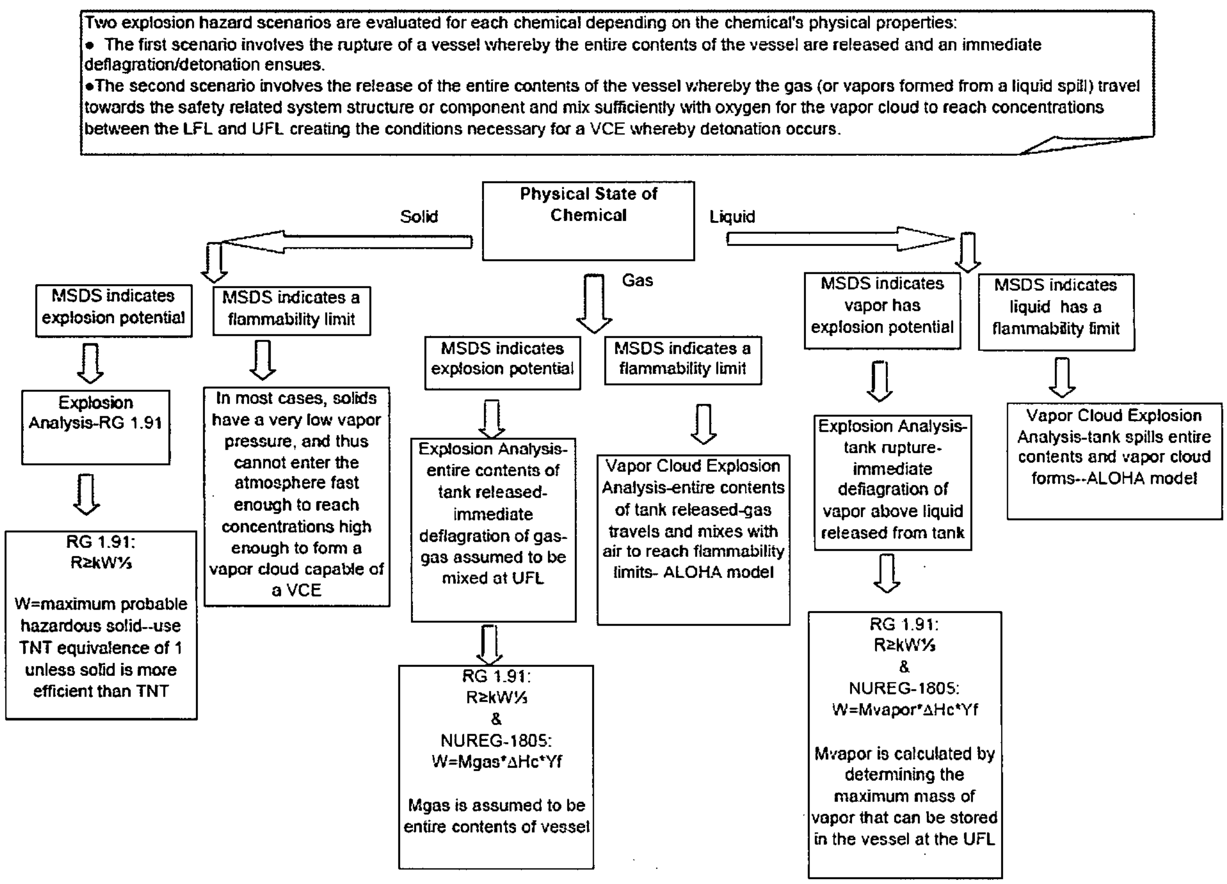
M_{vap}= 278 scf * 0.004958 lb/ft^3= 1.38 lbs

W= (1.38lbs * 50,080 Btu/lb) / (2,000 Btu/lb) = 34.56 lbs

R≥ 45 * (34.56)$^{1/3}$ = 146.57 ft

FIGURE 1

Explosions/Vapor Cloud Explosions



References:

(CHRIS, 1998) U.S. Coast Guard, *Chemical Hazards Response Information System, Hazardous Chemical Data Manual*, June 1998.

(FLOW, 1988) *Flow of Fluids through Valves, Fittings and Pipes*, Crane Valves North America, 1988.

(FMGLOBAL, 2006) Factory Mutual Global Property Loss Prevention Data Sheets, Data Sheet 7-42, "Guidelines for Evaluating the Effects of Vapor Cloud Explosions Using a TNT Equivalency Method". Section 3.4, September 2006.

(NFPA 68, 2002) NFPA 68, *Guide for Venting of Deflagrations,* 2002 Edition, National Fire Protection Agency.

(NFPA 921, 2004) NFPA 921, *Guide for Fire and Explosion Investigations,* 2004 Edition, National Fire Protection Agency.

(NUREG-1805, 2004) U.S. Nuclear Regulatory Commission, NUREG-1805, "Fire Dynamics Tools (FDT ^{s}): Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program", December 2004.

(RG 1.91, 1978) U.S. Nuclear Regulatory Commission, Regulatory Guide 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants," Revision 1, February 1978.

FSAR Impact:

No changes to the FSAR are required.

RAI Number 02.02.03-5: FSAR Section 2.2.3

RG 1.206 provides guidance regarding the information that is needed 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. FSAR Section 2.2.3.1.2 does not provide enough information for the NRC staff to perform an independent review of that section. The probability of an accident involving a gasoline refueling tanker is determined as 2.03 x 10-7 per year (2.2.3.1.2 p.2-23). However, no details were given in determining this probability. Provide the details such as accident frequency, release rate and other assumed parameters used in estimating the probability along with the reference cited (MSHA, 2004).

UniStar Response:

In FSAR Section 2.2.3.1.2 the probability of a vapor cloud explosion resulting from an accident involving a gasoline refueling tanker occurring within exposure distance of the ultimate heat sink was reported as 2.03×10^{-7} per year. The evaluation of the gasoline refueling tanker spill event was performed in accordance with methodology presented in FSAR Section 2.2.3.1.2. The risk from potential vapor cloud explosion hazards can be shown to be sufficiently low on the basis of low probability of explosions when the rate of exposure to a peak overpressure in excess of 1 psi is less than 10^{-6} per year using conservative assumptions or less than 10^{-7} per year using realistic assumptions (USNRC, 1978). The probability of a vapor cloud explosion from a gasoline refueling tanker resulting in an overpressure that exceeds 1 psi at the nearest safety-related source was determined by the following equation found in RG 1.91:

$$r = n_1 \cdot n_2 \cdot f \cdot s \qquad \text{(Equation 1)}$$

where,

r = exposure rate (the probability of an explosion occurring),
n_1 = accidents per mile for the transportation mode (truck transport),
n_2 = cargo explosion per accident for the transportation mode,
f = frequency of shipment for the substance, in shipments per year,
s = exposure distance in miles.

The number of accidents per mile, n_1, is 7.2022×10^{-8} based on the total large truck accident rate (i.e. over 10,000 pounds gross vehicle weight) for Calvert County, as reported by the Maryland State Highway Administration (MSHA, 2004). The total number of accidents involving large trucks in Calvert County for the year 2003 was 52, and 722 million vehicle miles were traveled by large trucks (MSHA, 2004).

The number of cargo explosions per accident, n_2, was assumed to be 1, or 100%. It was conservatively assumed that every accident resulted in a catastrophic failure of the gasoline tanker where the entire contents spilled and formed a vapor cloud. Using a value of 100% is a very conservative assumption given that for large truck transport, accidents resulting in a significant release of cargo are generally in the range of 1.2-18% (USNRC, 1999).

The frequency of shipment, f, for onsite delivery of gasoline to the site was reported as 12 times per year in a 3,500 gallon on-site gasoline delivery tank truck.

The exposure distance, s, was calculated by determining the safe separation distance for a vapor cloud explosion. The safe distance for a 3500 gallon gasoline truck is 648 feet as presented in FSAR 2.2.3.1.2. Using the guidance provided in RG 1.91 (Figure 2), the exposure distance was calculated from the distance between the two intersection points of the gasoline tanker delivery route with a 648-foot minimum radius around the nearest safety related structure (NSRS). The result is an exposure distance of 1239 feet (0.235 miles).

Regulatory position C.2 of RG 1.91 states that if it is demonstrated that the rate of exposure to a peak positive incident overpressure in excess of 1 psi is less than 10^{-6} per year, when based on conservative assumptions, the rate of exposure is acceptable. Using the inputs to Equation 1 as described above, an annual accident rate of 2.03×10^{-7} was obtained. The analyzed scenario involves a complete loss of cargo, however, this is very conservative given that strict supervision and site safety procedures would be in effect to prevent leaks, spill, or accidents. Furthermore, it is conservatively assumed that every accident that occurs will result in an explosion. Therefore, a postulated gasoline truck accident during onsite delivery has an attendant risk of potential crash, total release, and explosion of less than 10^{-6} per year and is not considered a credible event.

References:

(USNRC, 1978) Regulatory Guide 1.91, Rev. 1, *Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants,* U.S. Nuclear Regulatory Commission, February 1978.

(MSHA, 2004) Maryland Traffic Safety Facts 2003, Maryland State Highway Administration available online: http://www.sha.state.md.us/Safety/oots/Factbook2003April15.pdf

(USNRC, 1999) NUREG/CR-6624, *Recommendations for Revision of Regulatory Guide 1.78.* U.S. Nuclear Regulatory Commission, November 1999.

FSAR Impact

No changes to the FSAR are necessary.

RAI Number 02.02.03-7: FSAR Section 2.2.3

RG 1.206 provides guidance regarding the information that is needed 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. FSAR Section 2.2.3.1.3 does not provide enough information for the NRC staff to perform an independent review of that section. The probability of an accident occurring involving a gasoline refueling tanker is estimated as 2.66 x 10-7 per year, and the probability of the ammonia hydroxide tank spill is estimated to be 5 x 10-7 per year based on empirical data (2.2.3.1.3 p. 2-28). However, no details were given in determining these probabilities. Please provide the details of assumptions used in determining these probabilities along with the copies of references cited (MSHA, 2004; Beerens, 2006).

UniStar Response:

A probabilistic analysis was performed for the two onsite chemicals, gasoline and ammonium hydroxide, that were determined to have significant potential consequences that could exceed the guidelines of 10 CFR Part 100. Regulatory Guide (RG) 1.78 provides that releases of toxic chemicals that have the potential to result in a significant concentration in the control room need not be considered for further evaluation if the releases are of low frequencies (10^{-6} per year, or less) because the resultant low levels of radiological risk are considered acceptable (USNRC, 2001).

The methodology used for each evaluation is presented below:

Probability of a Gasoline Refueling Tanker Accident

The probability per year of a 3500 gallon gasoline refueling tanker accident occurring resulting in the formation of a toxic vapor cloud that may have potential consequences serious enough to affect the control room habitability is estimated using the following methodology (USNRC, 1978):

$$r = n_1 \cdot n_2 \cdot f \cdot s \qquad \text{(Equation 1)}$$

where,

r = exposure rate (the probability of an accident occurring),
n_1 = accidents per mile for the transportation mode (truck transport),
n_2 = cargo release per accident for the transportation mode,
f = frequency of shipment for the substance, in shipments per year,
s = exposure distance in miles.

The number of accidents per mile, n_1, is 7.2022×10^{-8} based on the total large truck accident rate (i.e. over 10,000 pounds gross vehicle weight) for Calvert County, as reported by the Maryland State Highway Administration (MSHA, 2004). The total number of accidents involving large trucks in Calvert County for the year 2003 was 52, and 722 million vehicle miles were traveled by large trucks (MSHA, 2004).

The number of cargo spills per accident, n_2, was assumed to be 1, or 100%. It was conservatively assumed that every accident resulted in a catastrophic failure of the gasoline tanker where the entire contents spilled and formed a vapor cloud. Using a value of 100% is a very conservative assumption given that for large truck transport, accidents resulting in a significant release of cargo are generally in the range of 1.2-18% (USNRC, 1999).

The frequency of shipment, f, for onsite delivery of gasoline to the site was reported as 12 times per year.

The exposure distance, s, was calculated by determining the safe separation distance for a toxic vapor cloud. The safe distance for a 3500 gallon gasoline truck is 1230 feet as presented in FSAR 2.2.3.1.3. Using the guidance provided in RG 1.91 (Figure 2), the exposure distance was calculated from the distance between the two intersection points of the gasoline tanker delivery route with a 1230-foot minimum radius around the control room. The result is an exposure distance of 1626 feet (0.308 miles).

Using the inputs to Equation 1 as described above, an annual accident rate of 2.66×10^{-7} was obtained. The analyzed scenario involves a complete loss of cargo, however, this is very conservative given that strict supervision and site safety procedures would be in effect to prevent leaks, spill, or accidents. Furthermore, it is conservatively assumed that every accident that occurs will result in a spill. Regulatory Guide (RG) 1.78 provides that releases of toxic chemicals that have the potentials to result in a significant concentration in the control room need not be considered for further evaluation if the releases are of low frequencies (10^{-6} per year, or less) because the resultant low levels of radiological risk are considered acceptable (USNRC, 2001). Therefore, a postulated gasoline truck accident during onsite delivery resulting in a total cargo release and formation of a toxic vapor cloud is not considered a credible event.

Probability of an Ammonium Hydroxide Tank Spill

The probability per year of an ammonium hydroxide tank spill event resulting in the formation of a toxic vapor cloud that may have potential consequences serious enough to affect the control room habitability was estimated based on empirical data. The ammonium hydroxide is stored in an 8500 gallon, double-walled tank located in a tank farm with a sump. The assumptions used in the ammonium hydroxide tank analysis involved a worst case scenario in which an instantaneous release of the entire tank contents occurred and formed an unconfined puddle, 1 cm in depth, under stable atmospheric conditions. In this scenario, the failure rate for a tank is reported as 5×10^{-7} per year based on historical data. The failure rate of 5×10^{-7} per year applies to an instantaneous release of the entire contents of the tank to the atmosphere from a tank with an outer protective shell. (Beerens, 2006 and CPR, 1999) This is below the frequency of 10^{-6} per year or less that is stipulated in RG 1.78, therefore a postulated ammonium hydroxide accident resulting in a total storage release and formation of a toxic vapor cloud is not considered a credible event. (USNRC, 2001)

References:

(USNRC, 2001) Regulatory Guide 1.78, Rev. 1, *Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release,* U.S. Nuclear Regulatory Commission, December 2001.

(USNRC, 1978) Regulatory Guide 1.91, Rev. 1, *Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants,* U.S. Nuclear Regulatory Commission, February 1978.

(MSHA, 2004) *Maryland Traffic Safety Facts 2003*, Maryland State Highway Administration available online: http://www.sha.state.md.us/Safety/oots/Factbook2003April15.pdf (and attached)

(USNRC, 1999) NUREG/CR-6624, *Recommendations for Revision of Regulatory Guide 1.78*. U.S. Nuclear Regulatory Commission, November 1999.

(Beerens, 2006) Beerens, H.I., Post, J.G. and Uijt de Haag, P.A.M., *The Use of Generic Failure Frequencies in QRA: The Quality and Use of Failure Frequencies and How to Bring Them Up-to-Date,* Journal of hazardous Materials, Volume 130, Issue 3, pp 265-270, March 2006. (attached)

(CPR, 1999) Guidelines for Quantitative Risk Assessment – "Purple Book," CPR 18E, Committee for the Prevention of Disasters (CPR), SDU, The Hague, 1999. (attached)

FSAR Impact

No changes to the FSAR are necessary.