

Safety & Health Aspects

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Safety and Health Aspects

This section presents a brief overview of the plant and the methanol production process, including the materials and process involved, followed by potential hazards presented. It then describes the general safeguards and protective measures that will be used to protect workers, the public, and the environment. Since the largest amount of material (and the largest risk) on-site is methanol, it is a major focus of this section.

PROCESS DESCRIPTION

GENERAL DESCRIPTION OF THE METHANOL PROCESS

The plant will be designed to produce 10,000 metric tons (10 million pounds) per day of AA-grade methanol from natural gas feedstock (5000 metric tons per day from each of two process trains).

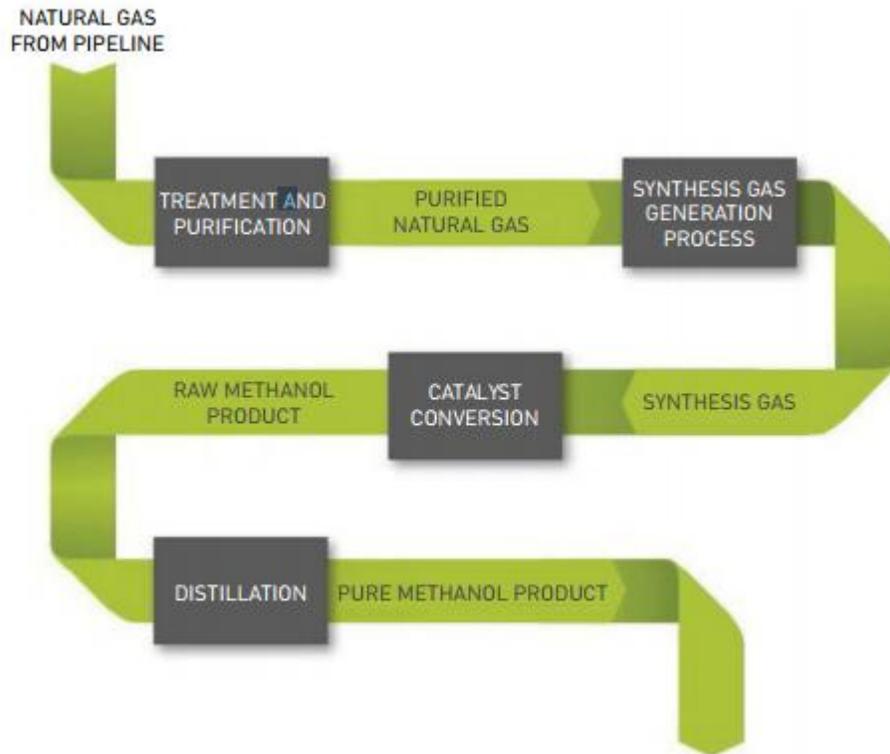
Making pure methanol from natural gas is an established technology: natural gas is combined with steam and heat to produce a “synthesis gas” of carbon monoxide, carbon dioxide, and hydrogen. A catalyst is then used to create a chemical reaction and the resulting liquid is distilled to yield 99.9 percent pure methanol and 0.1 percent water.

The process for producing methanol from natural gas has three key steps:

1. Natural gas reforming – the process of converting natural gas to synthesis gas (a mixture of hydrogen and carbon oxides; also referred to as syngas);
2. Methanol synthesis – the process of converting syngas to methanol; and
3. Methanol distillation – the process of purifying the methanol product to the required purity.

The plant will use ultralow emission (ULE) reforming technology licensed from Johnson Matthey, with synthesis gas from a gas heated reformer (GHR) and oxygen blown secondary autothermal reformer operating in series. The process will use two tube-cooled converters in series to carry out the methanol synthesis reaction and a three-column distillation train to produce refined methanol.

Figure 1 – Methanol Production Process



FEED GAS PURIFICATION

Natural gas feed to the Site will be by an underground pipeline branch from an existing underground pipeline (Williams Northwest Pipeline) that passes to the east of the site. Within the site, distribution will be by aboveground piping. The pipeline will feature a remotely actuated automatic shutdown valve at the point where the pipeline enters the plant. Valve activation will be from Williams Northwest Pipeline gas control and a low pressure interlock (indicative of a loss of containment).

The natural gas feedstock will pass through a sulfur removal unit to remove low levels of sulfur impurities which would otherwise foul the catalysts used to promote the chemical reactions carried out in the process plant. The natural gas will be heated before passing over a catalyst bed where the sulfur compounds will react with hydrogen to convert the sulfur to hydrogen sulfide. Hydrogen sulfide will be subsequently removed by absorption over a zinc oxide bed. The resulting zinc sulfide (as well as other chemicals/catalysts utilized in the process) will be disposed off-site in accordance with applicable regulations.

NATURAL GAS REFORMING – PRODUCTION OF SYNTHESIS GAS

The treated natural gas will be compressed and then broken down into a mixture of basic components in a reaction process referred to as reforming, which will convert the natural gas into

a mixture of carbon monoxide and carbon dioxide, hydrogen and unreacted methane in the presence of steam. The resulting mix of carbon oxides and hydrogen is referred to as synthesis gas (syngas), and contains the reactants for the formation of methanol.

Syngas will be produced using ULE reforming technology from Johnson Matthey Catalysts. The GHR is a heat exchanger with catalyst inside the tubes. The reaction heat will be supplied by the autothermal reformer (ATR) exit gas which flows counter-current to the natural gas steam feed mixture. ULE reforming technology is the most energy efficient and environmentally sound syngas generation process available, producing the lowest levels of CO₂ and NO_x (greenhouse gas contributors) emissions and water demand.

CRUDE METHANOL SYNTHESIS

The methanol synthesis reactions will take place over a copper/zinc catalyst. Two reactors will be used, with the majority of the gas fed to the lower pressure reactor. Crude methanol will be condensed out of each reactor product stream. The unconverted reactants from the second methanol reactor will be recycled back to the first methanol reactor by a compressor. A small gas purge will be taken from the recycle gas to prevent excess hydrogen and non-reactive components (including residual methane and nitrogen) in the synthesis gas from building up. The purge stream will be vented to the site boilers where it will be used as fuel.

Re-Work Tanks will be provided to store crude methanol prior to refining the product in the distillation section of the plant. In the event of the distillation section being off-line, the crude methanol will be sent to the Crude Methanol Tanks. The Crude Methanol Tanks will also be used as storage prior to re-processing for any off-specification material from the Product Methanol Shift Tanks. The crude methanol will be returned to the refining section by means of the Crude Methanol Pump.

PRODUCTION OF REFINED METHANOL

There are a number of chemicals synthesized at the same time as methanol which will be condensed with the crude methanol. These chemicals will be separated from the methanol in the distillation section. The impurities will be removed as two liquid streams consisting of a small flow of heavy organic by-products known as fusel oil and a much larger flow of water containing traces of water-soluble organic components.

Refined methanol from the Refining Column will be sent to the Product Methanol Shift Tanks. When the purity of the methanol in the shift tanks has been checked, it will be transferred to the Product Storage Tanks or returned to the Crude Methanol Tanks if off-specification, using the Product Transfer Pumps.

Methanol will be transferred to ship by means of two marine loading arms. Vessels mooring at the facility could hold up to 100,000 tons of methanol. Pumping time, after connection, will be up to 36 hours. Methanol-rich vapors produced from pumping and tank filling will be scrubbed with water in a vapor recovery system.

NO_x PACKAGE

Selective Catalytic Reduction (SCR) technology is designed to minimize the release of NO_x compounds to the atmosphere. SCR technology will utilize aqueous ammonia (NH₄OH), which will be injected into the vent streams, which will then pass over a catalyst. The NO_x will react with NH₃ (ammonia) on the catalyst to yield nitrogen and water, which will be safely vented to the atmosphere.

FLARE

A flare system will be provided as part of the safety systems incorporated into the process design to dispose of flammable gases and vapors which are released from the process on an intermittent or emergency basis. The flare header will collect process gases released, some of which may contain liquids. The Flare header discharges into a Flare Knockout Drum along with liquid from the Natural Gas Knockout Drum. Any entrained liquid is separated out and any condensate collecting in the drum is pumped to the Fusel Oil Drum.

The dry gases will then pass to the Flare Stack. The Flare Stack is provided with pilot burners which will be running continuously to ensure the flare will be available if gases are vented. The flare height is currently estimated at 260 feet; this height allows the ground level thermal radiation to be below the safe thermal radiation threshold of 500 Btu/ft²/h.

POTENTIAL HAZARDS PRESENTED

CHARACTERISTICS AND HAZARDS OF NATURAL GAS

Natural gas is a hydrocarbon consisting mainly of methane, although it usually also contains a variable percentage of nitrogen, ethane, CO₂, H₂O, butane, propane, mercaptans and traces of heavier hydrocarbons. Methane is one carbon atom joined to four hydrogen atoms (CH₄) and is the major constituent of natural gas (up to 97%). The flammability limits for natural gas are: Lower Flammability Limit (LFL) – 5%, Upper Flammability Limit (UFL) – 15%.

CHARACTERISTICS AND HAZARDS OF SYNTHESIS GAS

Syngas, or synthesis gas, is a fuel gas mixture consisting primarily of hydrogen, carbon monoxide, and very often some carbon dioxide. The name comes from its use as an intermediate in creating synthetic natural gas. At NWIW, syngas will be generated from natural gas. The relative composition of the components of the NWIW syngas will change throughout the production train as listed in Table 1 below, but will be limited to the substances listed:

Table 2 - Typical Composition of Syngas

Component	Reformer Exit	ATR Exit	Syngas to Methanol Synthesis
Water, %	42	27	.5
Hydrogen, %	34	49	68
Carbon Monoxide, %	4	15	21
Carbon Dioxide, %	6	5	7
Methane	13	2	2

CHARACTERISTICS AND HAZARDS OF METHANOL

Methanol, also known as methyl or wood alcohol, is a colorless organic liquid (alcohol) at normal temperature and pressure. Methanol is hygroscopic (readily taking up water) and completely water soluble. It is lighter than water (specific gravity 0.8 versus 1.0 for water). This simple single-carbon alcohol is a volatile solvent and a light fuel.

Key points connected with methanol safety are the following:

- Methanol is a flammable, easily ignited liquid that burns and can explode in air under certain limited conditions (methanol vapor concentration between 6 and 36 volume percent in air).
- The molecular weight of methanol vapor is marginally greater (denser) than that of air (32 versus 28 grams per mole). As a result, and depending on the circumstances of a release or spill, methanol liquid will pool and vapor may migrate near the ground and collect in

confined spaces and low-lying areas. It is expected that methanol vapor, being near neutral buoyancy, will dissipate readily from ventilated locations. Methanol may not dissipate from non-ventilated locations such as sewers and enclosed spaces. If ignited, methanol vapor can flash back to its source.

- Methanol is completely soluble in water and retains its flammability even at very high concentrations of water. A 75/25% mixture of water and methanol (by volume) is considered to be a flammable liquid. This has important consequences for firefighting, therefore NWIW will have fire suppression foam stored onsite, as well as fixed foam monitors, for the methanol storage tanks.

While the methanol product is a liquid, much of the process takes place at temperatures above its boiling point. As a result, both vapor and liquid releases of methanol could occur. The plant safeguards and precautions for addressing potential methanol releases are detailed in the Health and Safety Protection section below

Methanol Toxicity

Human

Methanol's properties and toxicity are well understood. According to the extensive literature reviewed for this study, methanol is neither mutagenic nor carcinogenic. Human exposure to an accidental release of methanol can occur via inhalation, ingestion, or skin contact. Inhalation of methanol vapors can cause irritation of the mucus membranes, dizziness, nausea, headaches, and blurred vision if exposure at high levels occurs. While inhalation is the most common route of exposure to the body, ingestion (drinking) represents the most serious acute health hazard due to the much higher volume of methanol which can be ingested relative to the volume which can be inhaled. The effects of ingestion follow the same pattern described for inhalation. With respect to skin contact, methanol readily absorbs into the dermal layer with repeated exposure causing eczema, redness, and scaling. However, the current evidence shows that acute toxic effects on humans and some animals from methanol only occur when methanol accumulates in the blood at high concentrations (> 10 mg/l [blood concentration]). The primary means of protecting workers from methanol exposure are detailed in the Health and Safety Protection section below.

Aquatic

Methanol is significantly less toxic to marine life than crude oil or gasoline, and many of the effects of short term exposure are temporary and reversible. The U.S. EPA Office of Pollution Prevention and Toxics indicated that methanol is essentially non-toxic to four aquatic fish species that were tested. (US EPA, OPPT, 1994) A large methanol spill into a surface water would have some immediate impacts to the biota in the direct vicinity of the spill. However, because of its properties (i.e., methanol readily mixes with water and evaporates quickly in the atmosphere) methanol would rapidly dissipate into the environment, and within fairly short distances from the spill would reach levels where biodegradation would rapidly occur (Malcom Pirnie, 1999).

Methanol Spills to the River

The potential exists for a release of methanol to the Columbia River during the vessel-loading process. The following information discusses methanol spills.

Introduction

The behavior of methanol when released to surface water can be estimated based on its physical and chemical properties and has been observed and tested in numerous studies, including laboratory and actual spill situations. Methanol is the simplest alcohol and is infinitely soluble in water. When the volume of methanol released is small compared to the receiving water, this solubility results in rapid dilution to low concentrations. Once diluted, biodegradation is the main mechanism for the destruction of methanol. For methanol, biodegradation can occur under both aerobic and anaerobic conditions.

Much of the research into methanol spills has been conducted for the release of vehicle fuels that contain varying percentages of methanol and other constituents, such as gasoline. This research is referenced below and is useful to this review as the conclusions show that methanol is eliminated from the environment much faster than hydrocarbon mixtures such as gasoline. It is important to note that the methanol produced by NWIW will not be used as a fuel. In comparison to gasoline or other fuels, methanol is safer and more environmentally benign.

Potential for Surface Water Release Scenarios

The potential release scenarios for methanol into surface water are:

- Release from piping during ship loading
- Failure of a ship compartment due to internal or external causes.

Methanol Losses from Surface Water

The processes that contribute to methanol losses from surface water bodies include biodegradation, abiotic degradation, volatilization and bioaccumulation. The dominant loss mechanism in surface waters is expected to be biodegradation. Methanol concentrations in the vicinity of a surface water release will rapidly decrease due to advection, dispersion, and diffusion. The infinite solubility of methanol will result in rapid (within 1 hour) wave-, wind-, and tide enhanced dilution to low concentrations. Due to methanol's infinite solubility in water, a release in open water will disperse to non-toxic levels at a rate much faster than a similar gasoline release. In computer simulations: a) a 10,000-ton release of methanol in the open sea reached a concentration of 0.36% within one hour of the spill; and b) a 2,500-gal/hour spill from a coastal pier exhibited a concentration of <1% within two hours and 0.13% within three hours after the spill ceased. (Clary, 2013) Once concentrations have been diluted the dominant mechanism of methanol loss is expected to be biodegradation. The rate of dispersion is directly proportional to the amount of mixing in the aquatic environment. Tidal flows combined with wind-induced wave action will cause a large methanol spill to rapidly disperse to levels below toxic thresholds. In all cases measured, gasoline components quickly mixed throughout the upper layer of the surface water bodies; methanol is even more soluble in water than most gasoline components and will, consequently, mix even more rapidly.

Compared to other loss mechanisms identified, including volatilization and chemical degradation, biodegradation is expected to be the dominant process controlling the fate of methanol in the soil, groundwater, and surface water environments. In addition, the biodegradation of methanol can occur under both aerobic (oxygen present) and anaerobic (oxygen absent) conditions. (Malcolm Pirnie, 1999) The reported half-life of methanol in surface waters under aerobic conditions is short and ranges from 1-7 days (under aqueous aerobic biodegradation conditions) (Howard et al., 1991).

In flowing water bodies, wind- or current-enhanced mixing maintains dissolved oxygen concentrations at a level sufficient to support aerobic microbial processes. Even in oxygen-limited environments such as the bottom layers of stratified lakes, anaerobic biodegradation is expected to proceed at rapid rates; the reported half-life for methanol biodegradation under anaerobic conditions ranges from 1 to 5 days (Howard et al., 1991). Additionally, the nutrient supply in rivers and lakes is generally not expected to restrict the rate of methanol metabolism because the required nutrient supplies are constantly recharged by runoff (Alexander, 1994). However, high concentrations of methanol resulting from a large spill in an enclosed area could deplete the surface water of oxygen required to sustain aquatic life.

Abiotic degradation (i.e., non-biological or chemical) reactions are not likely to contribute significantly to methanol removal from surface water bodies. Hydrolysis reactions usually transform compounds into more polar products; methanol is a very polar molecule and is stable in water. Photolysis involves the transformation of a compound as a consequence of its direct absorption of light. Methanol does not absorb light in the visible spectrum and long wavelength UV. It does absorb very short wavelength UV, which is present in negligible amounts in solar radiation. In addition, methanol can be naturally oxidized by hydroxyl radicals formed in the water by the photolysis of nitrate, nitrite, and hydrogen peroxide resulting from reactions with excited humic materials or from the reaction of H₂O with iron (Fe(II)) (Schwarzenbach et al., 1993). Thus, naturally occurring photooxidation of methanol via direct or indirect oxidation is possible; however, these reactions are slow and, thus, not expected to be significant in surface waters.

The bioaccumulation of fuel hydrocarbons and certain additives in freshwater fish and invertebrates has been studied extensively (e.g. Brault, et al., 1994). Bioaccumulation in aquatic organisms is expressed by bioconcentration factors, BCF (Streit, 1994). To our knowledge, no studies have been reported for methanol bioaccumulation. However, octanol-water coefficients (K) and bioconcentration factors for methanol and other oxygenates have been reported and may be used as an indicator for bioaccumulation potential (Mackay et al., 1992). Methanol is expected to bioaccumulate slightly less than ethanol, and significantly less than benzene and most other more hydrophobic constituents in gasoline. Regardless, small quantities of methanol introduced into mammals as a result of bioaccumulation from methanol releases can be rapidly metabolized, negating any long term effect (Clary, 2013).

Volatilization, the evaporation of methanol from the liquid phase into a gas, is not a primary source of loss for a methanol/water mixture since methanol has a low air/water partition coefficient and the rate of biodegradation most likely exceeds the rate of volatilization. The air/water equilibrium partitioning behavior of methanol can be predicted using Henry's Law when methanol concentrations are less than 100,000 ppm (i.e., less than 10% by weight). The Henry's Law constant represents the ratio of a contaminant's concentration in the air to its concentration in the water at equilibrium. A compound with a dimensionless Henry's Law constant less than 0.05 will partition strongly from the gas phase into the water phase when contaminated air is brought into

contact with clean water (Zogorski et al., 1997). The value of Henry's Law constant for methanol is 1.09×10^{-4} [-] at 25°C. Since this value is quite low, atmospheric methanol will partition into water droplets. Conversely, methanol in water bodies is likely to remain in the aqueous phase. Therefore, once in water, methanol will be difficult to remove by volatilization.

Applying the hazard assessment guidelines from USEPA's Office of Pollution Prevention and Toxics, another study concluded that methanol is not persistent in the environment because it readily degrades in air, soil and water, and has no persistent degradation intermediates (ENVIRON, 1996). In the event of a large methanol spill to water, methanol will rapidly dilute within one hour to low concentrations and subsequently biodegrade in 30-60 days. (Clary, 2013, White, et al.) If clean-up measures are implemented, they must be instituted at a much faster pace compared to petroleum spills in order to capture the methanol plume prior to significant dilution.

Methanol, like other fuels, is a toxic substance; and since methanol is completely miscible with water, it is necessary to examine the potential concentrations of concern of methanol/water mixture pertinent to human health. The potential concentrations and impacts to drinking water intakes downstream as a result of a methanol discharge or release to a waterway is presented in the paper *Fate of Methanol Spills into Rivers of Varying Geometry* (Jamali, 2002).

The Jamali paper used the following concentrations as human health benchmarks (Marcus, 1993):

- One-day Drinking Water Health Advisory Limit (DWHAL) for methanol of 200 mg/l for children and 350 mg/l for adults.
- Ten-day DWHAL for methanol of 100 mg/l for children and 350 mg/l for adults.
- Lifetime DWHAL methanol concentration of 3.5 mg/l as the lifetime DWHAL.

In this study a range of methanol spill sizes (1,000, 10,000, and 30,000 US gallons) discharged into four hypothetical river sizes were evaluated to determine the potential impact a methanol release could have on human health. Given the dimensions of the Columbia River, it would fall into the "very large" category in the Jamali paper:

- Flow: Greater than 10,000 m³/s
- Width: Greater than 539 meters
- Length: Greater than 2,494 kilometers

Based on the Quantitative Risk Assessment (QRA) conducted for the proposed NWIW methanol facility, a range of accidental release scenarios were considered and evaluated. While the QRA was focused on impacts to onsite workers and surrounding community from a release to the atmosphere (e.g., potential for fire, explosion, and toxicity from inhalation), the scenarios developed for the wharf can be used to bound a worst-case release into the Columbia River. The dimensions and operating conditions of the methanol loading line are:

- Pipe Diameter: 16 inch
- Pipe Length: 1,000 feet
- Operating Pressure: 87 psig

The QRA assumed that a release at the wharf would be detected and isolated by the personnel working in the area within 30 minutes. Given the loading line dimensions, operating conditions, and isolation time, a worst-case release of 15,000 US gallons was calculated. This volume is in between the medium (10,000 US gallons) and large (30,000 US gallons) release size ranges from the Jamali paper.

To be conservative, the Jamali results for a 30,000 US gallon release are applied for a spill from NWIW into the Columbia River. Under Jamali's analysis, this release would have minor to no impact in a very large river such as the Columbia River. As a more conservative comparison, that same 30,000 gallon release into a "large" river would have the following modeled impacts:

- The methanol concentration falls below the estimated one-day drinking water health advisory limit for children (200 mg/l) in less than one hour, at a distance of 2 kilometers from the spill site.
- The methanol concentration drops below the lifetime 3.5 mg/l DWHAL within 10 hours and at a distance of 44 kilometers from the spill site.

As detailed in the Jamali paper, the short-lived duration of the methanol release is not only due to the speed of dilution but also to the rapid rate of methanol biodegradation. Methanol biodegradation plays an important role in ensuring the complete elimination of methanol from the river environment.

Methanol Spills to Land/Groundwater

Introduction

As a result of its high solubility, slow movement (low retardation factor) and ease of biodegradability, the dominant mechanisms of methanol loss from subsurface soil and groundwater are expected to be biodegradation and advection (i.e., transport from the source area by groundwater flow), with little loss due to adsorption.

Biodegradation

In general, microorganisms have been shown to play a prominent role in governing the fate of volatile hydrocarbons in subsurface aquatic and soil systems (NRC, 1993). When environmental conditions are amenable to microbial activity, aerobic microbial populations oxidize organic contaminants and consume oxygen in the process. Once the localized area has been depleted of the oxygen necessary for aerobic respiration, anaerobic conditions develop and anaerobic biodegradation proceeds. While it is well established in the scientific literature that methanol will biodegrade readily in the subsurface under both aerobic and anaerobic conditions, three factors are required for successful methanol biodegradation: the presence of indigenous methanol-degrading microbial populations, the availability of electron acceptors and nutrients, and adequate pH and temperature levels.

Only large concentrations (>100,000 ppm) of alcohols are generally considered to be toxic to most microorganisms and are therefore not biodegradable (Brusseau, 1993; Hunt et al, 1997a, b). High concentrations of methanol may occur near pure methanol spills and may inhibit microbial activity near the source; however, these concentrations will become more dilute with time and with increasing distance from the source (as little as 30-60 days) (Katsumata and Kastenburger, 1996, White, et al.).

The biodegradation of methanol has been measured both in the field and in laboratory studies. In an extensive field study at the Canadian Forces Base Borden site in Canada, the fate and persistence of an 85 percent methanol/15% gasoline fuel was investigated in an aerobic shallow

sandy aquifer (Barker et al., 1990). The average concentration of methanol introduced into the aquifer was 7030 ppm. By day 476 of the experiment, about 99% of the methanol was degraded. Insufficient oxygen was present in the plume to account for the removal of all the methanol; the researchers therefore concluded that the methanol degraded first aerobically then anaerobically (Hubbard et al., 1994).

In 2002, a 40,000 gallon methanol spill from the Borden Chemical site in Springfield, Oregon, reached shallow groundwater and the Willamette River (in samples collected from the river bank near a spill containment area). Methanol was not detected in samples collected downstream from the site. The spill location was less than 100 feet from the river. (Oregon DEQ)

Adsorption

Another methanol loss mechanism from the groundwater is adsorption to soil materials. However, adsorption will not contribute significantly to the loss of methanol from the environment due to the rapid rates of biodegradation in soil and groundwater and vaporization from dry soils. Little adsorption is expected for compounds such as methanol because of its polarity, low K values, and water solubility as discussed previously. (Malcolm Pirnie, 1999)

Volatilization from Groundwater and Vaporization from Soil

Methanol's high solubility and low Henry's constant are expected to result in minimal methanol losses from groundwater due to volatilization. However, in the soil, methanol will vaporize from the residual phase or source area under low soil moisture conditions (ENVIRON, 1996).

CHARACTERISTICS AND HAZARDS OF CATALYST HANDLING

The proposed project (both technology alternatives) would use catalytic process units to promote chemical reactions necessary for the reformation of natural gas to methanol. The catalytic processes would employ catalysts consisting primarily of oxides of aluminum, impregnated with cobalt, copper, magnesium, molybdenum, nickel, zinc and silicon and lower concentrations of other metallic compounds to achieve the necessary chemical activity. The catalysts will be delivered to the facility in pellet form (2 to 17 millimeters in diameter). These pellets will be placed in fully contained process vessels. Neither the catalysts nor the catalytic process will be exposed to the environment or to occupational areas during normal operations. Catalyst changeout is a common and well-understood practice in the petrochemical industry. Catalyst handling is typically conducted by contractors who specialize in this activity, utilizing equipment designed to ensure safe handling of both fresh and spent catalyst.

A zinc oxide catalyst will be used to remove sulfur compounds from the incoming natural gas. Hydrogen sulfide found in the incoming natural gas and also formed in the removal process will be reacted with the zinc oxide as the natural gas is passed through the catalyst bed. Hydrogen sulfide is a toxic gas, but it will be present only at very low concentrations in the natural gas, which will be fully contained in the catalytic process vessel. Eventually, the catalysts lose effectiveness and must be replaced approximately once every 6 to 12 months. The spent desulfurization catalyst will consist primarily of zinc oxide and zinc sulfide. It will be disposed offsite at a licensed waste disposal facility.

Catalysts used to reform natural gas to methanol will last 3 to 5 years. The metallic compounds in these spent catalysts generally will retain their original chemical composition and will be in the form of dust and larger particles. Some of these compounds may be toxic if inhaled and some may have potential to self-heat and combust when exposed to the atmosphere under certain circumstances. Therefore, they must be carefully managed when they are removed from the catalytic process vessels. These spent catalyst will be hauled offsite to a facility that will recover valuable metals (depending on market conditions) or to a licensed disposal facility.

All spent catalyst must be removed and replaced by a specialty contractor to ensure the safety of the workers. Removal will entail first purging the catalytic process unit of all process gases with an inert gas such as nitrogen. Once purged of process gases, the unit will be opened and the spent catalyst will be transferred to containers using appropriate dust control procedures. Certain spent catalysts may exhibit pyrophoric or self-heating properties when first exposed to air. Removal of catalyst under a nitrogen blanket and temperature monitoring of the catalyst charge are utilized to minimize this risk during removal.

This work will be done by workers equipped with personal protective equipment to prevent exposure to catalyst dust, either by inhalation or skin exposure. If confined spaces must be entered, all applicable requirements for confined space entry, including provisions for emergency extraction, provision of breathing air, and strict permitting procedures will be in place.

Care will be taken to ensure that dust is controlled. Air handling equipment is equipped with appropriate filters to ensure dust is not released to the atmosphere.

All catalyst workers will receive specific training in the hazards of catalysts and in the safety rules and procedures that must be followed to ensure worker safety and health.

CHARACTERISTICS AND HAZARDS OF AQUEOUS AMMONIA

Aqueous ammonia solution, also known as ammonium hydroxide or aqua ammonia is a solution of ammonia in water. Aqueous ammonia (19 weight percent ammonia) will be used in the methanol plant for the treatment of nitrogen oxide emissions, using ammonia as a reducing agent, and will be stored on site for that purpose. At normal temperatures and pressures, aqueous ammonia is liquid.

The following are some of the key properties of aqueous ammonia:

- Eye contact may cause severe irritation with corneal injury, which may result in permanently impaired vision, chemical burns, or blindness. Brief skin contact may cause burns, irritation, local redness, or tissue damage. Even a single inhalation exposure may be hazardous. Excessive inhalation, prolonged skin contact, or ingestion of ammonia may cause severe irritation to the upper respiratory tract (nose and throat) and lungs, the gastrointestinal tract or skin. In confined or poorly ventilated areas, vapor can readily accumulate and cause unconsciousness and death. Effects may be delayed.
- Aqueous ammonia is stable under normal storage and use conditions. Elevated temperatures can cause the material to decompose. Aqueous ammonia can react with acids, bleach, chlorinated hydrocarbons, chlorine, halogens, oxidizers, and metals such as zinc, aluminum alloys, brass, bronze, copper alloys, silver, iron, and mercury

- Ammonia is volatile and may will evaporate from water, however, due to its solubility in water, once introduced, it has a tendency to remain in water with little tendency to bind to soil or sediment. Ammonia is unlikely to be persistent in the soil since it is part of the nitrogen cycle in the environment. Ammonia is an important source of nitrogen for living systems, and is also a byproduct of metabolism in animals. Since the compound is oxidized to nitrate by microorganisms, it will be removed from water and soil environments. Ammonia is not expected to bioconcentrate in the food chain. However, the compound is toxic to fish and other aquatic organisms on an acute basis.

HEALTH & SAFETY PROTECTION

TECHNOLOGY CHOICE –ULE REFORMING TECHNOLOGY

In terms of safety, the benefit of the ULE reforming technology and its use of a gas heated reformer (GHR) is the elimination of the externally-fired heater utilized in the more conventional steam methane reforming (SMR) technology. If not controlled properly, externally-fired heaters may be subject to a number of risks, such as: explosions in the fire box due to improper purging prior to startup or failure of controls, or failure of heater tubes (with subsequent loss of containment) due to failure of temperature controls or loss of flow. ULE reforming technology does not present these same risks.

REGULATORY/GENERAL

Safe plant operations will be governed on the federal level by the Occupational Safety and Health Administration (OSHA). OSHA’s requirements are administered on the state level by the Washington State Department of Labor & Industries’ Division of Occupational Safety & Health (DOSH). These requirements ensure safe and healthful working conditions by setting and enforcing standards and providing training, outreach, education, and assistance to workers. Employers are required to provide a safe workplace for their employees by following all relevant health and safety standards, identifying and addressing hazards, abiding by chemical hazard communication requirements, providing workers with personal protective equipment, and reporting and record-keeping consistent with regulatory requirements. See the table below for an overview of the regulations addressing safety and health aspects of the facility and its operation. In addition, while there are specific regulatory requirements protecting the public and the environment for some of the chemicals that will be in use at the facility, operations will exceed those requirements by implementing Process Safety Management (PSM) principles for all processes that involve methanol synthesis. These principles will be implemented in conjunction with, and in addition to the codes and standards employed.

Table 3 - Regulation Overview

Aspect	Governing Body	Applicable Regulations	Notes
Overall facility siting and permitting process	Washington State Department of Ecology	SEPA Statute (Chap 43.21C); SEPA Rules (Chap 107-11 RCW)	The Washington State Environmental Policy Act governs the overall process.
Natural Gas Pipeline	Federal Energy Regulatory Commission (FERC)	Natural Gas Pipeline Regulations	FERC regulates pipelines delivering natural gas to the site. Once in use at the facility as feedstock, other regulations address its use and handling.

Aspect	Governing Body	Applicable Regulations	Notes
Process Safety Management of Highly Hazardous Chemicals (e.g., methanol, natural gas, ammonia)	OSHA	29 CFR §1910.119	The State of Washington has delegated authority from OSHA to administer OSHA’s PSM regulations.
	DOSH	Chap 296-67 WAC	
Accidental Release Prevention Chemicals	EPA	40 CFR Part 68	Commonly called RMP – Risk Management Plan/Program
General Worker Safety (several areas)	OSHA	29 CFR §1910	The State of Washington has delegated authority from OSHA to administer OSHA-level regulations.
	DOSH	Chap 296-800 WAC	

DESIGN CODES AND STANDARDS

JM Davy Technologies, the facility process design firm, has developed a list of codes and standards that will be employed during the detailed design phase. These codes and standards are developed by internationally recognized standards development bodies, including the following:

- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)
- American Petroleum Institute (API)
- American Society of Heating, Refrigeration and Air Conditioning Engineering (ASHRAE)
- American Concrete Institute (ACI)
- American Society of Civil Engineers (ASCE)
- International Electrotechnical Commission (IEC)
- International Organization for Standardization (ISO).
- National Fire Protection Association (NFPA)
- National Electrical Code (NEC)
- National Electrical Manufacturer's Association (NEMA)
- Heat Exchanger Institute (HEI)
- Institute of Electrical and Electronic Engineers (IEEE)
- Institute Society of America (ISA)
- American National Standard Institute (ANSI)

- International Conference of Building Officials (ICBO)
- Manufacturer's Standardization Society of the Valve and Fittings Industry (MSS).
- Tubular Exchanger Manufacturing Association (TEMA)
- Welding Research Council (WRC)
- International Code Council
- International Building Code (IBC)
- International Mechanical Code (IMC)
- International Fire Code (IFC)
- Washington State Building Code
- Washington State Energy Code

PROCESS SAFETY MANAGEMENT

As noted above, the processes at the facility that produce and handle methanol will be designed, operated, and maintained under the principles of Process Safety Management (PSM). The requirements for PSM in Washington are found at WAC 296-67 - Process Safety Management of Highly Hazardous Chemicals. Highlights of the protective measures of PSM are noted below:

Employee Participation

Employees throughout the facility will participate in all aspects of PSM. This includes participation in the development of the PSM program, as well as in individual PSM elements. This broad participation helps to ensure that a broad base of knowledge is available and used, and also helps to foster a stronger understanding of all of the aspects of safety design, operation, and maintenance.

Process Safety Information

A broad range of information will be gathered, developed, and maintained up-to-date. This ensures that information needed to implement other aspects of PSM is available and accurate. A Management of Change (MOC) procedure will be in place and implemented during plant operation to ensure that any risk associated with process changes will be well-managed and controlled. Process safety information covers information pertaining to the hazardous chemicals, information pertaining to the process technology, and information pertaining to the equipment in the process.

Process Hazards Analysis

As part of the detailed design effort, the design of all methanol processes will be reviewed in a Process Hazards Analysis (PHA). PHA is an analytical methodology that reviews design details to determine where hazards may occur and whether the engineering and administrative controls

detailed in the design or contained in the facility's operating procedures are sufficient to prevent and/or mitigate these hazards. The PHA will be conducted by a multi-functional team with expertise in process design, operations, maintenance and safety. The outcome of the PHA will be a list of action items intended to improve the safety of the plant.

Operating Procedures

Operating procedures will be developed and maintained for all reasonably foreseeable situations. This includes procedures for startup, shutdown, and operation during both normal and upset conditions. The procedures will be reviewed and certified at least annually to ensure that they are up-to-date and accurate.

Training

All affected personnel, including operations and maintenance, will be required to undergo significant initial and ongoing training. The effectiveness of the training will be verified by means of employee testing and field verifications. Records of training will be maintained. Minimum frequencies for refresher training will also be established.

Contractors

Any contractor who works on or near a covered process will be verified as appropriately trained and qualified to do the work they are performing. In addition, the facility will evaluate each contractor's safety record and performance in the selection and maintaining of contractors.

Pre-Startup Safety Review (PSSR)

This element relates to both the initial startup of the facility as well as to the Management of Change aspect (see below). The PSSR will provide a methodical, detailed approach to ensuring that construction is in accordance with design, and that all requirements for safe operation have been completed before starting up or restarting the process.

Mechanical Integrity

All equipment will be maintained according to recognized and generally accepted good engineering practices (RAGAGEP). These practices apply not only to the maintenance and reliability of the equipment, but to the frequency of maintenance, inspections, and testing of the equipment as well. Records documenting the maintenance actions performed, the results, and any corrective actions taken will be maintained for the life of the equipment. As noted above, the personnel performing this work will be appropriately trained to carry out their work.

Hot Work Permit

Due to the potential flammable nature of chemicals used in the process, any work that can produce sparks, heat, flames, or other ignition sources will be managed to prevent ignition. This will be

done via an internal permitting process to ensure that all precautions have been taken prior to, during, and following any hot work activities. The hot work program will be one of several aspects of the site permit to work system, which will include confined space entry, lockout/tagout, line breaking, etc.

Management of Change (MOC)

The plant will also be covered by a MOC program. Once the detailed process design is completed, any changes to that design will be subject to a review to determine if the change can negatively impact plant safety and if so, what will be done to eliminate or mitigate that impact. The MOC process will be an active component of the operating plant's safety program. All changes to equipment that are not direct replacement in kind and all changes to operating and safety procedures, will be reviewed under the MOC program.

Incident Investigation

All process safety incidents and near misses, and all injuries and illnesses will be investigated in a timely manner, by a diversified, qualified team. The investigation will identify causal factors that led to the incident and make appropriate recommendations from the lessons learned. Response to the recommendations will be documented.

Emergency Planning and Response

The facility will have a comprehensive emergency response plan (ERP). The ERP will address a broad range of contingencies and the appropriate response measures. In addition, regular drills will be conducted. These drills (and any incident responses) will be critiqued, with appropriate follow-up measures recommended. Implementation of recommendations will be addressed in a timely manner and documented.

Compliance Audits

To ensure that the principles and practices of PSM are properly followed and effective, regular audits will be conducted. Any findings from the audits will be addressed in a timely manner and documented.

NWIW REPRESENTATIVE SAFEGUARDS

While detailed design engineering has not yet commenced, NWIW has identified a preliminary list of safeguards, which summarizes some of the key engineering and administrative controls that will be in place to ensure the safety of workers, the public, and the environment. Items noted as "PSM element" will be defined in more detail in the NWIW PSM Program as detailed above. These safeguards will prevent, detect, or mitigate the effects of accidental releases of regulated substances.

Table 4 - Representative Safeguards

Safeguard	Type	Purpose
Pipelines, vessels and equipment designed to current codes and standards	Engineering	Ensure adequate vessel/equipment strength for intended service
Preventive maintenance program	Engineering Administrative PSM element	Ensure ongoing integrity of equipment and training/certification of maintenance personnel
Corrosion control program	Engineering Administrative	Ensure equipment is sufficiently robust to minimize releases due to corrosion
Process plant control systems (monitoring, alarm and communications)	Engineering	Ensure ongoing control of regular plant operations
Process Hazard Analyses	Administrative PSM element	Detailed review of design and operating procedures to identify hazards and assess the adequacy of safeguards
Management of Change	Administrative PSM element	Ensures that any changes to equipment, procedures or personnel are adequately reviewed and potential impacts on operation are addressed prior to change implementation.
Operating procedures	Administrative PSM element	Ensure plant operations are conducted per approved procedural steps and provide operations personnel with sufficient information to operate safely
Training	Administrative PSM element	Ensure personnel are capable of performing all regular and emergency tasks
Isolatable inventories	Engineering	Ensure hazardous material equipment contains means to quickly stop leaks/releases

Safeguard	Type	Purpose
Relief, blowdown and flare systems	Engineering	Ensure high pressure events can be safety controlled by safe disposal of released materials. Ensure startup/shutdown/emergency events do not result in releases of hazardous materials to the atmosphere
Ignition source control program	Engineering Administrative	Ensure installed electrical equipment is designed to minimize ignition sources. Ensure sources of ignition (vehicles, hot work, etc.) are controlled in areas where hazardous materials are located
Fire and gas detection systems	Engineering	Ensure that incipient fires or hazardous material releases can be detected quickly to allow for automatic response (i.e., isolation valves) or emergency response
Equipment spacing and layout	Engineering	Ensure that equipment layout minimizes the risk of domino or knock-on effects in the event of a fire/explosion
Fire protection system	Engineering	Ensure that firewater/foam can be delivered to suppress/extinguish fires
Emergency Response Plan	Administrative PSM element	Ensure that plant emergency response activities are managed. Responder training, procedures, drills, emergency response equipment, etc.
Safety instrumented systems (interlocks and emergency shutdown)	Engineering	Automated systems independent of everyday plant controls to identify deviations from normal and return the system to a safe state by means of process interlocks
Fixed foam systems within dikes	Engineering	Ensure that releases of methanol to diked areas can be suppressed by means of covering the spill with a fire suppression foam layer.

Safeguard	Type	Purpose
Fixed roof methanol tanks, internal floating roofs	Engineering	Ensure tank integrity per industry standards for tank construction
Closed circuit TV system	Engineering Administrative	Provide operations with overview of site activities. Fixed cameras for specific locations. Also provides for site security.
Earthquake valves	Engineering	Designed to interrupt flow of hazardous material in the event of: a) an earthquake of sufficient magnitude, and b) low-pressure due to a line leak or rupture.
NW Pipeline remotely actuated shutdown valve at takeoff point to plant lateral. Activation from NW Pipeline gas control and low pressure interlock	Engineering	Provide ability to interrupt flow of natural gas to the site in the event of a line leak/rupture (indicated by low line pressure) or any situation where manual activation is required.
Barricades around tanks and equipment	Passive	Minimize the likelihood of vehicles impacting tanks/equipment and causing releases of hazardous material.
Drainage and berms to control releases	Passive	Provides means to control releases and route them to a contained area.

ADDITIONAL SAFETY ASPECTS

A number of other safety and environmental protection systems will be included in the plant design as aspects of the various portions of the operation.

Within the site, the plant design will feature fixed gas detection systems to provide warning of a release of natural gas and to automatically take the process to a safe state by means of the closure of automatic isolation valves. In addition, there will be pressure monitors within the pipeline itself which can sense potential loss of containment and automatically shut the isolation valves.

Similar to natural gas, the syngas areas of the site will feature fixed gas detection systems to provide warning of a release of syngas and to automatically take the process to a safe state by means of the closure of automatic isolation valves.

While methanol's flash point is 52°F, methanol does not present any unique hazards from a firefighting perspective. Facility firefighting systems will be designed to address a potential methanol fire. Fixed analyzers throughout the processing and storage areas will continuously monitor for the presence of concentrations of organic vapors and provide warnings to personnel and take automatic actions if concentrations approach flammability limits.

The sulfur removal packages will not present a risk of exposure to the public from toxic sulfur compounds either in normal operation or in the event of a release since the peak level of sulfur compounds in the natural gas delivered to the facility is expected to be in the range of 6-12 ppm. The main risk of exposure to sulfur compounds would be to maintenance personnel, who would need to work on the packages. For maintenance operations, such as vessel entry or replacement of catalyst, maintenance personnel will be required to follow confined space entry permitting requirements, which include an analysis of vessel atmosphere prior to entry, continuous monitoring of vapor spaces, and the use of personal protective equipment, which may include respiratory protection equipment. The OSHA general industry ceiling level for H₂S is 20 ppm, with a peak limit of 50 ppm for up to 10 minutes.

Vapors from the Crude Methanol Tank Vent will be treated in the Crude Tank Vent Scrubber, which uses water from the Refining Column bottoms to scrub the methanol in the Crude Methanol Tank vapors down to the required level. In the scrubbing operation, methanol vapors will pass counter-currently to water in a vessel filled with packing to increase the surface area for mass transfer. This removal method is expected to be 99 percent efficient as methanol is water soluble. Any remaining methanol in the scrubber vapor outlet will be sent to the flare system. Similarly, a second scrubber will be included in the design to remove the methanol vapors that will be displaced when a vessel is loaded with product methanol.

The flare system will be sized to handle the worst-case release of materials from multiple simultaneous release points. The flare pilot flame remains on at all times, and so is always available in the event of a process upset condition that may send material to the flare system. The flare tower will be equipped with aircraft warning lights.

NWIW will utilize ammonia in the form of aqueous ammonia – ammonia diluted with water. Aqueous ammonia is much less hazardous than pure or anhydrous ammonia. Aqueous ammonia will be received by tank truck and stored on site. The NWIW facility will include fixed ammonia monitors in the vicinity of the aqueous ammonia system to provide personnel warning of ammonia leaks.

EMERGENCY RESPONSE SYSTEM OVERVIEW

NWIW is preparing a written emergency response plan, which will be distributed to local and state agencies before the first production of methanol. NWIW will have full emergency response capabilities to respond to all incidents within the plant site or on the dock. NWIW will assist the Maritime Fire and Safety Association and the county if there is an event that involves a ship, but NWIW is not expected to respond directly to an incident involving a ship.

NWIW will have all necessary emergency response equipment on-site and will develop close relationships with the Cowlitz County Fire Districts. At least four times a year, NWIW and Cowlitz County will conduct emergency response drills at the plant site. If an incident were to take place on the plant site, Cowlitz County Fire District #5 has agreed that NWIW will manage the response to an incident at the plant, and the county fire district will provide support. Incidents involving a ship while at the dock will be managed by Cowlitz County Fire District #5, with NWIW supporting. Also any ship on the Columbia River, will have a Coast Guard-approved emergency response plan.

Training

The plant emergency responders will respond to all plant emergencies, including fire, explosion, and injury. Emergency response training and certification will be in compliance with OSHA, PSM, and the NFPA requirements. Prior to initial assignment on the emergency response team, the prospective emergency response team member will be required to pass a medical examination, written and hands-on testing. After the completion of the initial testing, each emergency response team member must maintain training requirements and certification in First Aid, emergency alarm system, evacuation and vapor cloud monitoring, respiratory emergencies, rescue from electrical contact, SCBA, bunker gear inspection/cleaning, fire water system, , vapor suppression system, confined space rescue, HAZWOPER Hazmat (Technician level) certification, and fire extinguisher use.

Selected management staff and supervisors will be sent to Incident Command System (ICS) training at a facility recognized by the Federal Emergency Management Agency to certify students. This class takes an estimated 40 hours of initial training and requires refresher training annually.

On-site Fire Station

The proposed project will include a fire station to house an on-site fire brigade to respond to emergencies at the facility. The fire station will be designed to house any emergency response vehicles that will be used to transport the emergency response team's protective equipment, rescue equipment and first aid supplies. The fire station will also house other supplies required to respond to an incident at the site such as a foam generator and foam. The fire station would also act as a secondary command post during an emergency within the plant site.

The plant will include an emergency alarm system that will communicate to plant personnel that an unplanned, undesirable incident has occurred or is about to occur. Anyone, at any time, may actuate the emergency alarm system by tripping emergency alarm boxes (EAB) which will be located throughout the plant. The plant will also include fixed hazardous vapor monitors which will also trigger emergency response actions. When help is needed due to an incident, such as fire, vapor release, spill, injury, sickness, accident, etc., it is expected that within three to four minutes of actuating an EAB the emergency response team will be on the scene.

The Emergency Response Vehicle will be parked just inside the fire station. The vehicle will be equipped with supplies such as, Self-Contained Breathing Apparatus (SCBA), first aid kit, oxygen kit, back boards, stretcher, oxygen/explosive gas monitors, electrical rescue kit, bolt cutters, positive pressure fan, blankets, material safety data sheets, and HazMat response equipment.

The proposed project will include a comprehensive fire suppression system that will include;

- ✓ **Fixed Foam System** (foam used for fire suppression). Its role is to cool the fire and to coat the fuel, preventing its contact with oxygen, resulting in suppression of the combustion. The fixed foam system will be designed in accordance with NFPA 11 for the methanol storage area. The fixed foam system will include a foam storage tank, located outside the methanol storage tank containment dike, with an estimated 3,300 gallons of foam stored.
- ✓ **Portable Foam Generators.** A portable foam generator will be stored inside the fire station and have the capacity to discharge 60 gpm of foam. The portable unit will

be designed to be transported by fork truck. Sufficient foam concentrate (at least 225 gallons) will be kept on hand to operate the foam generator for at least 60 minutes.

- ✓ **Plant Fire Water System.** The plant fire water supply will be stored in the fire water pond located at the North West end of the plant, with an estimated capacity of five million gallons. The fire water pond make-up flow of about 300 gpm will be supplied by the blow down flows from cooling towers. Two fire water pumps, one driven by a diesel engine and the second driven by an electric motor, will take water from the pond. The plant will be designed to have 100% coverage of fire water, with fire hydrants and monitors throughout the facility. Hose houses will be installed next to each fire hydrant.
- ✓ **Deluge System.** Deluge systems are piping configurations with open spray nozzles. Water will be supplied to the piping network by the automatic trip of a single valve. When the deluge valve opens, water will flow through each nozzle until the system is manually closed off. The deluge system serves two purposes during a fire. First, it reduces the temperature in the fire area. In some cases, it will lower the temperature below the ignition temperature required for the burning material but a deluge system will seldom extinguish a fire. If the fire must be extinguished, it is done with dry powder extinguishers or hose lines where copious amounts of water can be directed on the fire. Second, and most important, the systems are designed so vessels and structure supports are water sprayed. By keeping the structure cool, its strength is maintained and it will not collapse during a fire situation. By keeping vessels cool, it prevents possible metal fatigue and over pressure when exposed to flame.
- ✓ **Fire Extinguishers.** In accordance with NFPA 10 and 29 CFR 1915.507, hand-held portable extinguishers will be located throughout the facility.

As part of the emergency response pre-plan, and the emergency response training required for the responders, NWIW will have the capabilities to respond to different types of emergencies or incidents beyond fires and explosions, such as:

- ✓ **Hazardous Material Leak or Spill** – Responders will identify and control the released material. NWIW will have a pre-plan in place, to ensure all required resources, including having all required emergency response equipment on-site. NWIW will inform local and state authorities in the event of a hazardous material release.
- ✓ **First Aid** – All Emergency response members will receive "Medic First Aid" training. This is a state-approved training program which consists of eight hours of basic and four hours refresher training annually. All emergency response members will know the location and will be trained in the use of on-site first aid equipment. The on-site incident commander will notify the control room, to initiate a 911 call, to inform the dispatcher of the type of injury that needs medical attention. If an injury results from chemical exposure, a Safety Data Sheet (SDS) will be sent with the injured person inside the ambulance. Part of NWIW emergency response plan will be to ensure the local hospitals are notified and have a copy of all major chemicals SDSs (included as part of Community Right-to-Know requirements).
- ✓ **Bomb Threat** – Upon initial receipt of a bomb threat, NWIW will notify the local police and fire departments of the threat. NWIW employees that are involved will be notified of any threat and evacuation of the plant site.

- ✓ **Police/Security Emergencies** – During operations, NWIW will be a secure site, which involves having security guards, cameras throughout the facility, and secure access points for employees. NWIW will require all of its employees to obtain a Transportation Workers Identification Card (TWIC), which involves passing a federal government background check. The Port of Kalama will provide the security plan and the security for the dock. In the event of an unauthorized entry, NWIW will not only notify the police and the Port; they will secure the site to ensure the safety of community and plant personnel.

QUANTITATIVE RISK ANALYSIS

Potential release scenarios were identified in a preliminary Hazard Identification screening exercise for further, in-depth analysis through a Quantitative Risk Analyses (QRA). The QRA utilized quantitative tools to assess the consequences of the identified release scenarios. Specific scenarios selected for QRA study included natural gas, synthesis gas, methanol (both liquid and vapor), and ammonia. See Quantitative Risk Assessment, Final Report, February 2016.

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