ATTACHMENT 2

Calculation 32-2400572-02,
"Natural Gas Pipeline Hazard Risk Determination"

FRAMATOME ANP

CALCULATION SUMMARY SHEET (CSS)

Document Identifier 32 - 2400572 - 02

Title Natural Gas Pipeline Hazard Risk Determination

PREPARED BY:

NAME S.T. Thomson

SIGNATURE S.T. Thomson

TITLE Sr Engineer DATE 1/16/04

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REVIEWED BY:

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NAME J.H. Snooks

SIGNATURE J.H. Snooks

TITLE Sr Env Consultant DATE 1/19/2004

TM STATEMENT: REVIEWER INDEPENDENCE [signature] 1/19/04

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PURPOSE AND REASON FOR REVISION 02:

This calculation has been revised to include the natural gas transmission incident data and telephonic incident notifications as an attachment. Also, the number of explosions was increased from six to seven to include an incident where both an ignition ' explosion occurred (i.e., NRC no. 437627). Therefore, the estimated gas line rupture and subsequent hazards yearly ɔability was recalculated and has been revised to 9.44×10^{-6}.

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THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV	CODE/VERSION/REV

THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

☐ YES ☒ NO

Record of Revisions

Affected Section and/or Page(s)	Description (Include changes to calculation attachments, microfiche, and electronic media)
Revision 01	Dated December 12, 2003.
Pg 2	Added Record of Revisions page as required by procedure.
Pg 3	Revised Table of Contents page numbers corresponding to calculation sections and attachments.
Attachment 4 (Pg 21)	Revised Section 6.0 to note use of a computer benchmark test case.
Attachment 10 (Pgs 38-42)	Added ALHOA benchmark test case.
Attachment 11 (Pgs 43-45)	Added Design Verification Checklist as required by procedure, effective 11/26/2003.

Valid and current pages: 1-45

Revision 02	Dated January 16, 2004 – new CSS
Pg 2	Added Record of Revisions associated with Revision 2
TOC, Pg 3	Table of Contents – Revised heading for Attachment 3
Sec. 2.0, Pg 4	1st paragraph, 4th sentence – inserted '(transmitted)' after "being sent".
Sec. 3.0, Pg 5	For equation 'P', changed 'Missile impact' to 'Missile generation'.
Sec. 5.0, Pg 5	Revised Input/Assumption No.3 – deleted 'and hence will be neglected in the probabilistic evaluation' and added the following: 'If a rupture length is not reported, it is assumed to be zero.'
Sec. 6.1, Pg 5	Revised wording for 'I' (i.e., included the word 'rupture').
Sec. 6.1.1, Pg 6	3rd paragraph, 6th sentence –added the following: - '(see Table 1, Note 8)'.
Sec. 6.1.2, Pg 6	1st paragraph, 2nd sentence – added 'be' between 'must' and 'an'. Revised the 1st sentence of 2nd paragraph and revised 'R_{C1}'.
Sec. 6.1.4, Pg 7	Revised '$P_{Explosion}$'.
Sec. 6.2, Pg 8	Last sentence, changed 'detonation' to 'explosion' probability and revised '$P_{missile\ generation}$'.
Sec. 6.4, Pg 8	Revised 'P'
Sec. 7.0, Pg 9	Revised yearly probability from $8.08x10^{-6}$ to $9.44x10^{-6}$, 2nd sentence of last paragraph.
Table 1, Pg 11	Revised table input and Notes 1, 3 and 4. Added Notes 5 through 8.
Attachment 3	Revised Pg 17: added reference source information for the table attachment. Also added pages 17a,b,c,d,e,f,g&h – Incidents and Telephonic Records 1998 – 2001 as well as noted this on Pg 17.
Attachment 11	Replaced the Design Verification Checklist for Revision 1 with that for Revision 2.

Valid and current pages: 1-45, including 17a,b,c,d,e,f,g&h

TABLE OF CONTENTS

1.0 PURPOSE AND OBJECTIVE

This calculation evaluates the hazard at the proposed National Enrichment Facility (NEF) in Eunice, New Mexico due to the presence of a natural gas pipeline.

The evaluation is part of the Integrated Safety Analysis (ISA) for the proposed site, as required by 10 CFR Part 70. It was performed in accordance with the Framatome ANP (FANP) Quality Assurance Program.

2.0 BACKGROUND

A 16-inch natural gas line runs along the southern boundary of Section 32, Township 21 South, Range 38 East, New Mexico Meridian, Lea County, New Mexico. The proposed NEF site (Figure 1) is situated north of New Mexico Highway 234 within Section 32. Sid Richardson Energy Services Co. (SRESCo), located in Jal, New Mexico, operates the pipeline. Information gathered from SRESCo via telephone revealed that the pipeline is a low-pressure line (<50 psi) that carries "wet sour gas," which is unprocessed, field gas from the well being sent (transmitted) for processing (Attachment 5). The gas line is buried to a depth of about 3 feet. The gas composition is approximately 72% methane, 11% ethane, 7% propane, and <1% hydrogen sulfide. The gas line flow is between 200-500 thousand cubic feet per day. It is 14-15 miles in length, with manual block valves at each end and in the middle. There also is a check valve at the connection with the main service line located near Eunice and Highway 234. At its closest approach, the pipeline is about 1800 feet (ft) from the Technical Services Building (TSB), the nearest critical NEF structure (Figures 1 and 2).

Following a postulated rupture of a segment of the gas pipeline shown in Figure 1, natural gas will be discharged into the atmosphere. The released gas mixes with the atmosphere and forms a vapor cloud. Depending on the environmental conditions, this vapor cloud will rise (due to buoyancy effects) and travel away from the rupture location. The vapor cloud may explode (or detonate). When this occurs, the shock wave associated with such an explosion may create an overpressure on plant structures. Also, the dynamic impulse from such an explosion may propel objects or missiles in the vicinity of the explosion towards the NEF structures and may structurally damage critical buildings. Alternatively, the vapor cloud may ignite and form a fireball, resulting in radiant heat that could cause potential structural damage.

Based on the above discussion, the hazards posed by an accidental rupture of the gas pipeline therefore consist of:

a. Overpressure on plant structures due to shock waves generated by detonation or explosion of the gas cloud from mixing of the released gas and the atmosphere.
b. Impact by missiles propelled by air bursts from detonation or explosion of the gas cloud.
c. Radiant heat flux on plant structures due to combustion of the gas/air mixture in the gas cloud (thermal impact).

3.0 METHOD OF ANALYSIS

This calculation uses a hazard model to estimate the likelihood of a gas line rupture and subsequent hazards that could impact NEF plant operations. In its general form, the probability, P, of an incident occurring that affects plant structures is

$$P = P_{Explosion} + P_{Missile\ generation} + P_{Thermal\ impact}$$

4.0 ACCEPTANCE CRITERIA

A natural gas pipeline incident is an external event. In accordance with NUREG-1520, Section 3.4 (Reference 1), an external event is considered not credible if the probability of the event initiation is less than 10^{-6} per year. If the probability is greater than 10^{-6} per year, the event is considered credible and must be evaluated further.

5.0 INPUT & ASSUMPTIONS

The analysis input and assumptions are as follows:

1. The pipeline diameter is 16 inches, with an operating pressure of 50 psi (Attachment 5).

2. The gas released is methane, which is the major constituent of wet sour gas (Attachment 5).

3. Ruptures less than 0.1 foot in length are assumed to be unable to cause a plant hazard. If a rupture length is not reported, it is assumed to be zero.

4. The external walls of the proposed NEF buildings that house critical components are made of concrete (Reference 10) and able to withstand an explosion as determined by the safe separation distance in Regulatory Guide 1.91 (Reference 3).

6.0 ANALYSIS AND RESULTS

6.1 Probability of Pipeline Explosion

The general form for the probability of a pipeline explosion is

$$P = I \times R_C \times D$$

where,

I = gas line rupture incident rate per mile
R_C = conditional probability that a significant incident will occur given an incident
D = exposure distance in miles

6.1.1 Probability of Pipeline Incident (I)

Historical data on pipeline accidents are available through the Office of Pipeline Safety (OPS) official website (Reference 7). Attachment 1 shows the incident summary statistics from 1986 to 2002. Attachment 2 contains the incident summary by cause for years 1998, 1999, 2000, and 2001. Data from these four years will be used to evaluate the yearly probability of a pipe rupture. The annual mileage of natural gas transmission pipelines in the country is given in Attachment 3. Only the "onshore" mileage is used in this evaluation.

Also available from the OPS website (Reference 7) are the detailed account of each reported incident, including incident address, incident date, type of incident and rupture length for a rupture incident as well as telephonic records of incidents involving chemical releases. The telephonic records contain information on incident description, and are used here to determine the number of incidents that involve explosions.

Table 1 synthesizes the information in Attachments 1 through 3, the detailed transmission incident accounts, and the telephonic incident notifications for years 1998 to 2001.* The telephonic records for 1998 and 2001 are only from January to June of each year. The number of on-shore rupture incidents and total mileage for these two years, as a result, are divided by two. The number of incidents that involve an explosion is determined from the telephonic records. If no telephonic records exist, or no mention is made of an explosion for an incident, no explosion is assumed for that incident. This is reasonable since an explosion would be reported if it did occur (see Table 1, Note 8). Also, if a rupture length is not reported, it is assumed to be zero. Only rupture incidents with a rupture length of greater than 0.1 ft are able to cause a plant hazard (Input/Assumption 3).

From Table 1, the annual incident rupture rate is

$$I = 50 \text{ ruptures}/873{,}305 \text{ miles} = 5.73 \times 10^{-5} \text{ ruptures/mile}$$

Hence, the probability of rupture of the pipeline under evaluation is 5.73×10^{-5} ruptures per mile.

6.1.2 Conditional Probability of Significant Incident (R_C)

The conditional probability of a significant incident, R_C, has two parts. Given a pipeline incident, in this case a rupture, there must be an explosion (R_{C1}), and given an explosion it must be substantial (R_{C2}) - i.e., be a detonation to affect plant buildings.

From Table 1, seven ruptures out of the 50 (with a rupture length greater than 0.1 foot) involved explosions. Hence the fraction of explosion events is

$$R_{C1} = 7/50 = 0.14$$

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* As of the date of this calculation, transmission data for 2002 to the present was available; however, telephonic incident notifications through 2001 were only available. Therefore, this calculation is based on data between 1998 and 2001.

As stated above, given an explosion it must be significant - i.e., a detonation, but not every explosion is a detonation. Instead, most explosions are deflagrations, which produce much less severe consequences than a detonation. Reference 5 suggests a denotation rate, R_{C2}, given an explosion of 0.28, which is considered conservative (Attachment 7). Therefore, in this calculation,

$$R_{C2} = 0.28$$

6.1.3 Exposure Distance (D)

The exposure distance, D, is a function of the safe separation distance. If an explosion occurs beyond the safe separation distance for a plant critical structure, then the structures will be unaffected.

The exposure distance has two parts: the distance to the gas upper and lower explosion limits (UEL and LEL), D_1, and the safe separation distance, D_2. D_1 is determined by employing the computer program ALOHA (Reference 6) to calculate the concentrations of gas from a postulated gas release along a direct pathway to the NEF. D2 is determined following Regulatory Guide 1.91 (Reference 3) and using the ALOHA results.

As shown in Attachment 4, D_1, the distance to the LEL is 4,095 ft and D_2, the safe separation distance, is 1,471 ft., for a total of 5,566 ft. This means that NEF critical structures must be at least 5,566 ft (1.05 miles) from the point of explosion. Using this distance as a radius, then swinging an arc from the approximate edge of the TSB, intersects the gas pipeline at two points (Figure 1). The distance of the cord between the two points is the exposure distance, D (Figure 1), with the maximum distance possible being two times the radius. Hence, for conservatism,

$$D = 2 \times 1.05 = 2.1 \text{ miles}$$

6.1.4 Final Probability of Pipeline Explosion

The final probability of a pipeline explosion is

$$P_{Explosion} = 5.73 \times 10^{-5} \text{ ruptures (explosions)/mile} \times 0.14 \times 0.28 \times 2.1 \text{ mile} = 4.72 \times 10^{-6} \text{ ruptures (explosions)}$$

6.2 Probability of Missile Hazard

The missile generation hazard depends on the detonation strength (TNT-equivalent weight), the dynamic pressure impulse, the projectile mass, air drag, and the distance between the detonation center and the facility. Since none of these parameters for the proposed enrichment facility has been established, it is conservatively assumed that every detonation will result in a hazard due to missile impact. Accordingly, the probability of a hazard due to missile generation is the same as the explosion probability previously calculated in Section 6.1, or

$$P_{\text{missile generation}} = 4.72 \times 10^{-6} \text{ / year}$$

6.3 Probability of Thermal Hazard

The thermal radiation hazard depends on the gas release rate, subsequent motion of the vapor cloud, flame temperature, flame speed, flame emissivity, air transmissivity, and distance between the vapor cloud and the facility. The gas release rate and subsequent motion of the vapor cloud for the present analysis are bounded by similar analysis involving a natural gas pipeline conducted by the Tennessee Valley Authority (TVA) at the Hartsville Nuclear Plants (Reference 9). The pipeline in the TVA analysis had a larger diameter (22 vs. 16 inches) and a higher operating pressure (560 vs. 50 psi). In addition, the TVA analysis used conservative values for flame temperature, flame speed, flame emissivity, and air transmissivity, all of which are applicable to the present evaluation. Lastly, although the distance to the pipeline for the NEF site is less than the TVA analysis (1800 ft vs. 2650 ft), considering other conservatisms as noted above, the TVA results for the radiant heat flux would bound those for a detailed analysis of the pipeline near the NEF.

The worst-case heat flux to critical plant structures in the TVA analysis was less than 800 Btu/ft^2 (page 2.2-12m, Attachment 9). Based on the above argument, the radiant heat flux to the proposed NEF is also expected to be less than 800 Btu/ft^2. This is substantially less than the heat flux expected to cause any damage to the concrete NEF structures. From Reference 9 (page 2.2-12l, Attachment 9), a heat flux of about 1750 Btu/ft^2 would be needed to cause spontaneous ignition of wood. The heat flux that would cause damage to concrete is expected to be much higher. Given the low gas pressure, any fireball would last a very short period of time before the flame front retreated back to the vicinity of the pipe, approximately 1800 ft from the NEF. Hence, there is no need to consider the hazard due to heat exposure from combustion of the gas/air mixture in the gas, resulting in a yearly probability of zero.

6.4 Probability of Hazard due to Gas Pipeline

The final probability of a hazard due to the natural gas pipeline in the vicinity of the proposed NEF site is the sum of the three hazards:

$$P = 4.72 \times 10^{-6} \text{ / year} + 4.72 \times 10^{-6} \text{ / year} + 0 = 9.44 \times 10^{-6} \text{ / year}$$

7.0 RESULTS AND CONCLUSIONS

A postulated rupture of the gas pipeline near the NEF could pose the following the hazards:

- Overpressure on plant structures due to shock waves generated by detonation or explosion of the gas cloud from mixing of the released gas and the atmosphere.
- Impact by missiles propelled by air bursts from detonation or explosion of the gas cloud.
- Radiant heat flux on plant structures due to combustion of the gas/air mixture in the gas cloud.

A hazard model estimated the likelihood of a gas line rupture and the subsequent hazards that could impact NEF plant operations. The yearly probability of these hazards is 9.44×10^{-6} / year. Therefore, the event is considered credible in accordance with NUREG-1520 (Reference 1).

The objective of this calculation has been met.

8.0 REFERENCES

1. NUREG-1520, Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, March 2002.
2. Framatome ANP Document 38-2400064-00, Letter from Mike Lynch dated September 9, 2003, Urenco Authorization of Use of Documents for Design Inputs.
3. Regulatory Guide 1.91, Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants, Revision 1, February 1978.
4. Fire Protection Handbook, 17th Edition, 1991, National Fire Protection Association, Quincy, MA. (Attachment 6)
5. Seabrook Station Updated Final Safety Analysis Report (UFSAR), Table 2.2-15. (Attachment 7)
6. ALOHA (Areal Locations of Hazardous Atmospheres) User's Manual, August 1999, U.S. EPA, Chemical Emergency Preparedness and Prevention Office, Washington, D.C. 20460 and National Oceanic Atmospheric Administration, Hazardous Materials Response Division, Seattle, WA, 98115.
7. Office of Pipeline Safety website: http://ops.dot.gov (Attachments 1-3)
8. SFPE Handbook of Fire Protection Engineering, Second Edition, June 1995, Society of Fire Protection Engineers, Boston, MA; National Fire Protection Association, Quincy, MA. (Attachment 8)
9. Tennessee Valley Authority (TVA), Preliminary Safety Analysis Report (PSAR), Hartsville Nuclear Plants, Amendment 30 (Attachment 9).
10. Framatome ANP Document 38-5035284-01, Preliminary Basis of Design.

9.0 QUALITY ASSURANCE

In addition to Urenco supplied design inputs, FANP is also using design inputs supplied by Lockwood Greene. Urenco has authorized FANP in writing (Reference 2) to use design inputs from Lockwood Greene for work in the preparation of the NEF License Application under the context of the FANP QA program.

Table 1
Pipeline Statistic for 1998 to 2001
(Source: Official website of Office of Pipeline Safety: ops.dot.gov, Reference 7)

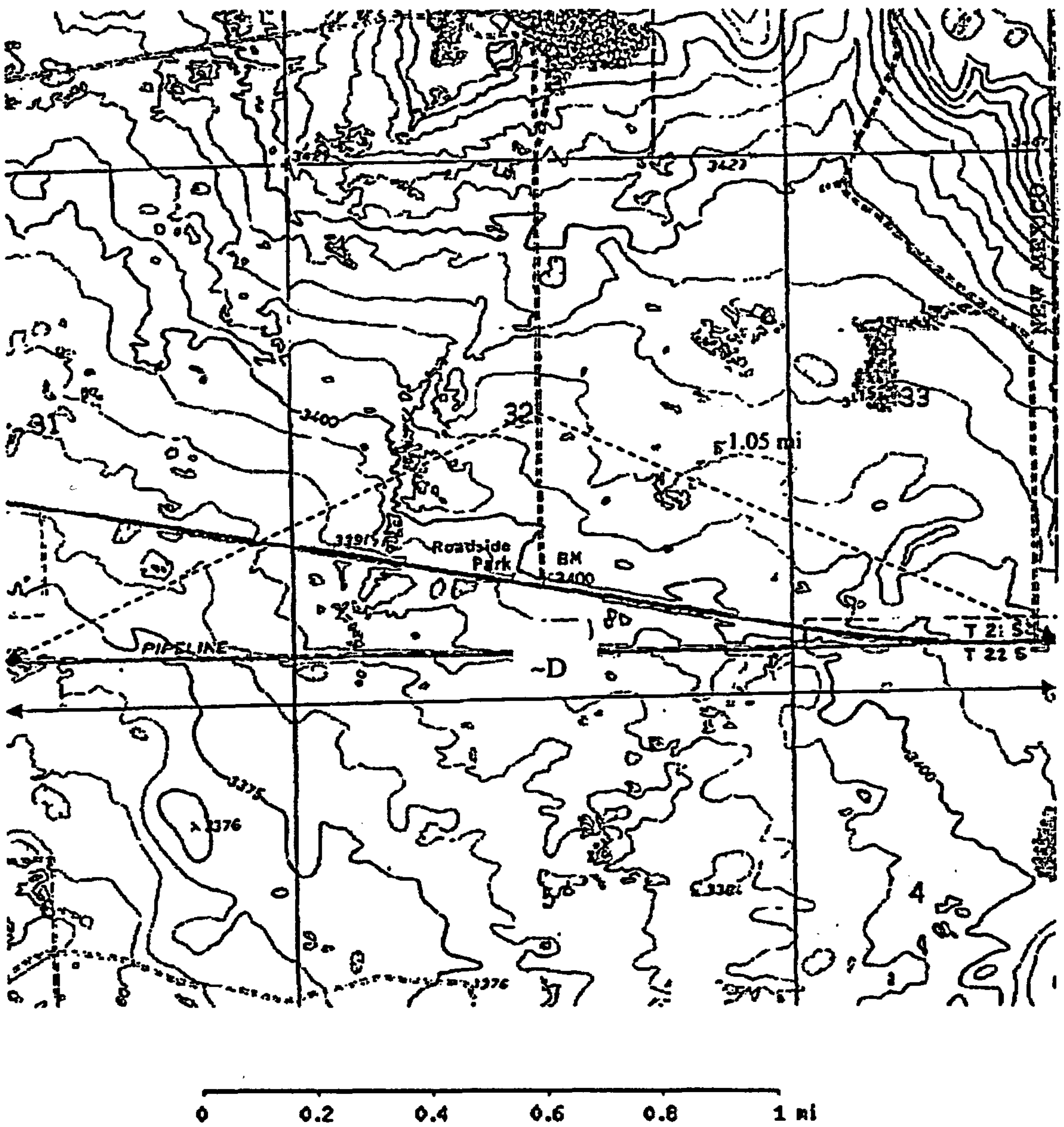
	1998	1999	2000	2001	Total
Rupture	24/2=12	16	24	16/2=8	60
Rupture>0.1'	21/2=11	11	22	11/2=6	50
Total Mileage	295,598/2 = 147,799	290,083	292,957	284,932/2 = 142,466	873,305
No. Ignition	6	5	5	1	17
No. Explosion	3	3	1	0	7

Notes:

1. Only rupture incidents involving rupture lengths greater than 0.1 foot are considered. Unreported rupture lengths are assumed to be zero. (Input/Assumption 3)
2. Information on incident types (i.e., ruptures) is based on natural gas transmission incident data.
3. Information on incidents and explosions is based on telephonic incident notifications. The number of ignitions (fires) is for informational purposes. Ignition incidents include NRC Nos. (1998) 420106, 421437, 427286, 430284, 436523, 437627 (also associated with an explosion), (1999) 474992, 487294, 490844, 498467, 506063, (2000) 527789, 528256, 534705, 548619, 549015 and (2001) 560330.
4. Two ruptures in 1998 (dated 1/26/98 and 3/20/98) were associated with off-shore incidents and not included in the overall rupture total or in the rupture>0.1' total. Also note that in 1998, for one incident, (NRC no. 433654), two pipes ruptured; therefore, this was counted as two pipe ruptures in the rupture and rupture>0.1' totals.
5. Referring to Attachment 3 – Incidents and Telephonic Records 1998 - 2001, note that some incidents were not indicated to be a 'rupture' type incident on the transmission incident data report, although the telephonic incident notifications indicated a rupture occurred. Therefore if a rupture length of >0.1' was associated with an on-shore, non-rupture incident type, it was counted in the rupture and rupture>0.1' totals. This applies to the year 2000 (i.e., NRC No. 520444, dated 2/18/2000 – indicated to be a leak type incident).
6. Reported explosion incidents include NRC Nos. (1998) 424160, 426483, 437627, (1999) 472803, 476123, 491766 and (2000) 551181. Note that for NRC No. (1998) 437627, both a fire (ignition) and explosion were reported.
7. Although it has been assumed that rupture lengths <0.1' are unable to cause a plant hazard and unreported rupture lengths are assumed to be zero, except for NRC No. 476123, six of the seven reported explosions are associated with incident types that have no reported rupture length and/or are not indicated to be ruptures. However, they have been considered in the explosion total and used to determine R_{CI} in Section 6.1.2 without increasing the number of ruptures >0.1' (i.e., 50) in computing R_{CI}. [Note: The other explosion incident indicated to be a rupture is NRC No. 551181; however, it has no reported rupture length.]
8. Referring to Note 3 above, for some of the ignition incidents (i.e., NRC Nos. (1998) 421437, 430284, (1999) 487294, 490844, 498467 and (2000) 528256), the source of the ignition was reported as unknown and/or the incident may have been reported after the ignition started. Considering that no mention is made of an explosion, in addition to various conservatisms used in this evaluation (e.g., determination of $P_{missile\ generation}$ in Section 6.2), it is reasonable not to include these incidents in the explosion total.

Figure 1, Location of Pipeline near the Proposed NEF Site

Source: http://www.topozone.com



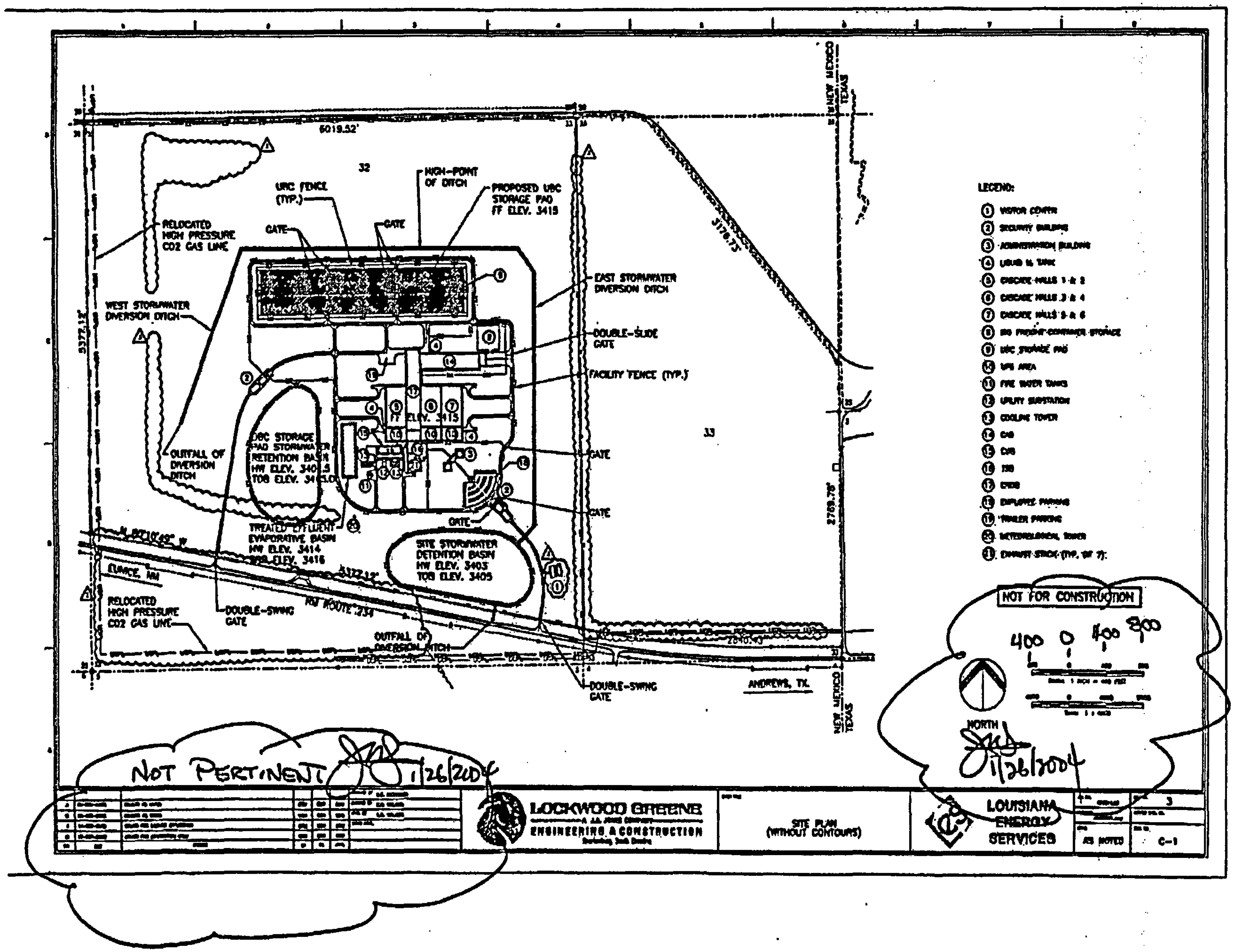


Figure 2, NEF Site Plan

Attachment 1: Incident Summary Statistics from 1986 to 2002

(For Informational Purposes)

OFFICE OF PIPELINE SAFETY
NATURAL GAS PIPELINE OPERATORS
INCIDENT SUMMARY STATISTICS BY YEAR
1/1/1986 - 08/31/2003

TRANSMISSION OPERATORS

Year	No. of Incidents	Fatalities	Injuries	Property Damage
1986	83	6	20	$11,166,262
1987	70	0	15	$4,720,466
1988	89	2	11	$9,316,078
1989	103	22	28	$20,458,939
1990	89	0	17	$11,302,316
1991	71	0	12	$11,931,238
1992	74	3	15	$24,578,165
1993	95	1	17	$23,035,268
1994	81	0	22	$45,170,293
1995	64	2	10	$9,957,750
1996	77	1	5	$13,078,474
1997	73	1	5	$12,078,117
1998	99	1	11	$44,487,310
1999	54	2	8	$17,695,937
2000	80	15	18	$17,868,261
2001	86	2	5	$23,610,883
2002	81	1	5	$24,365,559
Totals	1369	59	224	$324,821,316

Historical totals may change as OPS receives supplemental information on incidents.

Attachment 2: Incident Summary by Cause, 1998, 1999, 2000 and 2001

(For Informational Purposes)

OFFICE OF PIPELINE SAFETY
TRANSMISSION PIPELINE
INCIDENT SUMMARY BY CAUSE
1/1/1998 - 12/31/1998
(Natural Gas)

Cause	No. of Incidents	% of Total Incidents	Property Damages	% of Total Damages	Fatalities	Injuries
CONSTRUCTION/MATERIAL DEFECT	19	19.19	$2,984,361	6.7	0	4
CORROSION, EXTERNAL	8	8.08	$1,289,036	2.89	0	0
CORROSION, INTERNAL	14	14.14	$3,259,500	7.32	0	0
DAMAGE BY OUTSIDE FORCE	37	37.37	$18,673,077	41.97	1	3
OTHER	21	21.21	$18,281,336	41.09	0	4
TOTAL	99		$44,487,310		1	11

Historical totals may change as OPS receives supplemental information on incidents.

OFFICE OF PIPELINE SAFETY
TRANSMISSION PIPELINE
INCIDENT SUMMARY BY CAUSE
1/1/1999 - 12/31/1999
(Natural Gas)

Cause	No. of Incidents	% of Total Incidents	Property Damages	% of Total Damages	Fatalities	Injuries
CONSTRUCTION/MATERIAL DEFECT	8	14.81	$6,654,800	37.6	0	0
CORROSION, EXTERNAL	3	5.55	$465,000	2.62	0	0
CORROSION, INTERNAL	10	18.51	$3,352,000	18.94	0	0
CORROSION, NOT SPECIFIED	1	1.85	$0	0	0	0
DAMAGE BY OUTSIDE FORCE	18	33.33	$5,684,100	32.12	1	2
OTHER	14	25.92	$1,540,037	8.7	1	6
TOTAL	54		$17,695,937		2	8

Historical totals may change as OPS receives supplemental information on incidents.

OFFICE OF PIPELINE SAFETY
TRANSMISSION PIPELINE
INCIDENT SUMMARY BY CAUSE
1/1/2000 - 12/31/2000
(Natural Gas)

Cause	No. of Incidents	% of Total Incidents	Property Damages	% of Total Damages	Fatalities	Injuries
CONSTRUCTION/MATERIAL DEFECT	7	8.75	$591,043	3.3	0	0
CORROSION, EXTERNAL	14	17.5	$3,475,500	19.45	0	0
CORROSION, INTERNAL	16	20	$2,635,086	14.74	12	2
CORROSION, NOT SPECIFIED	1	1.25	$730,000	4.08	0	0
DAMAGE BY OUTSIDE FORCE	20	25	$3,164,161	17.7	3	7
OTHER	22	27.5	$7,272,471	40.7	0	9
TOTAL	80		$17,868,261		15	18

Historical totals may change as OPS receives supplemental information on incidents.

OFFICE OF PIPELINE SAFETY
TRANSMISSION PIPELINE
INCIDENT SUMMARY BY CAUSE
1/1/2001 - 12/31/2001
(Natural Gas)

Cause	No. of Incidents	% of Total Incidents	Property Damages	% of Total Damages	Fatalities	Injuries
CONSTRUCTION/MATERIAL DEFECT	12	13.95	$1,639,070	6.94	0	0
CORROSION, EXTERNAL	7	8.13	$1,961,350	8.3	0	0
CORROSION, INTERNAL	9	10.46	$3,301,200	13.98	0	0
DAMAGE BY OUTSIDE FORCE	36	41.86	$14,807,928	62.71	0	0
OTHER	22	25.58	$1,901,335	8.05	2	5
TOTAL	86		$23,610,883		2	5

Historical totals may change as OPS receives supplemental information on incidents.

ADDED
Pgs 17a, b, c, d, e, f, g & h

Attachment 3: Natural Gas Transmission Pipeline Annual Mileage

Office of Pipeline Safety

Natural Gas Transmission Pipeline Annual Mileage

		Transmission		Gathering	
Year	No. of Records	Onshore	Offshore	Onshore	Offshore
1984	885	277,601	7,353	33,290	3,671
1985	952	282,745	7,719	33,729	1,740
1986	1,008	280,667	9,291	29,737	1,958
1987	963	284,235	7,622	29,654	2,477
1988	1,019	280,252	7,908	28,941	3,101
1989	1,033	279,728	8,198	29,597	2,547
1990	1,105	283,880	8,110	29,266	3,154
1991	1,211	285,295	8,567	29,009	3,704
1992	1,183	283,071	8,397	28,909	3,720
1993	1,131	285,043	8,220	28,431	3,625
1994	1,229	293,438	8,107	27,392	3,912
1995	1,267	288,846	8,101	26,657	4,262
1996	1,247	285,338	6,848	24,844	4,761
1997	1,352	287,745	6,625	28,234	6,161
1998	1,164	295,598	7,108	23,480	5,673
1999	1,176	290,083	6,017	26,348	5,916
2000	1,158	292,957	5,241	21,706	5,682
2001	1,306	284,932	5,536	17,659	3,865
2002	1,389	301,312	6,212	15,968	3,355

Source: http://ops.dot.gov/stats/GTANNUAL2.htm - Pipeline Statistics, Transmission Annual Mileage Totals (1984 – 2002).

NRC No.	Incident Date	Offshore?	Incident Type	Rupture Length	Description of Incident
418580	19980105	No	OTHER		20IN NATURAL GAS PIPELINE / LINE WAS RUPTURED WHEN A CONTRACTOR STRUCK IT WITH A GRADER
NONE	19980108	No	RUPTURE	0.35	No telephonic record
	19980109	Yes	LEAK		N/A, offshore
	19980111	Yes	LEAK		N/A, offshore
419522	19980113	No	RUPTURE	8.5	U/G 10 INCH NATURAL GAS TRANSMISSION LINE PIPE/RUPTURED DUE TO UNKNOWN CAUSES
420106	19980116	No	OTHER		NATURAL GAS COMPRESSOR / COMPRESSOR CAUGHT FIRE
420030	19980116	No	RUPTURE		20 INCH NATURAL GAS TRANSMISSION PIPELINE / CAUSE OF RELEASE UNKNOWN ATTIME OF REPORT
420718	19980121	No	RUPTURE	15	5 INCH NATURAL GAS TRANSMISSION LINE / LINE STRUCK BY HOWARD COUNTY ROAD DEPT. VEHICLE
	19980126	Yes	RUPTURE	5	N/A, offshore
	19980126	Yes	LEAK		N/A, offshore
421437	19980127	No	RUPTURE	92	NATURAL GAS TRANSMISSION LINE / GAS IS BEING RELESED FROM THE PIPELINE AND BURNING / CAUSE OF RELEASE IS UNKNOWN
	19980130	Yes	OTHER	5	N/A, offshore
424160	19980207	No	LEAK		GAS HEATER/EXPLODED-CORROSION RELATED PROBLEM
425454	19980220	No	LEAK		SUBTERRANEAN 20 INCH NATURAL GAS PIPELINE LEAK/ UNKNOWN CAUSE.
425942	19980225	No	OTHER		20 INCH PIPELINE / THE LINE RUPTURED
426217	19980226	No	LEAK		24 INCH NATURAL GAS PIPELINE (TRANSMISSION LINE) / UNKNOWN....DEVELOPEDA LEAK
426463	19980301	No	LEAK		EXPLOSION AT MLNP FIRST AND INGRIA STREETS / MAY BE NATURAL GAS RELATEDCOMPANY IS STILL INVESTIGATING
427286	19980307	No	OTHER	0	CAR DROVE OVER 2" FEEDOFF LINE TO DISTRIBUTION SYSTEM; REGULATOR VALVE BROKEN OPEN RELEASING GAS WHICH IGNITED, SETTING CAR AFIRE.
427385	19980308	No	OTHER		8 INCH METER STATION / LIGHTNING STRUCK METER
	19980320	Yes	LEAK		N/A, offshore
429154	19980320	No	LEAK	0	NATURAL GAS PIPELINE (TRANSMISSION LINE) / A CONTRACTOR STRUCK AND RUPTURED PIPELINE
NONE	19980324	No	LEAK		No telephonic record
	19980327	Yes	RUPTURE	13	N/A, offshore
	19980328	Yes	LEAK		N/A, offshore
430284	19980329	No	RUPTURE	159	FIRE WAS DISCOVERED BY LOCAL POLICE ALONG PIPLINE AREA / CAUSE OF BREAKIS STILL UNKNOW
430957	19980402	No	LEAK		SOURCE: 26" PIPELINE/CAUSE: POSSIBLE CORROSION TO THE PIPELINE CAUSE THE RELEASE
430914	19980402	No	RUPTURE	8	16IN BELOW GROUND NATURAL GAS PIPE/ UNKNOWN CAUSE/ TRANSMISSION LINE INTERSTATE PIPELINE/ COMPANY LINE NAME 2-AD
431768	19980408	No	LEAK		12 IN TRANSMISSION PIPELINE / LEAK UNDERWATER IN INTERCOASTAL WATERWAY (Note: Although it appears from the telephonic record that this incident is associated with an off-shore (underwater) leak, the incident data indicates it is not.)
431743	19980408	No	RUPTURE	16	16 INCH NATURAL GAS TRANSMISSION PIPELINE / LINE FAILURE CAUSED RUPTURE
432039	19980410	No	LEAK		4 INCH NATURAL GAS TRANSMISSION LINE / CAUSE UNKNOWN
433267	19980420	No	LEAK		NATURAL GAS PIPELINE (SIZE & TYPE UNKNOWN) / UNKNOWN....AN OVERFLIGHT OBSERVED WHAT APPEARED TO BE A LEAKING PIPELINE
433654	19980422	No	RUPTURE	700	2 PIPES (TYPE UNKNOWN)/ LANDSLIDE CAUSED PIPES TO RUPTURE (Note: There is only one incident listed for this date in the incident data report. However, the telephonic incident notification report also has a listing for NRC no. 433655 (same city as NRC no. 433654). No. 433655 also pertains to a pipe rupture due to a landslide on the same date [i.e., per the telephonic records: No. 433655 - PIPELINE / LANDSLIDE CAUSED PIPE TO RUPTURE]. Thus, it appears that no. 433655 is not associated with a natural gas pipeline.)
	19980504	Yes	LEAK		N/A, offshore
	19980505	Yes	LEAK		N/A, offshore
435589	19980506	No	RUPTURE	30	30 INCH UNDERGROUND TRANSMISSION LINE / RUPTURED DUE TO UNKNOWN CAUSES
435986	19980508	No	LEAK		22 INCH STEEL PIPELINE / LEAK IN PIPELINE DUE TO UNKNOWN CAUSES RELEASED NATURAL GAS TO THE ATMOSPHERE / LINE: TRANSMISSION LINE
	19980511	Yes	LEAK		N/A, offshore
436523	19980512	No	OTHER		22 INCH TRANSMISSION LINE / WHILE REPAIRING A RELEASE AN IGNITION OCCURRED RESULTING IN AN INJURY TO AN EMPLOYEE
	19980518	Yes	LEAK		N/A, offshore

ATTACHMENT 3 SHT 17a / 45
CALC. NO. 32-2400572-02

NRC No.	Incident Date	Offshore?	Incident Type	Rupture Length	Description of Incident
	19980519	Yes	LEAK		N/A, offshore
437627	19980519	No	OTHER		ABOVE GROUND TRANSMISSION LINE(SIZE UNKNOWN)AT METERING FACILITY/DURINGREPAIR WORK AN EXPLOSION OCCURED FOLLOWED BY A FIRE
439300	19980530	No	RUPTURE	30	10 INCH PIPELINE/CAUSE UNKNOWN
439772	19980602	No	OTHER		30 INCH NATURAL GAS PIPELINE / IMPROPER VALVE SEQUENCE CAUSED A RELEASE OF NATURAL GAS
	19980606	No	OTHER		No telephonic record
	19980606	No	LEAK		No telephonic record
	19980615	Yes	LEAK		N/A, offshore
	19980619	No	OTHER		No telephonic record
	19980706	No	LEAK		No telephonic record
	19980707	No	LEAK		No telephonic record
	19980707	No	OTHER		No telephonic record
	19980711	No	OTHER		No telephonic record
	19980715	No	LEAK		No telephonic record
	19980715	No	OTHER		No telephonic record
	19980717	No	LEAK		No telephonic record
	19980717	No	LEAK		No telephonic record
	19980721	No	OTHER		No telephonic record
	19980723	No	LEAK		No telephonic record
	19980723	Yes	LEAK		N/A, offshore
	19980723	Yes	LEAK		N/A, offshore
	19980727	No	OTHER		No telephonic record
	19980802	No	LEAK		No telephonic record
	19980802	No	LEAK		No telephonic record
	19980803	No	OTHER		No telephonic record
	19980808	No	LEAK		No telephonic record
	19980814	No	OTHER		No telephonic record
	19980818	No	OTHER		No telephonic record
	19980825	No	OTHER		No telephonic record
	19980826	Yes	LEAK		N/A, offshore
	19980828	No	LEAK		No telephonic record
	19980828	No	RUPTURE	2	No telephonic record
	19980903	No	RUPTURE	20	No telephonic record
	19980906	No	RUPTURE	15	No telephonic record
	19980917	Yes	LEAK		N/A, offshore
	19980920	Yes	LEAK		N/A, offshore
	19980923	Yes	LEAK		N/A, offshore
	19980923	No	LEAK		No telephonic record
	19980929	No	OTHER		No telephonic record
	19980929	Yes	OTHER		N/A, offshore
	19980930	Yes	LEAK		N/A, offshore
	19981002	Yes	OTHER		N/A, offshore
	19981006	No	RUPTURE		No telephonic record
	19981006	Yes	LEAK		N/A, offshore
	19981008	No	LEAK		No telephonic record
	19981012	No	OTHER		No telephonic record
	19981012	No	RUPTURE	10	No telephonic record
	19981026	No	OTHER		No telephonic record
	19981029	No	RUPTURE		No telephonic record
	19981114	No	RUPTURE	55	No telephonic record

ATTACHMENT 3 SHT 17b/45
CALC. NO. 32-2400572-02

NRC No.	Incident Date	Offshore?	Incident Type	Rupture Length	Description of Incident
	19981123	No	LEAK		No telephonic record
	19981130	Yes	LEAK		N/A, offshore
	19981202	No	OTHER		No telephonic record
	19981206	No	RUPTURE	80	No telephonic record
	19981207	No	RUPTURE	33	No telephonic record
	19981210	No	RUPTURE	1	No telephonic record
	19981210	No	OTHER		No telephonic record
	19981213	No	RUPTURE	1	No telephonic record
	19981216	No	OTHER		No telephonic record
	19981217	No	RUPTURE	29	No telephonic record
	19981221	No	LEAK		No telephonic record
469388	19990102	No	RUPTURE		22 INCH PIPELINE / THE MATERIAL RELEASED DUE TO AN UNKNOWN FAILURE ON THE LINE
469420	19990103	No	OTHER		8 INCH TRANSMISSION PIPELINE / UNKNOWN
NONE	19990113	No	LEAK		No telephonic record
NONE	19990117	No	LEAK		No telephonic record
	19990117	Yes	LEAK	0	N/A, offshore
471924	19990125	No	LEAK		20 INCH GAS PIPELINE / CORROSION OF LINE (Note: include even though city differs between the incident and telephone records)
472364	19990130	No	LEAK	0	22 INCH STEEL BELOW GROUND TRANSMISSION PIPELINE / COUPLING FAILED
472803	19990202	No	OTHER		INSIDE PLUMBING OF BUILDING/PLUMBING CONTRACTOR TURNED GAS VALVE ON TO PURGE PLUMBING LINES CAUSING EXPLOSION WHEN PLUGGING IN WATER HEATERS
472633	19990202	No	RUPTURE	0	OPERATOR ID 19136 / 20 INCH TRANSMISSION PIPELINE / THE CAUSE HAS NOT YET BEEN DETERMINED / THERE WAS NO FIRE OR EXPLOSION
474992	19990224	No	LEAK		COMPRESSOR STATION / FAILURE OF COMPRESSOR ENGINE GAS RELEASE AND FIRE / 24 INCH PIPELINE
475272	19990226	No	RUPTURE		26INCH NATURAL GAS TRANSMISSION PIPELINE / FAILURE DUE TO UNKNOWN CAUSE
475494	19990228	No	LEAK		18 INCH NATURAL GAS TRANSMISSION PIPELINE / DOT REGULATED / NO SERVICESAFFECTED / FLANGE GASKET ON LINE LEAKED
475747	19990303	No	LEAK		BELOW GROUND 36IN TRANSMISSION PIPELINE/UNKNOWN DOT REGULATED PIPELINE
476123	19990307	No	RUPTURE	16.5	12 INCH TRANSMISSION LINE RUPTURED AND EXPLODED
	19990323	Yes	LEAK		N/A, offshore
483495	19990512	No	OTHER		3 INCH TRANSMISSION NATURAL GAS PIPELINE / THE LINE WAS STRUCK BY A 3RDPARTY CONTRACTOR / THERE WAS NO FIRE OR EXPLOSION
NONE	19990513	No	LEAK		No telephonic record
	19990520	Yes	LEAK		N/A, offshore
485403	19990528	No	RUPTURE	2	8 INCH TRANSMISSION LINE / CAUSE:UNKNOWN / LINE IS REGULATED BY THE DOT
487294	19990613	No	RUPTURE	10	SOURCE UNKNOWN/ IGNITION AT PIPELINE STATION/ UNDER INVESTIGATION UNKNOWN SIZE OF LINE/STATION IGNITION/NO INJURIES/NO BUILDINGS DAMAGED
490844	19990710	No	RUPTURE	35	NATURAL GAS PIPELINE /NGPL 30INCH GULF COAST LINE RUPTURED CAUSING FIREUNDERGROUND TRANSMISSION LINE / DOT REGULATED LINE
491766	19990718	No	OTHER		METER STATION EQUIPMENT FAILURE RESULTED IN A BUILDING EXPLOSION/ALSO A PIPELINE IS RUPTURED INCIDENTS ARE POSSIBLY RELATED
494775	19990811	No	RUPTURE	4	12 INCH NATURAL GAS PIPELINE /CAUSE UNK / RELEASED NATURAL GAS INTO ATMOSPHERE
495259	19990814	No	OTHER		PURGING 20 INCH PIPELINE / LINE RUPTURED IN TWO PLACES DURING PURGING LINE IS DOT REGULATED
495123	19990815	No	LEAK		6 INCH PIPELINE/DREDGING OPERATION
496056	19990816	No	LEAK		ABOVE GROUND 2IN PIPING WITHIN PLANT/POSSIBLY DUE TO CRACK IN WELD
496023	19990823	No	RUPTURE	43	16IN BELOW GROUND PIPELINE / CAUSE OF RELEASE IS UNDETERMINED TRANSMISSION LINE / NO SERVICE INTERRUPTED
NONE	19990826	No	LEAK		No telephonic record
497288	19990901	No	OTHER		DOT REGULATED TRANSMISSION PIPELINE / RELEASE FROM A 6 INCH BLOW OFF/ 6 INCH LINE COMES OFF A 26 INCH LINE / ABOVE GROUND PIPELINE
497979	19990908	Yes	LEAK		N/A, offshore

ATTACHMENT 3 SHT 17c / 45
CALC. NO. 32-2400572-02

NRC No.	Incident Date	Offshore?	Incident Type	Rupture Length	Description of Incident
498467	19990912	No	RUPTURE	25	THERE IS A RUPTURE IN A 24 INCH PIPELINE/ CAUSE OF THE RUPTURE IS UNKNOWN/ GAS IGNITED AS A RESULT OF THE RUPTURE/ DOT REGULATED LINE
498554	19990913	No	RUPTURE		6 INCH GAS TRANSMISSION LINE / LINE HIT BY FARMING EQUIPMENT / RELEASEDNATURAL GAS INTO ATMOSPHERE "DOT REG" LINE NO. 20007"
499423	19990920	No	RUPTURE	1	SEMI TRUCK ROLLED INTO NATURAL GAS FACILITY AND BROKE A SMALL PIPELINE SIZE OF PIPE UNK / NO FIRE/NO INJURIES
	19990923	Yes	LEAK		N/A, offshore
499904	19990923	No	RUPTURE	29	26 INCH NATURAL GAS PIPELINE RUPTURE/ REASON FOR RUPTURE IS UNKNOWN/ THIS IS A DOT REGULATED TRANSMISSION LINE
	19990925	Yes	LEAK		N/A, offshore
501339	19991005	No	OTHER		8 INCH STEEL TRANSMISSION GAS PIPELINE / DOT REGULATED / CONTRACTOR STRUCK WITH BACKHOE
505595	19991016	Yes	LEAK		N/A, offshore
	19991026	Yes	LEAK		N/A, offshore
503884	19991027	No	LEAK		24 INCH NATURAL GAS PIPELINE(GATHERING LINE) / UNKNOWN...LINE WAS DISCOVERED LEAKING
NONE	19991103	No	OTHER		No telephonic record
505133	19991109	No	RUPTURE		24 INCH BELOW GROUND PIPELINE / RELEASE OCCURRED DUE TO UNKNOWN CAUSES
507411	19991111	No	LEAK		A 12 INCH PIPELINE WAS RUPTURED BY A THIRD PARTY
505495	19991111	No	RUPTURE	6	10 INCH TRANSMISSION NATURAL GAS PIPELINE / THE LINE WAS STRUCK BY A 3RD PARTY CAUSING THE LINE TO BLOW OUT / TWO EMPLOYEES ARE MISSING
505500	19991111	No	OTHER		8 INCH TRANSMISSION NATURAL GAS PIPELINE / A BULLDOZER GOUGED THE LINE CAUSING A RELEASE / THERE WAS NO FIRE OR EXPLOSION
NONE	19991113	No	LEAK		No telephonic record
506063	19991117	No	LEAK		4.5 INCH TRANSMISSION NATURAL GAS PIPELINE / THE LINE WAS STRUCK BY A CONTRACTOR CAUSING A RELEASE / A FIRE RESULTED
506639	19991124	No	OTHER		No telephonic record
508490	19991209	No	LEAK		8 INCH.TRANSMISSION NATURAL GAS PIPELINE / A LEAK IN A VENT UNDER A HIGHWAY WAS DISCOVERED / THE CAUSE HAS NOT BEEN DETERMINED
508805	19991210	No	OTHER		12 INCH PIPELINE / THE MATERIAL RELEASED DURING MAINTENANCE WORK
509409	19991216	No	RUPTURE	0.25	NATURAL GAS PIPELINE / 3RD PARTY CONTRACTOR STRUCK LINE WITH BACKHOE / TRANSMISSION LINE / DOT REG. LINE (Note: Same state in incident and telephonic records but different city; conservative to include)
509538	19991220	No	LEAK	0	10 INCH NATURAL GAS TRANSMISSION PIPELINE / A THIRD PARTY STRUCK THE LINE CAUSING A RELEASE / THERE WAS NO FIRE OR EXPLOSION
515184	19991222	No	LEAK		BELOW GROUND 42IN DOT REGULATED PIPELINE/PIPELINE WAS DUG UP TO REPAIR ND IT WAS DISCOVERED THAT PIPELINE NEEDS TO BE BLOWN DOWN PRIOR TO REP
515660	19991231	Yes	LEAK		N/A, offshore
515947	20000101	No	LEAK	0	UNKNOWN UNDERGROUND PIPELINE BREAK
516665	20000111	No	OTHER		THE MATERIAL RELEASED OUT OF A 20 INCH NATURAL GAS PIPELINE DUE TO THIRY DAMAGE. THERE WAS NO FIRE OR EXPLOSION
517700	20000124	No	OTHER		PRESSURE STATION CAME OFF LINE WHICH CAUSED A VALVE TO RELEASE NATURAL E TO HIGH PRESSURE
517943	20000127	No	RUPTURE	2	20 INCH GAS LINE RUPTURED
518022	20000127	No	RUPTURE	770000	20 INCH NATURAL GAS PIPELINE / LINE BLEW OUT CAUSING RELEASE
518173	20000129	No	RUPTURE	50	NATURAL GAS PIPELINE RUPTURE OCCURRED
518468	20000201	No	RUPTURE	5	CALLER STATED THAT THERE HAS BEEN A RELEASE A 24 INCH TRANSMISSION LINEO UNKNOWN CAUSES (Note: telephonic record for 2/2/2000)
518475	20000202	No	RUPTURE	40	30 INCH TRANSMISSION PIPELINE / LINE RUPTURED FOR UNKNOWN REASONS
518851	20000205	No	LEAK		TRANSMISSION PIPELINE RUPTURE
519574	20000211	No	LEAK		THE CALLER STATES THAT TEXAS KEYSTONE COMPANY HIT A 12 INCH NATURAL GAS LINE WHICH WAS OWNED BY CNG TRANSMISSION WITH A BULLDOZER, RUPTURING
520444	20000218	No	LEAK	5	THE MATERIAL SPILLED DUE TO A CRACK ON A WELD IN A 24 INCH PIPELINE.
520406	20000218	No	OTHER		16 INCH HIGH PRESSURE STEEL PIPELINE / PIPELINE DAMAGED BY 3RD PARTY

ATTACHMENT 3 SHT 17d / 45
CALC. NO. 32-2400572-02

NRC No.	Incident Date	Offshore?	Incident Type	Rupture Length	Description of Incident
520905	20000223	No	LEAK		A 24 INCH PIPELINE DEVELOPED A LEAK DUE TO UNKNOWN CAUSES AT THIS TIME
520825	20000223	No	RUPTURE	12	NATURAL GAS PIPELINE RUPTURED DUE TO UNKNOWN CAUSES. (Note: In the telephonic records, NRC no. 520806 is also indicated to have occurred in the same state (MI) as NRC no. 520825 and on the same date [i.e., per the telephonic record, no. 520806 is: 12 INCH PIPELINE "TRANSMISSION LINE" / RUPTURE IN LINE DUE TO UNKNOWN CAUSES]. However, in the incident report, there is only one listing for the state of MI on this date. Thus, it appears that no. 520806 is not associated with a natural gas pipeline. Therefore, this is considered one incident.)
NONE	20000225	No	OTHER		No telephonic record
521265	20000227	No	RUPTURE	300	24" TRANSMISSION LINE HAD A RUPTURE
522377	20000308	No	OTHER		A CONTRACTOR HIT A 16 INCH STEEL HIGH PRESSURE LINE, RUPTURING THE LINE AND RELEASED THE MATERIAL
523063	20000316	No	LEAK	0	BELOW GROUND 18 INCH TRANSMISSION LINE RELEASED NATURAL GAS FOR UNKNOWN REASONS
523107	20000316	No	LEAK		UNKNOW PIPELINE/ CAUSE UNKNOWN
523820	20000322	No	LEAK		10 INCH NATURAL GAS TRANSMISSION LINE / POSSIBLE CORROSION
523850	20000322	No	RUPTURE	200	PIPELINE RUPTURE DUE TO UNKNOWN CAUSES
524202	20000327	No	RUPTURE	102	26 INCH STEEL TRANSMISSION PIPELINE / CAUSE UNKNOWN
524643	20000330	No	LEAK		VALVE ON PIPELINE AT PRESSURE LIMITING STATION WAS STRUCK BY A TRUCK CAUSING THE RELEASE.
525947	20000424	Yes	LEAK		N/A, offshore
527237	20000426	Yes	LEAK		N/A, offshore
527789	20000502	No	OTHER		DURING WELDING GAS THAT WAS PRESENT IN THE AREA IGNITED
528256	20000507	No	OTHER		CALLER SAYS THERE WAS A FIRE NEAR A NATURAL GAS PIPELINE
NONE	20000513	No	OTHER		No telephonic record
529301	20000518	No	OTHER		20 INCH KA PIPELINE STRUCK BY MINING COMPANY
NONE	20000603	No	LEAK		No telephonic record
532311	20000614	No	OTHER		THIRD PARTY DAMAGE ON 16 INCH GASLINE CAUSED RELEASE OF MATERIAL/TRACTOR RIPPED HOLE IN LINE
532481	20000617	Yes	LEAK		N/A, offshore
532694	20000619	Yes	LEAK		N/A, offshore
533053	20000622	No	RUPTURE	25	No telephonic record
533867	20000628	No	RUPTURE	6	6 INCH PIPELINE "TRANSMISSION" / UNKNOWN CAUSES
533922	20000629	Yes	LEAK		N/A, offshore
534181	20000702	No	LEAK		30 INCH NATURAL GAS PIPELINE / CAUSE:UNKNOWN
534468	20000702	No	RUPTURE	9	MATERIAL WAS RELEASED FROM A SIX INCH NATURAL GAS PIPELINE DUE TO UNKNOWN CAUSE.
534097	20000703	No	RUPTURE	36	NATURAL GAS LINE HAS BROKEN VALVE AND IS RELEASING MATERIAL (telephonic record dated 7/1/00)
534444	20000705	No	RUPTURE	22	TUG BOW STRUCK GAS LINE CAUSING A RELEASE
	20000705	Yes	LEAK		N/A, offshore
534705	20000707	No	LEAK		A FIRE AT A METER STATION CAUSED A RELEASE OF NATURAL GAS
534686	20000707	Yes	LEAK		N/A, offshore
NONE	20000715	No	OTHER		No telephonic record
535726	20000718	No	OTHER		LINE BLOCKAGE TO MAIN DISTRIBUTION LINE. CALLER BELIEVES A VALVE WAS LEFT SHUT
536155	20000721	No	OTHER		THE MATERIAL RELEASED OUT OF A 16IN NATURAL GAS PIPELINE DUE TO A THIRD PARTY PIECE OF CONSTRUCTION EQUIPMENT STRIKING THE LINE.
536096	20000721	Yes	LEAK		N/A, offshore
537404	20000802	No	RUPTURE	3	THE MATERIAL WAS RELEASING FROM A 16 INCH STEEL PIPELINE DUE TO THE PIPELINE RUPTURING.
NONE	20000804	No	LEAK		No telephonic record
538593	20000814	No	LEAK		PIPELINE LEAK
538917	20000816	Yes	LEAK		N/A, offshore
538990	20000816	No	LEAK		THE CALLER STATED THAT A PIPE CAME OUT OF A COUPLING DUE TO THE LINE BEING PRESSURED UP
539215	20000819	Yes	LEAK		N/A, offshore
539219	20000819	No	RUPTURE	59	30 INCH NATURAL GAS PIPELINE HAS A RUPTURE IN IT DUE TO UNKNOWN CAUSE
539897	20000825	No	LEAK		12 INCH "TRANSMISSION LINE" LINE IS LEAKING NATURAL GAS FOR UNKNOWN REASONS.
540289	20000828	No	LEAK		BELOW GROUND 30 IN MAIN GAS LINE RELEASED MATERIAL. FARMER SPOTTED DARK SPOT ON HIS LAND. SRP INVESTIGATED AND DISCOVERED LEAK.

ATTACHMENT 3 SHT 17e, 45
CALC. NO. 32-2400572-02

NRC No.	Incident Date	Offshore?	Incident Type	Rupture Length	Description of Incident
540327	20000829	No	LEAK		THE CALLER STATED THAT A NATURAL GAS PIPELINE WAS RELEASING MATERIAL DUE TO CORROSION.
541917	20000912	No	OTHER		THE MATERIAL IS RELEASING DUE TO A PLANNED BLOWDOWN IN AN 8 INCH PIPELINE. THE BLOWDOWN HAD TO OCCUR TO AVERT A RUPTURE. THIS IS AN EMERG (Note: Although the cities are not the same in the incident and telephonic reports, conservatively include)
543279	20000926	No	RUPTURE		THE MATERIAL RELEASED FROM A 12" GAS PIPELINE DUE TO UNKNOWN CAUSES.
543441	20000927	No	LEAK		THE MATERIAL RELEASED FROM A NATURAL GAS PIPELINE DUE TO UNKNOWN REASONS.
543746	20000929	No	RUPTURE	83.5	THE MATERIAL WAS RELEASED FROM A RUPTURED 30 INCH PIPELINE DUE TO UNKNOWN CAUSES.
544293	20001003	No	OTHER		2 INCH WKM GATE VALVE, "SAFETY SEAL", THE BOLTS ON THE BONNET FAILED.
545019	20001012	No	LEAK		THE MATERIAL RELEASED OUT OF A 24 INCH PIPE LINE DUE TO AN UNDETERMINED CAUSE.
546637	20001026	No	LEAK		THE CALLER STATED THAT A PIPELINE VALVE IS RELEASING GAS. THE CAUSE IS UNKNOWN.
546628	20001030	Yes	LEAK		N/A, offshore
548089	20001113	No	OTHER		THE CALLER STATED THAT A NATURAL GAS DISTRIBUTION SYSTEM HAS LOST SERVICE TO SOME CUSTOMERS. THE CAUSE FOR THE SYSTEM FAILURE IS UNKNOWN.
548441	20001116	Yes	LEAK		N/A, offshore
548619	20001118	No	LEAK		FIRE IN TOWN BOARDER STATION IN THE HEATER. NATURAL GAS DISTRIBUTION CENTER
548759	20001120	No	OTHER		THE MATERIAL RELEASED FROM A RELIEF VALVE ON AN EMERGENCY SHUTDOWN DEVICE DUE TO UNKNOWN CAUSES.
549015	20001123	No	OTHER		THE CALLER IS REPORTING A FIRE IN A COMPRESSOR BUILDING DUE TO UNKNOWN CAUSES. THERE WAS NO EXPLOSION.
549118	20001125	No	LEAK		LEAK IN A 22 INCH NATURAL GAS LINE
549286	20001127	No	LEAK		THE CALLER STATED THAT A GAS LINE MAY HAVE A LEAK IN IT, AND THERE IS BUBBLE COMING FROM THE WATER (NOTE: Same state in incident and telephonic records; conservative to include)
NONE	20001128	No	OTHER		No telephonic record
549612	20001130	No	RUPTURE	28	THE PIPELINE WAS DAMAGE DUE TO A THIRD PARTY. (POSSIBLY AN EMPLOYEE OR CONTRACTOR OF VALLEY TELEPHONE)
549947	20001204	No	RUPTURE	26.25	A 30 INCH TRANSMISSION LINE HAS RUPTURED DUE TO A UNDETERMINED CAUSE CAUSING NATURAL GAS TO RELEASE FROM THE LINE INTO THE ATMOSPHERE.
550268	20001206	No	LEAK		THE MATERIAL IS LEAKING FROM A 30" BALL VALVE DUE TO UNKNOWN CAUSES.
550498	20001209	No	RUPTURE	76	A NATURAL GAS PIPELINE RUPTURED. THE CAUSE IS UNKNOWN.
551181	20001216	No	RUPTURE		EXPLOSION DUE UNKNOWN CAUSES AT AN UNDERGROUND STORAGE FACILITY
551911	20001226	No	NO DATA		CALLER STATED SRP DUG INTO A 32 INCH GAS TRANSMISSION LINE, THE SRP WAS GRADING FOR A STREET
552219	20001229	No	RUPTURE	40	26 INCH NATURAL GAS PIPILINE RUPTURED DUE TO UNKNOWN CAUSE
552464	20010103	No	LEAK		A TRACKHOE HIT A 16 INCH NATURAL GAS PIPELINE BY ACCIDENT WHILE EXCAVATING FOR ANOTHER LINE
552627	20010104	No	RUPTURE	120	THE CALLER REPORTS A RUPTURE OF A 22 INCH NATURAL GAS PIPELINE.
552669	20010104	No	LEAK		THE MATERIAL WAS RELEASED FROM A RUPTURED 18 INCH GAS LINE DUE TO UNKNOWN CAUSES. THE CAUSE FOR THE RELEASE IS UNDER INVESTIGATION
553588	20010115	No	OTHER		THE CALLER STATED THAT A FRONT END LOADER WENT OFF THE ROAD AND HIT A 20 INCH HIGHT PRESSURE GAS LINE. PART OF AN ABOVE GROUND SPAN. GAS RELE
553737	20010116	No	LEAK		THE CALLER REPORTS A LEAKING NATURAL GAS PIPELINE POSSIBLY DUE TO SUSPECTED CORROSION.
553780	20010116	No	OTHER		RELEASE DUE TO AN UNKNOWN CAUSE
554695	20010125	No	LEAK		16 INCH PIPELINE "FLOWLINE" LINE DEVELOPED A PINHOLE leak DUE TO UNKNOWN CAUSES
555048	20010129	No	LEAK		THE CALLER STATED THAT A 12 INCH NATURAL GAS TRANSMISSION PIPELINE RUPTURED, THE CAUSE IS UNKNOWN.
	20010203	Yes	LEAK		N/A, offshore
555725	20010204	No	RUPTURE	1	A THIRD PARTY CONTRACTOR STRUCK A UNDERGROUND 8 INCH NATURAL GAS TRANSMISSION LINE WITH A BACK HOE CAUSING NATURAL GAS TO RELEASE FROM THE LI
NONE	20010208	No	LEAK		No telephonic record
558117	20010228	Yes	OTHER		N/A, offshore
558599	20010305	No	LEAK		THE MATERIAL WAS RELEASED FROM A PIPLINE DUE TO A GASKET FAILURE. (Note: Same state but different cities in the incident and telephonic reports; conservatively include)
559149	20010310	Yes	LEAK		N/A, offshore
NONE	20010313	No	LEAK		No telephonic record (Note: none of the cities and/or counties match between the incident and telephonic reports)

ATTACHMENT 3 SHT 17F, 45
CALC. NO. 32-2400572-02

NRC No.	Incident Date	Offshore?	Incident Type	Rupture Length	Description of Incident
559926	20010317	No	OTHER		BLOW DOWN VALVE AT A COMPRESSOR STATION DID NOT SHUT DUE TO EQUIPMENT PROBLEMS / COMPRESSOR STATION IS PART OF A PIPELINE (Note: telephonic record for 3/18/2001)
559987	20010319	No	OTHER		No telephonic record (Note: No matching NRC no. in the telephonic record for given date)
560330	20010322	No	OTHER		NATURAL GAS WAS RELEASED FROM A TRANSMISSION PIPELINE, DUE TO A SCHEDULED BLOW-DOWN. THE GAS CAUGHT FIRE.
561006	20010328	No	RUPTURE	0.66	THE MATERIAL RELEASED OUT OF A 6 INCH STEEL TRANSMISSION PIPELINE DUE TO AN EXCAVATOR DAMAGING THE PIPELINE.
NONE	20010329	No	RUPTURE		No telephonic record (Note: none of the Texas cities and/or counties match between the incident and telephonic reports)
NONE	20010329	No	LEAK		No telephonic record (Note: none of the Texas cities and/or counties match between the incident and telephonic reports)
561310	20010330	No	LEAK		A PIPELINE LEAK WAS DETECTED BY A MOTORIST
561808	20010404	No	OTHER		THE CALLER IS REPORTING THAT THE SUSPECTED RESPONSIBLE PARTY TOOK THE COVER OFF A 10 INCH PIPELINE AND PUNCTURED THE LINE WITH A DOZER BLADE
561798	20010404	No	OTHER		A CONTRACTOR HIT THE RESPONSIBLE PARTY'S EIGHT INCH PIPELINE WITH A BULL DOZER CAUSING A RELEASE OF GAS.
561742	20010404	No	OTHER		A RELIEF VALVE ON TRANSMISSION LINE RELEASED GAS DUE TO OVER PRESSURIZATION.
561893	20010405	No	LEAK		THE MATERIAL WAS RELEASED FROM A PIPELINE DUE TO A LEAK IN THE LINE FROM UNKNOWN CAUSES.
561915	20010405	No	OTHER		No telephonic record (Note: No matching NRC no. in the telephonic records for given date.)
562056	20010406	Yes	LEAK		N/A, offshore
562463	20010407	No	OTHER		No telephonic record (Note: No matching NRC no. in the telephonic records for given date.)
563110	20010416	No	LEAK		THE MATERIAL IS LEAKING FROM A CRACKED 36 INCH UNDERGROUND TRANSMISSION PIPE.
564100	20010425	No	OTHER		A 12 INCH TRANSMISSION LINE WAS STRUCK BY A PIECE OF CONSTRUCTION EQUIPMENT CAUSING NATURAL GAS TO RELEASE FROM THE LINE INTO THE ATMOSPHERE.
564274	20010427	No	LEAK		THE MATERIAL RELEASED OUT OF THE TWENTY FOUR INCH UNDERGROUND NATURAL GAS PIPE DUE TO AN UNDETERMINED CAUSE AT THIS TIME.
565631	20010504	No	RUPTURE	18	THE MATERIAL RELEASED OUT OF A 20 INCH PIPELINE DUE TO A VALVE FAILURE. (Note: Description is associated with NRC no. 565031. It appears that the NRC no. of 565631 listed in the incident report, may be a typo.)
565794	20010511	No	LEAK		TRACTOR WITH DITCHING DEVICE STRUCK 12 INCH PIPELINE
565922	20010513	Yes	LEAK		N/A, offshore
567330	20010521	No	LEAK		LEAK ON AN INTERSTATE GAS PIPELINE DUE TO PIPE DAMAGE.
567182	20010524	Yes	LEAK		N/A, offshore
567198	20010524	No	RUPTURE		THE CALLER STATED THAT COUNTY ROAD GRADER HIT A NATURAL GAS PIPELINE AND CAUSED A LEAK.
569368	20010613	No	RUPTURE		No telephonic record
569577	20010614	No	LEAK		No telephonic record
NONE	20010616	No	OTHER		No telephonic record
570128	20010619	No	LEAK		No telephonic record
570250	20010620	No	LEAK		No telephonic record
NONE	20010630	No	LEAK		No telephonic record
572288	20010708	No	OTHER		No telephonic record
574018	20010723	No	LEAK		No telephonic record
NONE	20010724	No	OTHER		No telephonic record
NONE	20010725	No	LEAK		No telephonic record
NONE	20010725	No	OTHER		No telephonic record
NONE	20010729	No	LEAK		No telephonic record
575297	20010803	No	LEAK		No telephonic record
575940	20010809	No	LEAK		No telephonic record
576119	20010811	No	RUPTURE	19	No telephonic record
576520	20010814	No	LEAK		No telephonic record
576787	20010814	No	LEAK		No telephonic record
573077	20010815	No	OTHER		No telephonic record
NONE	20010820	No	LEAK		No telephonic record

ATTACHMENT 3 SHT 17a / 45
CALC. NO. 32-2400572-02

NRC No.	Incident Date	Offshore?	Incident Type	Rupture Length	Description of Incident
577245	20010821	No	RUPTURE		No telephonic record
577758	20010826	Yes	LEAK		N/A, offshore
577808	20010826	Yes	LEAK		N/A, offshore
NONE	20010831	No	LEAK		No telephonic record
578944	20010903	No	RUPTURE	10	No telephonic record
579144	20010907	No	RUPTURE	1	No telephonic record
580005	20010917	No	LEAK		No telephonic record
NONE	20010920	Yes	LEAK		N/A, offshore
580493	20010921	No	LEAK		No telephonic record
580834	20010925	No	RUPTURE	9	No telephonic record
582452	20011009	No	LEAK		No telephonic record
NONE	20011012	No	RUPTURE	4	No telephonic record
583347	20011016	No	LEAK		No telephonic record
583615	20011018	Yes	LEAK		N/A, offshore
584230	20011023	No	OTHER		No telephonic record
NONE	20011024	Yes	LEAK		N/A, offshore
NONE	20011105	No	OTHER		No telephonic record
585264	20011106	No	OTHER		No telephonic record
585408	20011107	No	OTHER		No telephonic record
585912	20011113	No	LEAK		No telephonic record
586663	20011121	Yes	LEAK		N/A, offshore
587965	20011206	No	LEAK		No telephonic record
587925	20011206	No	LEAK		No telephonic record
588102	20011207	No	LEAK		No telephonic record
588053	20011207	No	RUPTURE	10	No telephonic record
585285	20011210	No	OTHER		No telephonic record
588431	20011212	No	LEAK		No telephonic record
588473	20011212	No	RUPTURE		No telephonic record
588825	20011216	No	RUPTURE	610	No telephonic record
					Notes: 1) For some incidents (e.g., 1998 through 5/20/1999 and various others), no NRC number is given in the incident data report. Therefore, a comparison of the city, county and/or state information between the incident data report and telephonic incident notification records was made to determine the NRC number.
					2) Above information was compiled from the Office of Pipeline Safety website: http://ops.dot.gov - from the Online Library - Accident & Incident Data, Natural Gas Transmission Incident Data - mid 1984 to 2001 and from the Online Library - Telephonic Incident Notification, 1995-1998 & 1999-2001 Telephonic Incident Notifications.
					3) Rupture length units are assumed to be in feet (i.e., units are not indicated in the transmission incident data report).

ATTACHMENT 3 SHT 17b / 45
CALC. NO. 32-2400572-02

Attachment 4: Calculation of Distances D_1 and D_2

1.0 PURPOSE AND OBJECTIVE

Calculate the exposure distance, D, which has two parts, the distance to the gas upper and lower explosion limits (UEL and LEL), D_1, and the safe separation distance, D_2.

2.0 METHOD OF ANALYSIS

Employ the computer program ALOHA (Reference 6) to calculate the concentrations of natural gas from a postulated gas release along a direct pathway to the NEF. Use the model results to determine the distance to the upper and lower explosion limits (UEL and LEL), which is D_1. Then estimate the safe separation distance, D_2 from an explosion following Regulatory Guide 1.91 (Reference 3).

ALOHA was developed jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic Atmospheric Administration (NOAA). The program predicts the rates at which chemical vapors may escape into the atmosphere from broken gas pipes, leaking tanks, and evaporating puddles. It also predicts how the gas cloud disperses in the atmosphere after an accidental release.

3.0 INPUT AND ASSUMPTIONS

The following assumptions were made relating to the dispersion and transport of the pipeline gas:

- The gas released is methane, which is the major constituent of wet sour gas (Attachment 5).
- The postulated gas release is a guillotine pipeline break such that the break hole size equals the pipe diameter.
- The pipe is connected to an infinite source because there are no automatic shut-off valves in the pipeline (Attachment 5).
- The gas release is 1 hour; the maximum expected time before emergency crews arrive to shut off the source at a manual shut-off valve (Attachment 5).
- The pipe length is 200 times the pipe diameter, which is the minimum allowed by ALOHA and considered to be very conservative.
- A delayed explosion from a drifting plume 1 hour after release is more severe than an in-place explosion because the gas plume is closer to the plant.
- The atmosphere is stable, with minimal dispersion and effects due to elevation change.

- The distance from the gas release location to the plant is the "straight-line" distance, which is the shortest distance between the source and the plant measured on a plain surface that excludes intervening ground elevation changes and building surfaces.
- The TNT equivalent weight of an exploding material is represented by the SFPE Handbook method (Reference 8).

4.0 ANALYSIS

The safety of structures from an explosion is evaluated by determining the safe separation distance between the explosion and the structure. If there is sufficient separation such that structural damage is minimized, then the structure is assumed safe.

The method used to establish the safe separation distance is from Regulatory Guide 1.91 (Reference 3), which is based on a level of peak positive incident overpressure, conservatively chosen at 1 pound per square inch (psi), and TNT equivalent energy in the form

$$R = 45 W^{1/3}$$

where,

R = the safe separation distance in feet (ft), and

W = the TNT equivalent weight of the exploding material in pounds (lbs).

To calculate the safe separation distance, therefore, requires the TNT equivalent of the mass of methane volume released. For a continuous release such as postulated, this is the mass of methane between its lower explosion limit (LEL) and upper explosion limits (UEL) of 5 – 15 % by volume (Reference 8). Note that 5% by volume is equivalent to 50,000 parts per million (ppm) and 15 % by volume is equivalent to 150,000 ppm. Theses values are used as input to ALOHA (see Tables A2 and A1, respectively).

4.1 Methane Explosion Release Mass

The mass of methane released in its explosion range is calculated by using the "Sustained Release Rate" determined by ALOHA and the distance/time relationship to reach the UEL and LEL such that

$$M = S\,(T_{LEL} - T_{UEL})$$

where,

M = mass of methane in pounds (lbs)
S = sustained release rate in pounds per minute (lbs/min)
T_{UEL} = time to reach the UEL in minutes (min)
T_{LEL} = time to reach the LEL in minutes (min)

From ALOHA output Tables A1 and A2, the Sustained Release Rate of methane at 50 psi (i.e., the maximum gas pipeline pressure) is 5,820 lbs/min. The respective distances to the UEL and LEL (referred to as the "LOC" on the printout) are 727 yards (2181 ft), and 1365 yards (4095 ft). At the ALOHA input wind speed of 1 meter/second (m/s), or 3.28 feet per second (ft/s), the time to UEL and LEL is

T_{UEL} = 2181 ft / 3.28 ft/s / 60 s/min = 11.08 min, and

T_{LEL} = 4095 ft / 3.28 ft/s / 60 s/min = 20.81 min

Therefore,

M = 5,820 lbs./min x (20.81 min – 11.08 min) = 56,629 lbs.

4.2 Methane Mass to Equivalent TNT

From the SFPE Handbook, Section 3, Chapter 16, Equations 12 and 13 (Reference 8), the TNT equivalent weight can be expressed as

$$W_{TNT} = \frac{\alpha(\Delta H_C)(M_f)}{4500}$$

where,

W_{TNT} = TNT equivalent mass in kilograms (kg).
α = yield, which is the fraction of available combustion energy.
ΔH_c = theoretical net heat of combustion in kilo-Joules per kilogram (kJ/kg).
M_f = mass of flammable vapor released in kg.

From Reference 4 (Attachment 6), Table A-2, ΔH_c is conservatively chosen to be the gross heat of combustion, which is 55.50 MJ/kg, or 55,500 kJ/kg; M_f = 56,629 lbs/ 2.2 lbs/kg = 25,740 kg; and from Reference 8 (Attachment 8), the blast yield, α, is assumed to be 5%. Substituting,

$$W_{TNT} = \frac{0.05\left(55{,}500\,\frac{KJ}{kg}\right)(25{,}740\,kg)}{4500} = 15{,}873\ kg = 34{,}921\ \text{lbs}$$

4.3 Safe Separation Distance

From above, the safe separation distance, R, is

$R = 45\,(34{,}921)^{1/3} = 1{,}471$ ft

This means that plant critical structures must be at least 1,471 ft from the point of explosion.

5.0 CONCLUSION

The value of D_1 is 4,095 ft (1,365 yards), which is shown in ALOHA output Table A1 and is the distance from the gas release point to the LEL. The value of D_2 is 1,471 ft, which is the safe separation distance.

6.0 COMPUTER PROGRAM BENCHMARK

Attachment 10 demonstrates that ALOHA, version 5.2.3, is correctly predicting results on the installed computer, an IBM-compatible PC (ID#3W2BZ1) using Microsoft Windows XP® Professional, Version 2002, operating system with a Pentium(R) 4 processor.

Table A1
ALOHA Output, Methane UEL

Text Summary ALOHA® 5.2.3

```
SITE DATA INFORMATION:
  Location: EUNICE, NEW MEXICO
  Building Air Exchanges Per Hour: 0.50 (enclosed office)
  Time: October 10, 2003  1042 hours MDT (using computer's clock)

CHEMICAL INFORMATION:
  Chemical Name: METHANE        Molecular Weight: 16.04 kg/kmol
  TLV-TWA: -unavail-            IDLH: -unavail-
  Footprint Level of Concern: 150000 ppm
  Boiling Point: -258.68° F
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC INFORMATION: (MANUAL INPUT OF DATA)
  Wind: 1 meters/sec from s at 10 meters
  No Inversion Height
  Stability Class: F (user override)
  Air Temperature: 70° F
  Relative Humidity: 5%         Ground Roughness: open country
  Cloud Cover: 0 tenths

SOURCE STRENGTH INFORMATION:
  Pipe Diameter: 16 inches      Pipe Length: 267 feet
  Pipe Temperature: 70° F       Pipe Press: 50 lbs/sq in
  Pipe Roughness: smooth        Hole Area: 201 sq in
  Unbroken end of the pipe is connected to an infinite source
  Release Duration: ALOHA limited the duration to 1 hour
  Max Computed Release Rate: 7,640 pounds/min
  Max Average Sustained Release Rate: 5,820 pounds/min
     (averaged over a minute or more)
  Total Amount Released: 348,998 pounds

FOOTPRINT INFORMATION:
  Dispersion Module: Gaussian
  User-specified LOC: 150000 ppm
  Max Threat Zone for LOC:  727 yards
```

Table A2
ALOHA Output, Methane LEL

```
Text Summary                                              ALOHA® 5.2.3

SITE DATA INFORMATION:
  Location: EUNICE, NEW MEXICO
  Building Air Exchanges Per Hour: 0.50 (enclosed office)
  Time: October 10, 2003  1042 hours MDT (using computer's clock)

CHEMICAL INFORMATION:
  Chemical Name: METHANE        Molecular Weight: 16.04 kg/kmol
  TLV-TWA: -unavail-            IDLH: -unavail-
  Footprint Level of Concern: 50000 ppm
  Boiling Point: -258.68° F
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC INFORMATION: (MANUAL INPUT OF DATA)
  Wind: 1 meters/sec from s at 10 meters
  No Inversion Height
  Stability Class: F (user override)
  Air Temperature: 70° F
  Relative Humidity: 5%         Ground Roughness: open country
  Cloud Cover: 0 tenths

SOURCE STRENGTH INFORMATION:
  Pipe Diameter: 16 inches      Pipe Length: 267 feet
  Pipe Temperature: 70° F       Pipe Press: 50 lbs/sq in
  Pipe Roughness: smooth        Hole Area: 201 sq in
  Unbroken end of the pipe is connected to an infinite source
  Release Duration: ALOHA limited the duration to 1 hour
  Max Computed Release Rate: 7,640 pounds/min
  Max Average Sustained Release Rate: 5,820 pounds/min
     (averaged over a minute or more)
  Total Amount Released: 348,998 pounds

FOOTPRINT INFORMATION:
  Dispersion Module: Gaussian
  User-specified LOC: 50000 ppm
  Max Threat Zone for LOC:  1365 yards
```

Attachment 5: Gas Line Telephone Chronology

TELEPHONE CHRONOLOGY
REGULATORY COMPLIANCE PROGRAMS- MARLBOROUGH

Call With	See Below	Date	See Below
Phone #	See Below	Time	See Below
By	J.H. Snooks	PID	
Subject	LES-NM: Gas Lines		

DISCUSSION:

6/30/2003 Reviewed gas line maps and was able to identify the closest gas line as the 16" Fullerton Loop Line, which nearly parallel to NM Rte 234-Tx Rte 176. Called "One Call" (800-321-2537) to get info on gas line owner. Dispatcher named three companies: Trinity CO2, Texaco, and Sid Richardson Energy Services. Requested number for SR since gas maps were labeled as SR. Called SR (505-395-2116), but no one available.

7/1/2003 Called SR again, spoke w/ Royce, who gave me general info. The gas line is low pressure (< 50 psi) and carries "wet sour gas," which is unprocessed, field gas from the well being sent for processing. The gas line is buried to about 36", but could vary more or less in sandy soil due to the wind. Royce said he would have someone get back to me on characteristics of gas, e.g., percent methane, etc.

7/10/2003 Returned Royce Dunn's call. RD had additional info on gas line specs and gas characteristics as follows: methane = 72%, ethane = 11%, propane = 7%, H_2S = 695ppm (<1%). The gas line flow is between 200-500 thousand cubic feet per day. It is 14-15 miles in length, with manual block valves at each end and in the middle. There also has a check valve at the connection with the main service line located near Eunice and Hwy 176. The likelihood of internal rupture is small because of the low pressure (<50psi).

8/8/2003 Called "One Call" (800-321-2537) to place a pipeline location request for Sections 32 and 33. Used town ID# 838. One Call said there were three operators in area: Sid Richardson, Trinity, and Texaco. Companies will call in 2-5 business days with info. One Call confirmation number is 2003323641.

8/8/2003 Goose Armstrong from Sid Richardson responded to the One call inquiry to say they had two pipelines in Sections 32 and 33, both running parallel to the southern boarder along Rte 234/176. One is 14-inch line that is "idle," i.e., in active. The other is a 16-inch line carrying natural gas. [See 7/1 and 7/10 above for more details.]

8/8/2003 Brent Washington from Conoco-Phillips (505-390-3425) returned my many calls to various Conoco offices to get info on potential pipelines near Eunice. Brent said there were no known lines, but that he would conduct a site walk down on 8/11 to confirm.

8/11/2003 Brent Washington from Conoco-Phillips (505-390-3425) called to say he walked the site and did not locate any Conoco-Phillips pipelines.

8/13/2003 Lon Briley from Trinity Gas (442-661-0162) responded to the One Call inquiry and said Trinity had one carbon dioxide line crossing Section 32. The line carries liquid CO2 at 2100 psi; the flow is about 15 MMcf per day. Briley said that there manual shut offs about 2 miles north and south of the site and that it would take 45 min to 1 hr to close the values. There also is an electronic shut down system, but it would still take about 45 min to 1 hr to shut off supply and "bleed the system." Alternate contact is Barry Petty (who Ed Maher has spoken to.) His tele no is 432-683-8262.

9/4/2003 Called Royce Dunn at Sid Richardson (505-395-2116) to ask if SR had a DOT risk report in case of a leak like Trinity CO2 gas. RD didn't know of any; he said there wouldn't be a fire or "blowout" explosion, like might occur in the CO2 line because SR gas line is low pressure. RD gave the web site of the state agency responsible for oil sites: www.emnrd.state.nm.us/ocd/.

Attachment 6: Fire Protection Handbook

Fire Protection Handbook™

Seventeenth Edition

Arthur E. Cote, P.E.
Editor-in-Chief

Jim L. Linville
Managing Editor

NFPA National Fire Protection Association
Quincy, Massachusetts

TABLE A-1. ***Heats of Combustion and Related Properties For Pure, Simple Substances* (continued)***

Material	Composition	W Molecular Weight	Δh_c^v Gross (MJ/kg)	Δh_c^l Net (MJ/kg)	$\Delta h_c^l/r_o$ (MJ/kg O_2)	r_o Oxygen-fuel Mass ratio	T_b Boiling temp. (°C)	Δh_v Latent Heat of Vaporization (kJ/kg)	C_{pl} Liquid Heat Capacity (kJ/kg-°C)	C_{pv} Vapor Heat Capacity (kJ/kg-°C)
cyclopropane	C_3H_6	42.08	49.70	46.57	13.61	3.422	−32.9	—	1.92	1.33
(decahydronaphthalene) → *cis*-decalin										
cis-decalin	$C_{10}H_{18}$	138.24	45.49	42.63	12.70	3.356	195.8	309	1.67	1.21
n-decane	$C_{10}H_{22}$	142.28	47.64	44.24	12.69	3.486	174.1	276	2.19	1.65
diacetylene	C_4H_2	50.06	46.60	45.72	15.89	2.877	10.3	—	—	1.47
(diamine) → hydrazine										
diborane	H_6B_2	27.69	79.80	79.80	23.02	3.467	−92.5	—	—	1.75
dichloromethane	CH_2Cl_2	84.94	6.54	6.02	10.65	0.565	39.7	330	1.18	0.60
diethyl cyclohexane	$C_{10}H_{20}$	140.26	46.30	43.17	12.56	3.422	174.		1.87	
diethyl ether	$C_4H_{10}O$	74.12	36.75	33.79	13.04	2.590	34.6	360	2.34	1.52
(2,4 diisocyanotoluene) → toluene diisocyanate										
(diisopropyl ether) → *iso*-propyl ether										
dimethylamine	C_2H_7N	45.08	38.66	35.25	13.24	2.662	6.9	—	—	1.60
(dimethyl aniline) → xylidene										
dimethyldecalin	$C_{12}H_{22}$	166.30	45.70	42.79	13.15	3.254	220.	260		
(dimethyl ether) → methyl ether										
1,1-dimethylhydrazine (UDMH)	$C_2H_8N_2$	60.10	32.95	30.03	14.10	2.130	25.	578	2.73	
dimethyl sulfoxide	C_2H_6SO	78.13	29.88	28.19	15.30	1.843	189.	677	1.89	1.14
1,3 dioxane	$C_4H_8O_2$	88.10	26.57	24.58	9.68	2.543	105.	404		
1,4 dioxane	$C_4H_8O_2$	88.10	26.83	24.84	9.77	2.543	101.1	406	1.74	1.07
ethane	C_2H_6	30.07	51.87	47.49	12.75	3.725	−88.6	—	—	1.75
ethanol	C_2H_6O	46.07	29.67	26.81	12.87	2.084	78.5	837	2.43	1.42
(ethene) → ethylene										
ethyl acetate	$C_4H_8O_2$	88.10	25.41	23.41	12.89	1.816	77.2	367	1.94	1.29
ethyl acrylate	$C_5H_8O_2$	100.12	27.44	25.69	13.39	1.918	100.	290		1.14
ethylamine	C_2H_7N	45.08	38.63	35.22	13.23	2.662	16.5	—	2.89	1.61
ethyl benzene	C_8H_{10}	106.16	43.00	40.93	12.93	3.165	136.1	339	1.75	1.21
ethylene	C_2H_4	28.05	50.30	47.17	13.78	3.422	−103.9	—	2.38	1.56
ethylene glycol	$C_2H_6O_2$	62.07	19.17	17.05	13.22	1.289	197.5	800	2.43	1.56
ethylene oxide	C_2H_4O	44.05	29.65	27.65	15.23	1.816	10.7	—	1.97	1.10
(ethylene trichloride) → trichloroethylene										
(ethyl ether) → diethyl ether										
formaldehyde	CH_2O	30.03	18.76	17.30	16.23	1.066	−19.3	—	—	1.18
formic acid	CH_2O_2	46.03	5.53	4.58	13.15	0.348	100.5	476	2.15	0.98
furan	C_4H_4O	68.07	30.61	29.32	13.86	2.115	31.4	398	1.69	0.96
α-D-glucose†	$C_6H_{12}O_6$	180.16	15.65	14.08	13.21	1.066	—	—	—	—
(glycerine) → glycerol										
glycerol	$C_3H_8O_3$	92.10	17.95	16.04	13.19	1.216	290.0	800	2.42	1.25
(glycerol trinitrate) → nitroglycerin										
n-heptane	C_7H_{16}	100.20	48.07	44.56	12.68	3.513	98.4	316	2.20	1.66
n-heptene	C_7H_{14}	98.18	47.44	44.31	12.95	3.422	93.6	317	2.17	1.58
hexadecane	$C_{16}H_{34}$	226.43	47.25	43.95	12.70	3.462	286.7	226	2.22	1.64
hexamethyldisiloxane	$C_6H_{18}Si_2O$	162.38	38.30	35.80	15.16	2.364	100.1	192	2.01	—
(hexamethylenetetramine) → methenamine										
n-hexane	C_6H_{14}	86.17	48.31	44.74	12.68	3.528	68.7	335	2.24	1.66
n-hexene	C_6H_{12}	84.16	47.57	44.44	12.99	3.422	63.5	333	2.18	1.57
hydrazine	H_4N_2	32.05	52.08	49.34	49.40	0.998	113.5	1180	3.08	1.65
hydrazoic acid	HN_3	43.02	15.28	14.77	79.40	0.186	35.7	690	—	1.02
hydrogen	H_2	2.00	141.79	130.80	16.35	8.000	−252.7	—	—	14.42
(hydrogen azide) → hydrazoic acid										
hydrogen cyanide	HCN	27.03	13.86	13.05	8.82	1.480	25.7	933	2.61	1.33
hydrogen sulfide	H_2S	34.08	48.54	47.25	16.77	2.817	−60.3	548	—	1.00
maleic anhydride†	$C_4H_2O_3$	74.04	18.77	18.17	14.01	1.297	202.0	—	—	—
melamine†	$C_3H_6N_6$	126.13	15.58	14.54	12.73	1.142	—	—	—	—
methane	CH_4	16.04	55.50	50.03	12.51	4.000	−161.5	—	—	2.23
methanol	CH_4O	32.04	22.68	19.94	13.29	1.500	64.8	1101	2.37	1.37
methenamine†	$C_6H_{12}N_4$	140.19	29.97	28.08	13.67	2.054	—	—	—	—
2-methoxyethanol	$C_3H_8O_2$	76.09	24.23	21.92	13.03	1.682	124.4	583	2.23	—
methylamine	CH_5N	31.06	34.16	30.62	13.21	2.318	−6.3	—	—	1.61
(2-methyl 1-butanol) → *iso*-amyl alcohol										
(methyl chloride) → dichloromethane										
methyl ether	C_2H_6O	46.07	31.70	28.84	13.84	2.084	−24.9	—	—	1.43
methyl ethyl ketone	C_4H_8O	72.10	33.90	31.46	12.89	2.441	79.6	434	2.30	1.43
1-methylnaphthalene	$C_{11}H_{10}$	142.19	40.88	39.33	12.85	3.038	244.7	323	1.58	1.12

Attachment 7: Seabrook Station UFSAR

SEABROOK UPDATED FSAR

TABLE 2.2-15

PUFF RELEASE ANALYSIS PARAMETER VALUES

Probability that a release will occur (P1)*	10^{-4} spills/year
Probability Ignition will be delayed (P2)**	0.24 delayed ignitions per spill
Probability of Ignition at a critical point (P5)	1.0
Probability of unacceptable damage per critical Ignition for a deflagration (P6)	1.0
Probability of a detonation occurring per critical ignition, for a detonation (P6')***	0.28
Site Temperature	104°F
Propane Mass Release	2.35×10^5 lb.
Flashing Fraction	0.478
Propane Puff Weight (M)	1.12×10^5 lb.
Propane Vapor density at 104°F (Pga)	0.107 lb./ft^3
Detonability Limits of Propane	3.0 - 6.8% (Ref. 96)

* Reference 70 gives an upper bound for boiler failures of 10^{-5} per year and Reference 98 gives the failure rate for fixed location chlorine tanks as 10^{-5} per year, excluding seismic events. A value of 10^{-4} per year is conservatively assumed.

** Study of rail car spills (Reference 70) shows that 76 percent of the spills ignited within 100 ft of the release, hence, a value of 0.24 delayed ignitions per spill.

*** Reference 71 suggests a detonation rate giving ignition of 0.28, which is considered conservative.

Attachment 8: SFPE Handbook of Fire Protection Engineering

SFPE Handbook of Fire Protection Engineering

Second Edition

Editorial Staff

Philip J. DiNenno, P.E., Hughes Associates, Inc.
Craig L. Beyler, PhD., Hughes Associates, Inc.
Richard L. P. Custer, Custer Powell, Inc.
W. Douglas Walton, P.E., National Institute of Standards and Technology
John M. Watts, Jr., PhD., The Fire Safety Institute
Dougal Drysdale, PhD., University of Edinburgh
John R. Hall, Jr., PhD., National Fire Protection Association

NFPA National Fire Protection Association
Quincy, Massachusetts

Society of Fire Protection Engineers
Boston, Massachusetts

TABLE 2-9.1 ***Summary of Limits of Flammability, Lower Temperature Limits (T_L), and Minimum Autoignition Temperatures (AIT) of Individual Gases and Vapors in Air at Atmospheric Pressure[3] (Continued)***

Combustible	Limits of flammability (volume-percent) L_{25}	U_{25}	T_L (°C)	AIT (°C)
Ethyleneimine	3.6	46	—	320
Ethylene glycol	[4]3.5	—	—	400
Ethylene oxide	3.6	100	—	—
Furfuryl alcohol	[15]1.8	[16]16	72	390
Gasoline:				
100/130	1.3	7.1	—	440
115/145	1.2	7.1	—	470
Glycerine	—	—	—	370
n-Heptane	1.05	6.7	−4	215
n-Hexadecane	[4]0.43	—	126	205
n-Hexane	1.2	7.4	−26	225
n-Hexyl alcohol	[1]1.2	—	—	—
n-Hexyl ether	[4]0.6	—	—	185
Hydrazine	4.7	100	—	—
Hydrogen	4.0	75	—	400
Hydrogen cyanide	5.6	40	—	—
Hydrogen sulfide	4.0	44	—	—
Isoamyl acetate[1]	1.1	[1]7.0	25	360
Isoamyl alcohol[1]	1.4	[1]9.0	—	350
Isobutane	1.8	8.4	−81	460
Isobutyl alcohol	[1]1.7	[1]11	—	—
Isobutyl benzene	[1]0.82	[10]6.0	—	430
Isobutyl formate	2.0	8.9	—	—
Isobutylene	1.8	9.6	—	465
Isopentane	1.4	—	—	—
Isophorone	0.84	—	—	460
Isopropylacetate	[4]1.7	—	—	—
Isopropyl alcohol	2.2	—	—	—
Isopropyl biphenyl	[4]0.6	—	—	440
Jet fuel:				
JP-4	1.3	8	—	240
JP-6	—	—	—	230
Kerosine	—	—	—	210
Methane	5.0	15.0	−187	540
Methyl acetate	3.2	16	—	—
Methyl acetylene	1.7	—	—	—
Methyl alcohol	6.7	[11]36	—	385
Methyl amine	[4]4.2	—	—	430
Methyl bromide	10	15	—	—
3-Methyl butene-1	1.5	9.1	—	—
Methyl butyl ketone	[5]1.2	[5]8.0	—	—
Methyl cellosolve	[17]2.5	[7]20	—	380
Methyl cellosolve acetate	[8]1.7	—	46	—
Methyl ethyl ether	[4]2.2	—	—	—
Methyl chloride	[4]7	—	—	—
Methyl cyclohexane	1.1	6.7	—	250
Methyl cyclopentadiene	[1]1.3	[1]7.6	49	445
Methyl ethyl ketone	1.9	10	—	—
Methyl ethyl ketone peroxide	—	—	40	390
Methyl formate	5.0	23	—	465
Methyl cyclohexanol	[4]1.0	—	—	295
Methyl isobutyl carbinol	[4]1.3	—	40	—
Methyl isopropenyl ketone	[5]1.8	[5]9.0	—	—
Methyl lactate	[1]2.2	—	—	—
α-Methyl naphthalene	[4]0.8	—	—	530
2, Methyl pentane	[4]1.2	—	—	—
Methyl propionate	2.4	13	—	—
Methyl propyl ketone	1.6	8.2	—	—
Methyl styrene	[4]1.0	—	49	495
Methyl vinyl ether	2.6	39	—	—
Methylene chloride	—	—	—	615
Monoisopropyl bicyclohexyl	0.52	[18]4.1	124	230
2-Monoisopropyl biphenyl	[18]0.53	[18]3.2	141	435
Monomethylhydrazine	4	—	—	—
Naphthalene	[19]0.88	[20]5.9	—	526
Nicotine	[1]0.75	—	—	—
Nitroethane	3.4	—	30	—
Nitromethane	7.3	—	33	—
1-Nitropropane	2.2	—	34	—
2-Nitropropane	2.5	—	27	—
n-Nonane	[21]0.85	—	31	205
n-Octane	0.95	—	13	220
Paraldehyde	1.3	—	—	—
Pentaborane	0.42	—	—	—
n-Pentane	1.4	7.8	−48	260
Pentamethylene glycol	—	—	—	335
Phthalic anhydride	[7]1.2	[22]9.2	140	570
3-Picoline	[4]1.4	—	—	500
Pinane	[23]0.74	[23]7.2	—	—
Propadiene	2.16	—	—	—
Propane	2.1	9.5	−102	450
1,2-Propandiol	[4]2.5	—	—	410
β-Propiolactone	[3]2.9	—	—	—
Propionaldehyde	2.9	17	—	—
n-Propyl acetate	1.8	8	—	—
n-Propyl alcohol	[12]2.2	[1]14	—	440
Propyl amine	2.0	—	—	—
Propyl chloride	[4]2.4	—	—	—
n-Propyl nitrate	[17]1.8	[17]100	21	175
Propylene	2.4	11	—	460
Propylene dichloride	[4]3.1	—	—	—
Propylene glycol	[24]2.6	—	—	—
Propylene oxide	2.8	37	—	—
Pyridine	[11]1.8	[25]12	—	—
Propargyl alcohol	[5]2.4	—	—	—
Quinoline	[4]1.0	—	—	—
Styrene	[26]1.1	—	—	—
Sulfur	[27]2.0	—	247	—
p-Terphenyl	[4]0.96	—	—	535
n-Tetradecane	[4]0.5	—	—	200
Tetrahydrofurane	2.0	—	—	—
Tetralin	[1]0.84	[5]5.0	71	385
2,2,3,3-Tetramethyl pentane	0.8	—	—	430
Tetramethylene glycol	—	—	—	390
Toluene	[1]1.2	[1]7.1	—	480
Trichloroethane	—	—	—	500
Trichloroethylene	[28]12	[28]40	30	420
Triethyl amine	1.2	8.0	—	—
Triethylene glycol	[29]0.9	[29]9.2	—	—
2,2,3-Trimethyl butane	1.0	—	—	420
Trimethyl amine	2.0	12	—	—
2,2,4-Trimethyl pentane	0.95	—	—	415
Trimethylene glycol	[4]1.7	—	—	400
Trioxane	[4]3.2	—	—	—
Turpentine	[1]0.7	—	—	—
Unsymmetrical dimethylhydrazine	2.0	95	—	—
Vinyl acetate	2.6	—	—	—
Vinyl chloride	3.6	33	—	—
m-Xylene	[1]1.1	[1]6.4	—	530
o-Xylene	[1]1.1	[1]6.4	—	465
p-Xylene	[1]1.1	[1]6.6	—	530

[1] T = 100° C. [2] T = 75° C. [3] T = 75° C. [4] Calculated.
[5] T = 50° C. [6] T = 85° C. [7] T = 140° C. [8] T = 150° C.
[9] T = 110° C. [10] T = 175° C. [11] T = 60° C. [12] T = 53° C.
[13] T = 85° C. [14] T = 130° C. [15] T = 72° C. [16] T = 117° C.
[17] T = 125° C. [18] T = 200° C. [19] T = 78° C. [20] T = 122° C.
[21] T = 43° C. [22] T = 195° C. [23] T = 160° C.
[24] T = 96° C. [25] T = 70° C. [26] T = 29° C.
[27] T = 247° C. [28] T = 30° C. [29] T = 203° C.

actual quenching of the advancing flame front in large vessels. Some agents provide chemical inhibition effects (most likely via free radical scavenging) in addition to diluent and thermal benefits, but this chemical inhibition effectiveness is both fuel dependent,[27] and dependent on the advancing flame front speed.[29]

Most of the suppression test data suggest that the various agents have comparable effectiveness for slow to moderate deflagrations, but that ammonium phosphate (and to a lesser extent potassium bicarbonate) becomes decidedly more effective for rapid deflagrations. However, Bartknecht concludes that none of these agents, as presently used in suppression systems, can suppress explosions in gases with K_G values exceeding 200 bar·m/s, or in dusts with K_{ST} values greater than 300 bar·m/s.

Recent tests at NIST[50] in a shock tube generating highly turbulent flames and quasidetonations demonstrate that these high-challenge explosions *can* be suppressed, provided (1) agent can be dispersed uniformly ahead of the shock wave, and (2) gaseous agent concentrations are around 10 vol percent, i.e., about twice as high as the Halon 1301 volumetric concentration used for more conventional, less challenging, explosion suppression applications.

The choice of agent must involve other considerations besides suppression effectiveness as determined by test data. Other relevant considerations include agent retention time to cope with repeated ignitions, agent compatibility with process materials, environmental impact regulations, and potential toxicity effects at the agent design concentration. U.S. regulations that define acceptable and unacceptable suppression agents, from environmental and toxicity considerations, are described in a significant new alternative policy for ozone-depleting chemicals.[51]

General guidelines for the design, installation, and maintenance of a reliable and effective explosion suppression system can be found in the literature[4,30,48] and in the manuals provided by system manufacturers. In addition, system manufacturers and approval organizations have a wealth of unpublished test and incident data that are often essential in developing system specifications and designs for specific applications.

VAPOR CLOUD EXPLOSIONS

Release of a large quantity of flammable gas or vapor into the atmosphere will result, at least temporarily, in the formation of a flammable vapor cloud. Ignition of the vapor cloud may, under certain vaguely defined conditions, result in sufficiently rapid flame propagation to generate destructive overpressures and blast waves. Qualitatively, the conditions required for a vapor cloud explosion are (1) a large quantity of detonation-prone gas/vapor; and (2) either a highly energetic ignition source or a highly obstructed environment supportive of turbulence-induced flame accelerations.

Historically,[31,32] all reported vapor cloud explosions have involved the release of at least 100 kg of flammable gas, with a quantity of 1000 to 10,000 kg being most common. The gases most often involved have been ethylene, propane, and butane. According to Wiekema's compilation of incident data,[32] all of the reported vapor cloud explosions have occurred in "semiconfined" environments such that buildings or other large structures were within the vapor cloud at the time of ignition. Wiekema's data suggest that the presence of a large building or structure within the cloud is a necessary, but not sufficient, condition for an explosion to occur, since at least 15 of 68 (22 percent) reported ignitions in semiconfined environments resulted in flash fires as opposed to explosions (37 other ignitions did result in explosions). Damage surveys indicate that many of the vapor cloud explosions were deflagrations rather than detonations. On the other hand, analyses of pressure waves generated from flame propagation through vapor clouds (e.g., Lee et al[33]) indicate that flame speeds of at least 100 m/s are necessary to generate potentially destructive overpressures greater than about 0.1 atm. Thus, the most likely scenario is that flame speeds on the order of a few hundred m/s (corresponding to so-called quasidetonations) were generated in the actual incidents as a result of flame acceleration around buildings and structures.

The most commonly used method* to assess blast wave effects from vapor cloud explosions is to employ ideal (point source) blast wave correlations based on the blast wave energy, i.e., the TNT equivalent energy. This energy is given by

$$E = \alpha \Delta H_c m_F \qquad (12)$$

where:

E = blast wave energy (kJ)
α = yield, i.e., the fraction of available combustion energy participating in blast wave generation
ΔH_c = theoretical net heat of combustion (kJ/kg)
m_F = mass of flammable vapor released (kg)

The corresponding TNT equivalent mass, kg, W_{TNT} is

$$W_{TNT} = E/4500 \text{ kg} \qquad (13)$$

Figure 3-16.14 is the ideal blast wave overpressure versus distance correlation used in conjunction with Equations 12 and 13. Distances in Figure 3-16.14 are scaled by the cube root of W_{TNT} in accordance with ideal blast wave theory.[34] The overpressures in Figure 3-16.14 are reflected shock wave overpressures associated with reflections of the incident shock wave off a solid surface perpendicular to the wave propagation direction. Nominal building damage and personnel injury thresholds are also indicated in Figure 3-16.14 and in Table 3-16.9. More accurate and comprehensive damage assessments should be based on actual structural dynamic loading calculations leading to impulse-overpressure damage thresholds as described, for example, by Fickett and Davis.[17]

Before Equations 12 and 13 can be used effectively, some guidance is needed on the selection of appropriate values of the yield, α. Data compiled by Gugan[32] and Davenport[31] on the effective yields from approximately 20 vapor cloud explosions showed a spread of four orders of magnitude, with the highest value in one particularly devastating incident being 25 to 50 percent. Wiekema's compilation[32] shows the effective yield to be about one percent for releases of 1,000 to 10,000 kg vapor, and to be in the range of 1 to 10 percent when more than 10,000 kg is released. The yield in the Flixborough explosion (one of the most destructive and the most thoroughly investigated and reported vapor cloud explosion to date) is 4 to 5 percent based on the 30 to 40 metric tons of cyclohexane released prior to ignition.[35] Thus, the specification of yields for blast damage predictions is an exercise in risk assessment, with

*Although the TNT equivalency method is most common in the United States, Europeans often use other methods.[32,39]

Attachment 9: TVA PSAR, Hartsville Nuclear Plants

TVA

HARTSVILLE NUCLEAR PLANTS

DOCKET NOS. STN-50-518,519,520,521

PSAR AMENDMENT 30

8002 290381

2.2.3.4 Gas Pipeline Hazard

A gas pipeline installation belonging to the East Tennessee Natural Gas Company (ETNG) passes through the northern part of the Hartsville Site. As shown in Figure 2.2-9(T) the pipeline crosses the site boundary near the northwest corner, enters a compressor substation north-northeast of the plant, and leaves the site at the northeast site boundary. Approximately 1.67 miles of pipe lie within the site boundary with a closest approach of approximately 2,650 feet to the nearest critical plant structure.

An extensive investigation into the safety hazards posed by this pipeline has been conducted. The yearly probability of a hazard to the plant was determined in this investigation. Events which could cause a hazard to the plant were identified in the form of a hazard tree shown in Figure 2.2-10(T). The hazards from thermal radiation, blast overpressure, missile generation, and plant contamination by gas at an unacceptable concentration were analyzed to determine the probability of exceeding acceptable levels at the plant site. The yearly probability of exceeding the acceptability criteria (referred to as the hazard probability) was calculated using sophisticated analysis techniques. The analysis accounted for a broad range of parameters, such as leak location and size, time varying gas cloud size, shape, and orientation relative to the plant, meteorological conditions, and the time at which the gas cloud ignites.

It was determined that the yearly probability of a hazard due to thermal radiation, missile generation, and plant contamination by gas at an unacceptable concentration is negligible. It was also determined that the best estimate of the yearly probability of a peak reflected overpressure of 2.4 psi at the plant due to a gas cloud detonation was 0.16 x 10[illegible], assuming that unconfined natural gas can detonate. (There is some doubt that unconfined natural gas can detonate. See section 2.2.3.4.6.3.3(3) for further discussion. If unconfined natural gas cannot detonate, then the probability of a 2.4-psi peak reflected overpressure is zero.) 17

2.2.3.4.1 <u>Gas Pipeline Description</u>. A natural gas pipeline installation belonging to the East Tennessee Natural Gas (ETNG) Company passes through the northern part of the Hartsville site. The pipeline was constructed in the early 1950's and is part of a network consisting of approximately 1000 miles of major pipelines operated by ETNG. 17

The buried pipeline follows the terrain along its route. It crosses the northwest plant perimeter at an elevation of approximately 520 feet and rapidly rises to an elevation of 800 feet. It is nearly 200 feet in elevation above reactor building grade at its point of closest approach to a critical plant structure (diesel building for plant A, Unit 2).

The pipe has an outside diameter of 22 inches and is operated at a maximum pressure of 720 psig at the compressor station. The average operating pressure at the point of closest approach is approximately 560 psig. The pipeline contains automatic isolation valves. The nearest ones to the plant are located

The minimum clearance for all conditions was found to be 275 feet. This occurs for break point 12, stability class G, and a wind speed of 7.5 miles per hour.

The minimum clearance for a given break point and stability class is relatively insensitive to wind speed. This is evident by comparision of the data within each column of Table 2.2-1(T). The time at which the minimum clearance condition occurs varies considerably with wind speed.

The results described above are based on the expected plume rise for each break point, stability class, wind speed, and time. An analysis was also performed to determine the impact of assuming worst-case estimates for plume rise equation variables, using the minimum clearance conditions (break point 12, stability class G, 7.5 mph, 750 seconds). A worst-case clearance of 60 feet was obtained in the analysis, which is described in the following paragraphs.

The results in Table 2.2-1(T) are calculated using the nominal plume rise coefficients given by Briggs (Reference 10). A maximum variation due to random factors of about 25 to 35 percent above or below the nominal rise can be expected. A worst-case coefficient of sixty-five percent of the nominal was therefore established as a lower bound on the plume rise due to random variations.

The gas temperature after expansion in the atmosphere may be less than the surrounding air, as discussed in Section 2.2.3.4.4.1. This temperature differential is expected to be not greater than 50° F. One hundred degrees Fahrenheit was established as a conservative bound on the temperature differential for the worst-case. This differential reduces plume rise uniformly by approximately twelve percent.

The clearances in Table 2.2-1(T) are based on a vertical temperature gradient of 7 degrees Centigrade per 100 meters for Stability Class G. The worst-case temperature gradient expected at the site is 10 degrees Centigrade per 100 meters. Use of this value results in plume rises approximately 90 percent less than those on which Table 2.2-1(T) is based.

When all of the above factors were combined, a worst-case plume rise reduction of approximately 50 percent was obtained. The corresponding worst-case clearance to the air intakes is 60 feet.

This demonstrated that the probability of a hazard due to gas contamination is essentially zero, since gas at flammable concentrations did not approach the plant air intakes under worst-case conditions.

2.2.3.4.6.2 Heat Exposure Hazard

The probability of a hazard at the plant due to heat exposure was found to be negligible under worst-case conditions. A maximum heat flux of 200 BTU/ft² was obtained in the analysis. This may be compared with a flux of approximately 1,750 BTU/ft² required for spontaneous ignition of wood (Reference 18). Since all of the critical plant surfaces exposed to the heat radiated from a burning cloud are concrete, the maximum flux is well below that which would cause any damage.

The largest gas cloud flammable regions and lowest plume rises occur for low wind speeds under stable atmospheric (class G) conditions. These conditions also give rise to the highest heat fluxes. For a given break point and wind speed, the heat flux increases with ignition time until the gas cloud recedes away from the plant. Analysis of the heat fluxes from various pipe segments revealed that the maximum flux resulted from a rupture in segment 14 (see Figure 2.2-16(T)), which has the lowest elevation. This condition occurred for a wind speed of 0.6 miles per hour and an ignition time of approximately 100 minutes after the start of gas release.

The maximum heat flux is based on the nominal plume rise for Stability Class G. If a worst-case reduction factor of 50 percent is applied to the nominal plume rise, as in the case of the gas contamination hazard (Section 2.2.3.4.6.1), the maximum heat flux is less than 800 Btu/ft². Thus, the worst-case heat flux is well below the flux which can cause damage to critical plant structures.

2.2.3.4.6.3 Detonation Hazard. The detonation hazard was determined by calculating the yearly probability of exceeding the structural capabilities of the safety-related structures at the plant by air blasts or missile impacts. Plant structural capabilities given in the response to Question 130.22 were used in these analyses. These established that a conservative value for the most vulnerable safety-related structure was 2.4 psi peak reflected pressure. Combinations of various rupture locations (break points), meteorological conditions, and detonation times were evaluated in the estimation of hazard probability. 17

Attachment 10: ALOHA Benchmarking Test Case

1.0 OBJECTIVE

Verify that ALOHA 5.2.3 version is correctly predicting results on the installed computer, an IBM-compatible PC (ID#3W2BZ1) using Microsoft Windows XP® Professional, Version 2002, operating system with a Pentium(R) 4 processor.

2.0 TESTING METHOD AND ACCEPTANCE CRITERION

Select an example test case from the ALOHA User's Manual as a benchmark. Enter the test case input data on the installed computer and then compare the example and installed computer results. The values should be identical.

3.0 RESULTS

User's Manual Example 3: A Pipe Source was chosen as the benchmark test case to compare results because it is very similar to the postulated scenario being evaluated in this calculation. Example 3 input data, as shown on user's manual pages 143 through 149, was entered into the installed computer, with one exception: the internal computer clock was used instead of the example date and time to distinguish the two printed results.

Copies of both the "Footprint Plot" and "Text Summary" from the user's manual (page 40 in this calculation) and the installed computer output (pages 41 and 42 in this calculation) are attached. As shown, the plots are identical and the predicted numerical values on the text summaries are virtually identical. The only variations are in the "Total Amount Released," where the Example 3 value is 84,565 pounds vs. 84,564 pounds for the installed version and the user's manual text summary includes a default LOC (i.e., from library: 50000 ppm). These difference are considered insignificant.

4.0 CONCLUSION

The installed ALOHA 5.2.3 version is correctly predicting results as designed.

ALOHA®

AREAL LOCATIONS OF HAZARDOUS ATMOSPHERES

User's Manual

AUGUST 1999

EPCRA Reporting Center
(703) 816-4445, x 353, 398, 364, 292

U.S. ENVIRONMENTAL PROTECTION AGENCY

Chemical Emergency Preparedness and Prevention Office
Washington, D.C. 20460

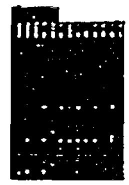
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Hazardous Materials Response Division
Seattle, Washington 98115

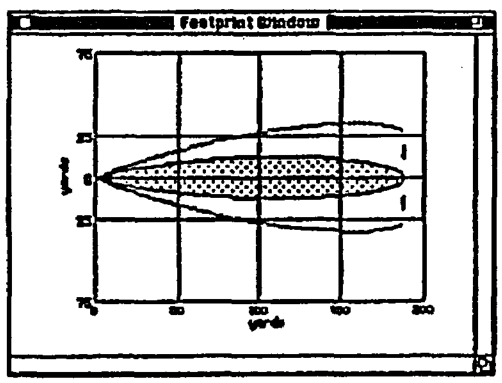
COMPUTER-AIDED MANAGEMENT OF EMERGENCY OPERATIONS

cameo®

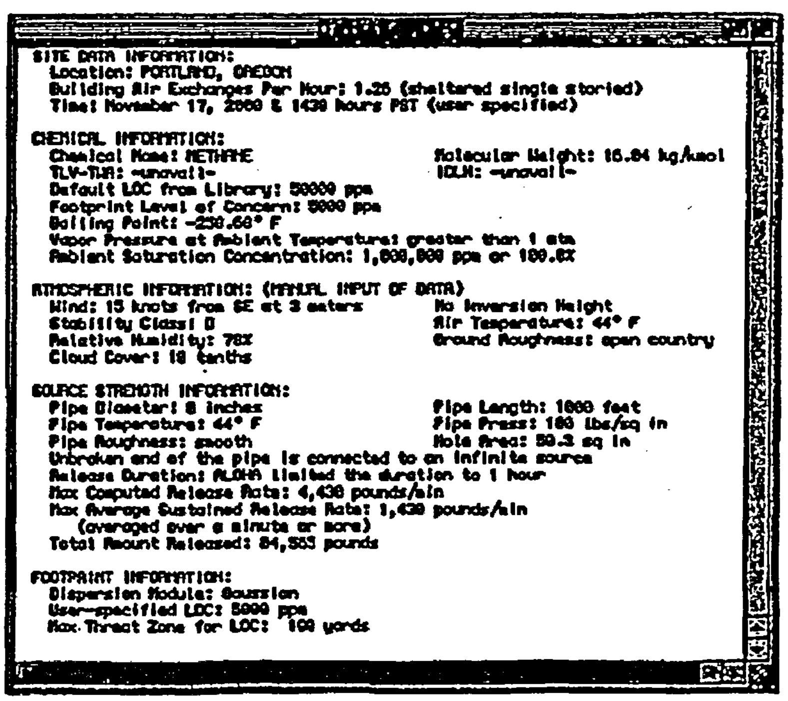
5 **Choose Footprint from the Display menu.**



ALOHA predicts that the concentration of methane may exceed 5,000 ppm for up to about 190 yards downwind of the leaking pipe.



Your Text Summary should now look like the one below.



```
SITE DATA INFORMATION:
  Location: PORTLAND, OREGON
  Building Air Exchanges Per Hour: 1.26 (sheltered single storied)
  Time: November 17, 2000 & 1430 hours PST (user specified)

CHEMICAL INFORMATION:
  Chemical Name: METHANE                    Molecular Weight: 16.04 kg/kmol
  TLV-TWA: -unavail-                        IDLH: -unavail-
  Default LOC from Library: 50000 ppm
  Footprint Level of Concern: 5000 ppm
  Boiling Point: -258.68° F
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC INFORMATION: (MANUAL INPUT OF DATA)
  Wind: 15 knots from SE at 3 meters        No Inversion Height
  Stability Class: D                        Air Temperature: 44° F
  Relative Humidity: 78%                    Ground Roughness: open country
  Cloud Cover: 10 tenths

SOURCE STRENGTH INFORMATION:
  Pipe Diameter: 8 inches                   Pipe Length: 1000 feet
  Pipe Temperature: 44° F                   Pipe Press: 100 lbs/sq in
  Pipe Roughness: smooth                    Hole Area: 50.3 sq in
  Unbroken end of the pipe is connected to an infinite source
  Release Duration: ALOHA limited the duration to 1 hour
  Max Computed Release Rate: 4,430 pounds/min
  Max Average Sustained Release Rate: 1,430 pounds/min
     (averaged over a minute or more)
  Total Amount Released: 84,583 pounds

FOOTPRINT INFORMATION:
  Dispersion Module: Gaussian
  User-specified LOC: 5000 ppm
  Max Threat Zone for LOC: 190 yards
```

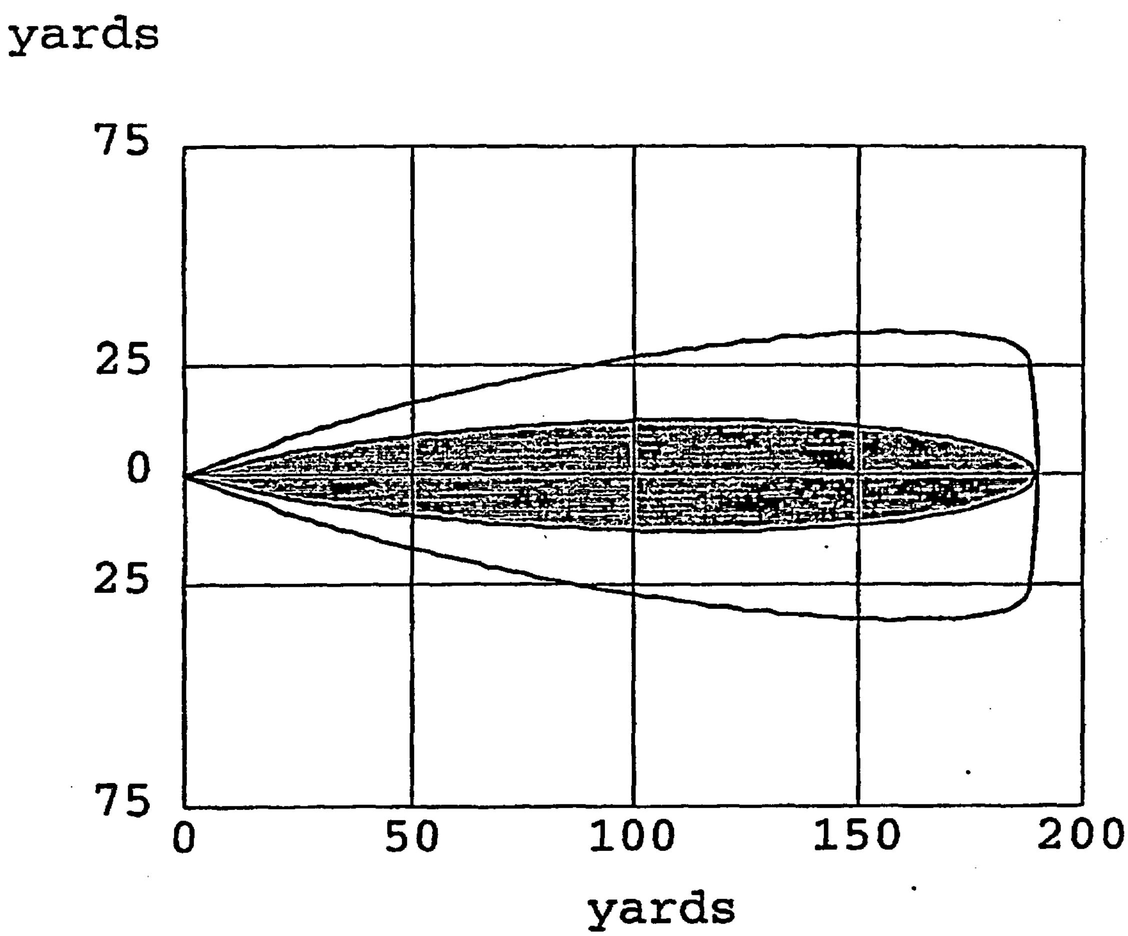
Footprint Window — ALOHA® 5.2.3

```
Time: December 5, 2003  0822 hours PST (using computer's clock)

Chemical Name: METHANE

Wind: 15 knots from SE at 3 meters

FOOTPRINT INFORMATION:
  Dispersion Module: Gaussian
  User-specified LOC: 5000 ppm
  Max Threat Zone for LOC:  190 yards
```



Text Summary ALOHA® 5.2.3

```
SITE DATA INFORMATION:
  Location: PORTLAND, OREGON
  Building Air Exchanges Per Hour: 1.26 (sheltered single storied)
  Time: December 5, 2003  0822 hours PST (using computer's clock)

CHEMICAL INFORMATION:
  Chemical Name: METHANE       Molecular Weight: 16.04 kg/kmol
  TLV-TWA: -unavail-           IDLH: -unavail-
  Footprint Level of Concern: 5000 ppm
  Boiling Point: -258.68° F
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC INFORMATION: (MANUAL INPUT OF DATA)
  Wind: 15 knots from SE at 3 meters
  No Inversion Height
  Stability Class: D           Air Temperature: 44° F
  Relative Humidity: 78%       Ground Roughness: open country
  Cloud Cover: 10 tenths

SOURCE STRENGTH INFORMATION:
  Pipe Diameter: 8 inches      Pipe Length: 1000 feet
  Pipe Temperature: 44° F      Pipe Press: 100 lbs/sq in
  Pipe Roughness: smooth       Hole Area: 50.3 sq in
  Unbroken end of the pipe is connected to an infinite source
  Release Duration: ALOHA limited the duration to 1 hour
  Max Computed Release Rate: 4,430 pounds/min
  Max Average Sustained Release Rate: 1,430 pounds/min
     (averaged over a minute or more)
  Total Amount Released: 84,564 pounds

FOOTPRINT INFORMATION:
  Dispersion Module: Gaussian
  User-specified LOC: 5000 ppm
  Max Threat Zone for LOC:  190 yards
```

Attachment 11: Design Verification Checklist

A RAMATOME ANP

DESIGN VERIFICATION CHECKLIST

Document Identifier 32-2400572-02

Title Natural Gas Pipeline Hazard Risk Determination

		Y	N	N/A
1.	Were the inputs correctly selected and incorporated into design or analysis?	☒ Y	☐ N	☐ N/A
2.	Are assumptions necessary to perform the design or analysis activity adequately described and reasonable? Where necessary, are the assumptions identified for subsequent re-verifications when the detailed design activities are completed?	☒ Y	☐ N	☐ N/A
3.	Are the appropriate quality and quality assurance requirements specified? Or, for documents prepared per FANP procedures, have the procedural requirements been met?	☒ Y	☐ N	☐ N/A
4.	If the design or analysis cites or is required to cite requirements or criteria based upon applicable codes, standards, specific regulatory requirements, including issue and addenda, are these properly identified, and are the requirements/criteria for design or analysis met?	☒ Y	☐ N	☐ N/A
5.	Have applicable construction and operating experience been considered?	☐ Y	☐ N	☒ N/A
6.	Have the design interface requirements been satisfied?	☐ Y	☐ N	☒ N/A
7.	Was an appropriate design or analytical method used?	☒ Y	☐ N	☐ N/A
8.	Is the output reasonable compared to inputs?	☒ Y	☐ N	☐ N/A
9.	Are the specified parts, equipment and processes suitable for the required application?	☐ Y	☐ N	☒ N/A
10.	Are the specified materials compatible with each other and the design environmental conditions to which the material will be exposed?	☐ Y	☐ N	☒ N/A
11.	Have adequate maintenance features and requirements been specified?	☐ Y	☐ N	☒ N/A
12.	Are accessibility and other design provisions adequate for performance of needed maintenance and repair?	☐ Y	☐ N	☒ N/A
13.	Has adequate accessibility been provided to perform the in-service inspection expected to be required during the plant life?	☐ Y	☐ N	☒ N/A
14.	Has the design properly considered radiation exposure to the public and plant personnel?	☐ Y	☐ N	☒ N/A
15.	Are the acceptance criteria incorporated in the design documents sufficient to allow verification that design requirements have been satisfactorily accomplished?	☐ Y	☐ N	☒ N/A
16.	Have adequate pre-operational and subsequent periodic test requirements been appropriately specified?	☐ Y	☐ N	☒ N/A
17.	Are adequate handling, storage, cleaning and shipping requirements specified?	☐ Y	☐ N	☒ N/A
18.	Are adequate identification requirements specified?	☐ Y	☐ N	☒ N/A
19.	Is the document prepared and being released under the FANP Quality Assurance Program? If not, are requirements for record preparation review, approval, retention, etc., adequately specified?	☒ Y	☐ N	☐ N/A

FRAMATOME ANP

DESIGN VERIFICATION CHECKLIST

Comments:

1. Although Reg. Guide 1.91 (Ref. 3) does not address effects of airblasts associated w/pipelines, equation 1 of Reg. Guide 1.91 ($R \geq kW^{1/3}$), used in the determination of the exposure distance (Section 6.1.3 on p. 7 and Attachment 4), is based on the concept of TNT equivalence and applicable to hydrocarbons under pressure.

2. The benchmarking test case for the ALOHA program (Attachment 10) meets the requirements of FANP procedure 402-01, Section VII.C.

Note: Comments 1 and 2 are from the Design Verification Checklist attached to Revision 1 of this calculation.

Verified By: (First, MI, Last)	J.H. Snooks	[signature]	1/19/2004
	Printed / Typed Name	Signature	Date