# *Amherst, NH – Pipeline Task Force Working Document*

## *Pipeline Hazards and Public Safety v. 1*

### *Overview:*

This document provides a review of the physical dangers associated with natural gas transmission pipelines, such as the proposed NED pipeline. The goal is to inform readers about the nature of the gas, the mechanisms by which it can cause harm to people, what actually happens during a pipeline accident, and what the chances of such a thing happening really are. The intent is to empower residents to make the most informed judgments possible when considering safety issues for pipelines. Hazards associated with pipeline construction activities, which may be significant, are not addressed.

### *Chemical Properties of Natural Gas:*

The primary constituent of natural gas in transmission pipelines is methane, which has the chemical formula $CH_4$ (one carbon atom and four hydrogen atoms). The gas may contain small amounts of other hydrocarbons, mostly ethane ($C_2H_6$) and propane ($C_3H_8$), as well as low levels of carbon dioxide and nitrogen. Other significant contaminants will generally have been removed prior to transportation in the pipeline.

With the exception of carbon dioxide, these compounds are biologically inert and therefore non-toxic, nor are they carcinogenic. The release of natural gas in low concentrations, a common occurrence within confined spaces like kitchens, poses no significant health threat. All the potential adverse effects are related to the possibility of high concentrations, causing either a fire hazard or displacing air and the oxygen it contains. We will concern ourselves here primarily with methane, which is likely to constitute over 95% of the pipeline gas.

### *Physical Hazards of Methane:*

Methane is colorless, odorless, and biologically inert. The direct hazards to humans are from ignition at moderate concentrations, and asphyxiation by displacement of air at high concentrations.

Methane is lighter than air, so that outdoors it rises swiftly away from ground level where people live and breathe (think of the hot air above an open fire). This is in contrast to propane gas, for example, which is denser than air and can pool in local depressions in the terrain, creating potential hazards that do not exist with methane. Therefore, the asphyxiation hazard is more or less exclusively limited to instances of major leaks in confined spaces. This situation is not relevant to members of the general public when considering hazards from natural gas transmission pipelines because major leaks would either be outdoors, or in pipeline company buildings with restricted access.

Far more pertinent is the danger of ignition. For methane to burn, it must first mix with oxygen in the air. There exist well-defined concentrations for methane in air that create flammable conditions. If the mixture is below 4.4% methane by volume, or above about 17% by volume, combustion *cannot* occur. After ignition, the burn can proceed at varying rates, depending on specific conditions. If a volume is well mixed with a concentration within the above range, the burn can be explosive. Alternatively if mixing is poor, the volume will typically contain many areas that fall either above or below the critical concentrations, and the burn will be slower, patchy, and incomplete. (Note: These basic physical properties are common to flammable mixtures, and are a primary reason why internal combustion engine design places a high premium on efficient mixing within the combustion chamber prior to the ignition spark.)

### *Pipeline Rupture Scenarios:*

Gas transmission pipelines can fail due to a variety of causes, and with a variety of severities. Defective welds, corrosion, unintentional damage from construction activities, unanticipated ground subsidence have all been implicated in incidents through the years. Only the more serious failures carry significant potential for injury or death. Sometimes, a single hole is punched in the wall of a pipeline, which will result in a major gas leak that may or may not ignite. A full-scale rupture is a catastrophic situation in which a section of the pipeline is usually completely destroyed.

Occasionally one will read of a gas pipeline explosion, and the common perception is that the flammable gas itself exploded – the reporting is almost always non-specific on this point. However, this is almost always not the case, and the explosions are generally caused by structural failure of the pipe, combined with a large volume of gas under as much as 100 atmospheres of pressure. It is the abrupt release of this pressure that shatters the pipe, sometimes hurling major pieces significant distances and creating deep craters – the explosions are mechanical in nature, not chemical. The escaping gas may subsequently ignite and cause additional damage, but the main explosion is due to the internal pressure of the pipeline, similar to the popping of a balloon. There are plenty of reported instances of pipeline leaks and explosions with no ignition.

### *Pipeline Rupture and Burn Consequences:*

In the event of a single hole in a pipeline, one may reasonably expect a jet of high pressure gas in one direction, which if ignited will burn in a stable envelope within a mixing zone where the gas interacts with the air – essentially a unidirectional tongue of flame. Outside the mixing zone the concentration will be too low, and inside the zone it will be too high. Due to the high pressure, the flame may be very large, and may take a substantial time to burn itself out by consuming all the gas in the affected pipeline section

A full-scale rupture will typically send gas in many directions simultaneously, and if ignited an extensive burn pattern is possible. In general, most of the gas at any one time will not be well mixed, and only a small fraction of it will carry true explosive potential, defined as a combustion front moving faster than the speed of sound. The bulk of the burning gas, in many situations, will be in an upwards plume caused by the lighter-than-air nature of methane.

It should specifically be noted that calculating the total energy content of the gas in a pipeline between shutoff valves (e.g. the contents of 10 miles of 36-inch pipeline containing 1450 psi gas) and trying to compare that to the energy yield and destructive effects of large explosions, is neither relevant nor useful. The energy release from combustion in a major pipeline rupture is almost all gradual, not explosive in nature. The primary concerns for safety are the magnitude and location of any explosive initial ignition dictated by specific gas quantities and mixing conditions, the subsequent burn pattern dictated by the way the gas sprays out of the rupture, and the duration of the burn which is dictated by the volume of gas in the affected segment and the leak rate.

The temperature of methane flames typically ranges from 900 to 1500 degrees Celsius. Objects within the flame envelope would obviously be destroyed, but of far greater significance and impact is the radiative heating of objects near the flames. Essentially, if you are in a location where the flames cover a large part of your field of vision, radiative heating will be extreme. This can ignite trees and buildings, and kill people. It is like getting too close to a bonfire - the bigger the bonfire, the further away you have to stand to avoid overheating. A major gas pipeline rupture and burn creates flames on an enormous scale, and radiative heating can be hazardous hundreds of feet away under some circumstances. Such burns can persist for many tens of minutes, causing great harm if in a populated area.

### *Potential Impact Radius (PIR):*

The prospect of a major rupture and attendant hazard is a frightening one, and has led to the coining of such emotive terms as "incineration zone". However, serious studies of the hazard potential use the accepted and official term "potential impact radius" usually abbreviated to PIR. The PIR is defined by the US government as the radius of a circle within which the potential failure of a pipeline ***could have significant impact*** on people or property. It is ***not*** the radius within which people or properties are ***expected*** to be incinerated in the event of an accident. The PIR is proportional to the pipeline diameter, and to the square root of the maximum operating pressure of the pipeline, and is plotted in Figure 1. It can be seen that the PIR for NED would be around 900 feet, meaning that in a worst-case scenario when operating at maximum pressure, hazardous conditions could occur this far from a rupture site. The risk of such conditions occurring decreases with distance from the site, and is deemed by the government to become negligible beyond the PIR distance. Obviously there is much more danger if you are 300 feet away than if you are 900 feet away.

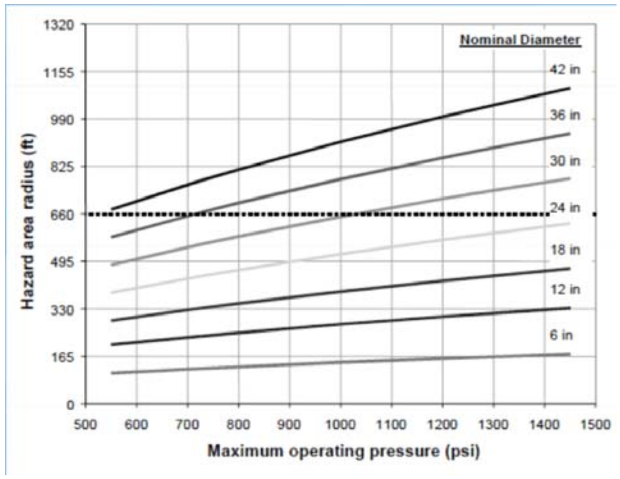


**Figure 1 - Illustration of potential impact radius (PIR). Taken from northerntier.org/upload/Pipeline_Wysox_May_2011.pdf**

The federal government also defines zones primarily according to population density, and specific types of buildings. There is a formal definition of "high consequence areas" in which extra safety measures are mandated.

### *Incidence Rate of Major Accidents:*

Using data from the federal Pipeline and Hazardous Materials Safety Administration (PHMSA), which is part of the US Department of Transportation, as of 2014 there were 297,450 miles of onshore gas transmission pipeline in use across the country, run by 982 different operators. These numbers have not changed much in the past several years.

The PHMSA maintains comprehensive statistics on accidents of varying severity. Most of the concern involving NED revolves around the most serious incidents. In Figure 2 the data for serious incidents, injuries and fatalities involving onshore gas transmission pipelines are shown for the past 15 years. Figure 3 shows the incident data graphically.

| Calendar Year | Number | Fatalities | Injuries |
|---|---|---|---|
| 1995 | 7 | 0 | 7 |
| 1996 | 6 | 1 | 5 |
| 1997 | 4 | 1 | 5 |
| 1998 | 11 | 1 | 11 |
| 1999 | 5 | 2 | 8 |
| 2000 | 7 | 15 | 16 |
| 2001 | 4 | 2 | 5 |
| 2002 | 4 | 1 | 4 |
| 2003 | 8 | 1 | 8 |
| 2004 | 2 | 0 | 2 |
| 2005 | 5 | 0 | 5 |
| 2006 | 6 | 3 | 3 |
| 2007 | 8 | 2 | 7 |
| 2008 | 5 | 0 | 5 |
| 2009 | 6 | 0 | 11 |
| 2010 | 6 | 10 | 61 |
| 2011 | 1 | 0 | 1 |
| 2012 | 3 | 0 | 7 |
| 2013 | 1 | 0 | 2 |
| 2014 | 2 | 1 | 1 |
| Grand Total | 101 | 40 | 174 |

**Figure 2 - Serious incident data**

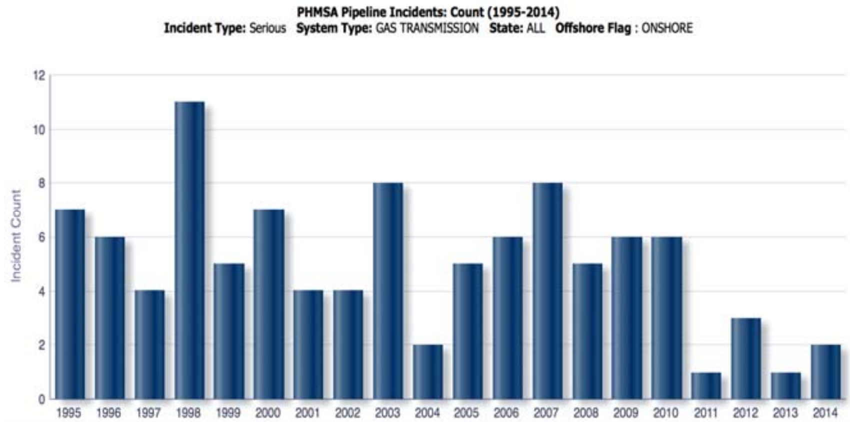


**Figure 3 – Serious incident rate trend over 15 years**

The central message from these data is that major accidents resulting in injury or death are very rare, and that in terms of incidents per mile of pipeline, the probability of an incident in a specific location is exceedingly low. We can quantify this in order to assist in understanding the true risk, and appropriate responses to that risk.

The average number of serious incidents per year, nationwide, over the past 15 years is 6.7, and as can be seen from Figure 3, there is fairly robust statistical evidence that the incidence rate is declining. Such a decline is not unusual, as technologies for construction, maintenance and inspection all improve over time. A similar decline is seen in automobile and airline statistics, for example. On average, each incident results in 0.4 fatalities and 1.7 injuries. The mean number of fatalities and injuries per year, nationwide, is 2.7 and 11.6 respectively.

We can use these numbers to estimate risk for the portion of the NED pipeline that runs through New Hampshire (about 70 miles), through Amherst (about 4 miles) and past a single building (worst case is twice the PIR, or about 1/3 of a mile). What we get for the typical expected time between incidents, fatalities and injuries respectively, is as follows:

- In New Hampshire – 640 yrs (incident), 1,590 yrs (fatality), and 370 yrs (injury)
- In Amherst – 11,200 yrs (incident), 27,800 yrs (fatality) and 6,475 yrs (injury)
- In a building – 134,000 yrs (incident), 330,000 yrs (fatality) and 78,000 yrs (injury)

Or, to put it another way, if the pipeline passes next to a house and a family lives there for 10 years, the chances of any member of that family dying from a pipeline accident at any time in those 10 years is about 1 in 30,000. This is a very low probability. For comparison, using data from Wikipedia, it is:

- 30 times lower than the US average risk from using a car
- 6 times lower than the risk of flying 30,000 miles per year
- 8 times lower than the risk of bicycling an hour per week
- 30 times lower than the risk of walking an hour per day
- 500 times lower than the risk of riding a motorcycle 10,000 miles per year
- 140 times lower than the risk of accidental death from all causes combined

In other words, the risk is much lower than those we routinely take and accept each and every day. If this were a risk taken voluntarily and which carried some perceived direct personal benefit, we would likely not give it a second thought. The risk of a pipeline accident is heavily exaggerated in our perceptions due to it being imposed externally upon us, and due to the potentially horrific nature of the incidents, which attract dramatic national media coverage.

### *Some Caveats, and a Summary Statement on Pipeline Accident Risk:*

The above analysis is simplistic, and fails to take into account many factors. A section of pipeline within a PIR of a residence is not representative of pipelines across the US, in that the local population density is higher than average due that residence, but conversely, using twice the PIR as the relevant length of pipe capable of inflicting fatal injury is a very pessimistic choice.

Fatality statistics include any workers who may have been responsible for the accident and who therefore are likely to have been next to the pipeline at the time, modestly biasing the numbers upward relative to the pipeline simply sitting close to a building. Federal regulations require mitigations to be employed in high consequence zones such as heavily populated areas or in proximity to places of gathering such as schools and churches – this may take the form of thicker pipe walls for example, reducing the risk locally.

Different pipeline operators use different practices for inspection and maintenance, and some pipelines thus carry higher risk levels than others. Some pipelines still in use are many decades old, and a percentage of accidents are due to corrosion, or lower construction standards in older pipe, such that new pipes can be expected to carry a lower risk, though of course defects in construction can still occur. Because the Northeast does not have many natural gas transmission pipelines, the Northeast is largely left out of the statistics, although that may not be a significant factor. In general, the numbers derived above are fairly conservative, though unique circumstances could present a relatively higher or lower statistical risk.

Nevertheless, even though the above estimates are not exact when applied to the proposed NED pipeline, the objective risk to New Hampshire residents from major pipeline incidents is extremely low, and much lower than everyday risks we already routinely take. The pipeline permitting authorities, namely FERC and NH SEC, are well aware of pipeline hazard and safety statistics.

### *Summary:*

While major pipeline accidents can be frightening and horrific in nature, they are extremely rare and expose populations along the proposed route to objective risks that are negligible compared to many other routine, unrelated and unavoidable hazards.

It should be emphasized and recognized that even if the physical risks are very low, they are not zero, and that fear of such accidents is very real, and a natural, inevitable and unavoidable consequence of pipeline installation, or plans for such installation. Such fears cause emotional distress in much the same way as many perfectly well adjusted people feel great stress during air travel, and that stress carries significant human costs that must not be dismissed or minimized.

Those stresses and costs are already taking a toll, even in the current pre-filing stage. Towns like Amherst, accordingly, have an obligation to take any and all measures in their power to further minimize risks and ease the associated impacts on residents, with attendant and significant financial costs.