Subject Matter Study Report

**Permian Highway Gas Pipeline**

**Probable Impact Distance**

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By

Royce Don Deaver, P.E.

DEATECH Consulting Company

203 Sarasota Circle South

Montgomery, Texas 77356

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**Executive Summary**

Natural gas and petroleum pipelines are the most highly stressed piping systems on earth and the Permian Highway Pipeline will be one of the largest high pressure pipelines on earth. Each foot of 42-inch diameter pipeline at 1440 psig has over 700,000 pounds (350 tons) of force per foot of pipeline length acting to rip the pipeline in half. Many natural gas pipelines ruptures are over 100 feet in length. The minimum standards in Federal and State regulations allow ruptures to be up to eight (8) pipe joints or about 360 feet in length.

When the high pressure Permian Highway Pipeline ruptures, the natural gas is initially released at the speed of sound, 1,300 to 1,400 feet per second. The two ends of the pipe are similar to two massive jet engines.

If an ignition source is near a ruptured pipeline, the effects of a fire can be felt thousands of feet away. If an immediate ignition source is not nearby, a massive cloud of natural gas can travel through the atmosphere until an ignition source is found to create an even greater danger to life and property than an early ignition source.

The attached report covers a comprehensive analysis of the impacts of a fire from the Permian Highway Pipeline. A radiant fire intensity of 1500 BTU/hr.-ft.2 allows people a reasonable chance of survival if adequate shelter is available within one (1) or two (2) minutes. This minimum survival distance from the Permian Highway Pipeline is about 3,500 feet, but only if the natural gas is ignited instantaneously. If an ignition source is not near, the minimum survival distance would be greater.

R. D. Deaver, P.E.

DEATCH Consulting Company

rdd5703@aol.com

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Introduction

My name is Royce Don Deaver and I am a registered professional engineer in the State of Texas in the area of mechanical engineering. I have been involved with pipeline safety for over 56 years. I was employed in an engineering capacity with Exxon Pipeline Company for 33.5 years and have worked as a consultant for 23 years. During my career I have investigated many pipeline failures and pipeline safety issues.

Gas pipeline companies have been required to comply with Title 49 Code of Federal Regulations (CFR) Part 192 titled *Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards.* The regulations were first issued in the early 1970’s. In 2003, additional integrity management regulations were added that require a pipeline company to analyze and identify high consequence areas along the route of each pipeline.

Minimum locations along a natural gas pipeline that must be evaluated and included as high consequence areas include:

1. Cities where multi-story buildings are prevalent (Class 4 locations).
2. Residential, shopping, and industrial areas (Class 3 locations).
3. Other areas with 20 or more buildings intended for human occupancy within the potential impact zone of the pipeline route.
4. A single high risk site within the potential impact zone of the pipeline such as:
   1. An outside area that is occupied by 20 or more people on at least 50 days within any 12 month period. Examples listed include:
      1. Beaches,
      2. Playgrounds,
      3. Recreational facilities,
      4. Camping grounds,
      5. Outdoor theaters,
      6. Recreational areas near a body of water, and
      7. Areas outside a rural building such as a religious facility.
   2. A building that is occupied by 20 or more people on at least five (5) days a week for 10 weeks within any 12 month period. Examples include:
      1. Religious facilities,
      2. Office buildings,
      3. Community centers,
      4. General stores,
      5. 4-H facilities, or
      6. Roller skating rinks.
   3. A facility occupied by persons who are confined, are of impaired mobility, or would be difficult to evacuate such as:
      1. Hospitals,
      2. Prisons,
      3. Schools,
      4. Day-care centers,
      5. Retirement facilities, or
      6. Assisted-living facilities.

Class Locations

Class locations for gas pipelines were a concept developed by the gas pipeline industry in the 1950’s when pipeline diameters and pressures were lower and pipelines were located outside most populated areas. Originally, the class locations were based on 440 yards (1,320 feet) on each side of the pipeline. The original intent was to identify higher consequence areas and reduce the likelihood of ruptures by reducing the pressures in the pipe or requiring thicker wall, stronger pipe. These class locations were included in the initial gas pipeline code, American Society of Mechanical Engineers (ASME) B31.8.

For some unexplained and illogical reason, the U.S. Department of Transportation reduced the width for determining class locations in half to 220 yards on each side of each gas pipeline. This may have been okay for smaller, low operating pressure pipelines, but not for large diameter, high pressure pipelines such as the Permian Highway Pipeline and many others. Large diameter, high pressure pipelines should have class locations based on the potential impact distances.

Since the 1950’s, the American gas pipeline code, ASME B31.8, has contained the following requirement:

When classifying locations for determining the design factor for pipeline construction and testing that should be prescribed, due consideration shall be given to the possibility of future development of the area. If at the time of planning a new pipeline this future development appears likely to be sufficient to change the Location Class, this shall be taken into consideration in the design and testing of the proposed pipeline.

Based on the above requirements, “future development” by humans should also be considered in identifying high consequence areas.

The hazardous distance on each side of a pipeline that is analyzed for where people live, work, and play should be based on the potential distance from the pipeline that could be affected by a pipeline rupture. The hazardous distance from a pipeline should also be based on the ability of humans to escape from the intense heat caused by ignited large pipeline releases. In less populated areas with few ignition sources, the impact distances should be wider or the pipeline should be required to provide ignition sources along each pipeline to limit impacts remote from the pipeline. Without ignition sources to contain fires to the area of the pipeline, offsite impacts including atmospheric migration must be considered.

Gas Pipeline Fractures

Natural gas and liquid petroleum pipelines are the most highly stressed piping systems on Earth. If a series of critical flaws and/or mechanical damage occurs in the pipeline, the pipeline ruptures and is severed in half. Natural gas is initially released at the speed of sound of the gas, 1,300 to 1,400 feet per second. The pipeline will continue to fracture until the initial pressure drops to or below about 30% of its original operating pressure.

About 30% of the critical incidents reported to the U.S. Department of Transportation are large ruptures, because of the potential energy of the compressed natural gas and highly stressed pipe. Each foot of 42-inch diameter pipeline at 1,440 psi has over 700,000 pounds (350 tons) of force acting to rip the pipeline in half. Many natural gas pipeline ruptures over 100 feet long occurred in the USA and are summarized in American Gas Association records.

The Kinder Morgan Permian Highway Pipeline will be among the largest and most highly pressurized natural gas pipelines on Earth. This pipeline has the potential for catastrophic loss of life, injury, and property damage.

Minimum Impact Distances

The minimum potential impact radius included in Title 49 CFR Part 192 is only:

1. 

where:

*r* = minimum potential impact radius, ft.;

*d* = pipeline diameter, inches; and

*p* = internal pipeline pressure, psig.

1. For the Kinder Morgan pipeline where *d* = 42 inches and *p* = 1,440 psig, the Title 49 CFR Part 192 minimum potential impact radius from the pipeline is:



The minimum potential impact radius in Title 49 CFR Part 192 was developed by C-FER Technologies under sponsorship by the gas pipeline industry for highly populated areas with numerous ignition sources. The C-FER calculations were based on the following unconservative and inappropriate assumptions:

1. The natural gas being released from the pipeline is quickly ignited. There is no migration through the atmosphere to a remote ignition source away from the pipeline.
2. A person near the ruptured pipeline would be able to gather their senses and be able to locate a shelter within five (5) seconds of the rupture and run for 245 feet at 2.5 meters per second on any terrain and reach shelter in a building within 25 seconds. The running speed would be 25% of the speed of an Olympic sprinter on a running track designed for speed.
3. For an impact distance of 1,100 feet and 25 seconds of running as stated in the C-FER criteria, a person would have to run at 44 feet per second, about 1.5 times the speed of an Olympic sprinter on a track.
4. For a running speed of 2.5 meters per second (8.25 feet per second) for 25 seconds as also stated in the C-FER criteria, the distance traveled is only 245 feet. For a maximum travel to safety distance of 245 feet, the impact limit in Title 49 CFR Part 192 would be set at only 245 feet.
5. For an impact distance limit of 245 feet, the pressure limit for a 42-inch pipeline must be lowered to 71.5 psig.
6. The person running to find shelter would be exposed to heat of 5,000 BTU per hour-ft.2 which assures death within 60 seconds if protective shelter from the fire is not available.
7. The C-FER criteria in Title 49 CFR Part 192 is based on the killing zone from exposure of a pipeline rupture and fire, not on safety of the public from a pipeline rupture and fire.
8. The shelter, if made of wood, provides 20 minutes of protection before it ignites. Temperature inside the shelter is unknown, but would be expected to be high.

Children, the elderly, and physically limited people will not be able to escape and find shelter even if shelter happens to be near.

C-FER Calculation Errors

In addition to the arbitrary unconservative assumptions for all members of the public, the C-FER calculations included the following unsupported factors to further reduce their calculated impact distances:

1. Gas flow rate reduction factor of 0.33 or 33% of the initial flow rate from the severed pipeline. Initial flow rate is three (3) times the C-FER equation flow rate. The early gas flow until the pressure drops by 67% is ignored
2. A flow reduction coefficient of 0.62 was erroneously used to reduce the full bore gas flow rate from the ruptured pipeline.
3. A combustion reduction efficiency of 0.3 or 30% for the released natural gas. American Petroleum Institute Standard 521 does not include a combustion reduction efficiency factor for incomplete combustion of natural gas. Natural gas in air is an extremely combustible material.

Neither the U.S. Department of Transportation nor the Railroad Commission of Texas have the knowhow, expertise, or will to identify flaws in the C-FER calculations.

When these erroneous flow reduction coefficient and combustion reduction efficiency factors are removed from the C-FER equations, the probable impact distance is increased by 75% or from 1,100 feet to 1,925 feet for the excessively high heat intensity of 5,000 BTU/Hr.-Ft.2

Other Sources of Heat Exposure Limits

Some of the effects and limits on heat exposure from fires are:

1. A heat exposure of 5,000 BTU/Hr.-Ft.2 causes skin to blister in six (6) seconds.
2. Limit on heat exposure in industrial areas such as a refinery for personnel performing emergency response actions lasting 2 to 3 minutes is 1,500 BTU/Hr.-Ft.2 (American Petroleum Institute).
3. Limit on heat exposure for offsite analysis for releases of flammable gas for Risk Management Planning is 1,585 BTU/Hr.-Ft.2 (Environmental Protection Agency’s Risk Management Program.)
4. Exposure limit for firefighters performing prolonged firefighting actions is 800 BTU/Hr.-Ft.2 (National Fire Protection Association.)
5. Department of Housing and Urban Development (HUD) limit for outdoor open spaces where people congregate is 450 BTU/Hr.-Ft.2

The C-FER limit of 5,000 BTU/Hr.-Ft.2 is clearly too high for human exposure and is borderline for property protection. The maximum outdoor heat exposure for people to have a reasonable chance of escape and survival is 1,500 BTU/Hr.-Ft.2

If the arbitrary and technically unjustified flow reduction factors are removed from minimum impact distance in Title 49 CFR Part 192 and a heat intensity of 1,500 BTU/Hr.-Ft.2 is used as a more appropriate value for public safety, the potential impact distance for an early ignition of the natural gas from the Permian Highway Pipeline becomes:



Recommended Analysis of Gas Pipeline Releases

Appropriate analysis of a pipeline release such as a natural gas rupture in a lower population area involves at least a three-step process to determine a potential hazardous distance or needed setback from a pipeline. This three-step process to analyze a pipeline release should include:

1. Gas migration distance to an ignition source,
2. Fireball analysis created by the accumulated natural gas during the time between the rupture and the ignition, and
3. Thermal radiation from the sustained fire that exists after ignition and after the fireball duration.

For a 42-inch diameter pipe at 1,440 psig, the initial flow rate from both ends of a ruptured pipeline for a density of 4.8 lb./ft.3 would be about:



74,000 lbs. per second

where:

*Qm* = gas flow rate, lbs. per second.

When the pressure decay factors from the C-FER report are applied, the cumulative amounts of natural gas released from both ends of the ruptured pipeline are:

|  |  |  |  |
| --- | --- | --- | --- |
| Time, Sec. | *Qm* | Ʃ *Qm* | Average *Qm* |
| 1 | 74,000 lbs./sec. | 74,000 lbs. | 74,000 lbs./sec. |
| 10 | 26,640 lbs./sec. | 508,100 lbs. | 50,810 lbs./sec. |
| 60 | 15,540 lbs./sec. | 1,781,000 lbs. | 29,680 lbs./sec. |
| 600 | 7,780 lbs./sec. | 8,926,000 lbs. | 14,880 lbs./sec. |

For a heat limit of 1,500 BTU/Hr.-Ft.2, the impact distance versus time after the rupture and immediate ignition are:

|  |  |
| --- | --- |
| Time, Sec. | Impact Distance  Feet |
| 1 | 8,260 |
| 10 | 6,695 |
| 60 | 5,115 |
| 600 | 3,620 |

For a delayed ignition resulting in a fireball, the calculations are:

1. Fireball durations after the rupture.
   1. Ignition in 1 second: 15 seconds
   2. Ignition in 10 seconds: 28 seconds
   3. Ignition in 60 seconds: 42 seconds
   4. Ignition in 600 seconds: 72 seconds
2. Fireball diameter versus time after the rupture.
   1. Ignition in 1 second: 585 feet
   2. Ignition in 10 seconds: 1,115 feet
   3. Ignition in 60 seconds: 1,690 feet
   4. Ignition in 600 seconds: 2,890 feet
3. No one can survive being caught within a fireball.
4. Hazardous distances from center of the fireball versus time after the rupture and delayed ignition.
   1. For 1% mortality probability:
      1. Ignition in 1 second: 870 feet
      2. Ignition in 10 seconds: 2,100 feet
      3. Ignition in 60 seconds: 3,750 feet
      4. Ignition in 600 seconds: 7,875 feet
   2. For 50% mortality probability:
      1. Ignition in 1 second: 625 feet
      2. Ignition in 10 seconds: 1,515 feet
      3. Ignition in 60 seconds: 2,700 feet
      4. Ignition in 600 seconds: 5,670 feet
   3. For 99% mortality probability:
      1. Ignition in 1 second: 435 feet
      2. Ignition in 10 seconds: 1,050 feet
      3. Ignition in 60 seconds: 1,875 feet
      4. Ignition in 600 seconds: 3,940 feet

For example, if the fireball ignition is delayed 600 seconds after the rupture, the mortality probability rate is at least 99% if you are located within 3,940 feet of the pipeline.

In remote areas, gas “clouds” from a pipeline rupture are unlikely to experience an immediate or early ignition. Atmospheric dispersion models can be used to estimate the distance a natural gas release can travel until and adequate ignition source is encountered. U.S. Environmental Protection Agency’s (EPA’s) Risk Management Program in EPA 550-B-99-009 on Guidance for Offsite Consequence Analysisincludes graphic solutions for a 10-minute release.

For a 10-minute release in a rural terrain and the lower flammable limit for natural gas, the potential migration distance to find an ignition source is about 1.8 miles.

**Bibliography**

R. D. Deaver, P.E.

DEATECH Consulting Company

rddeaver.com

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