White Paper

Using Nitrogen Gas to Remove Corrosive Gases from Fire Sprinkler Water

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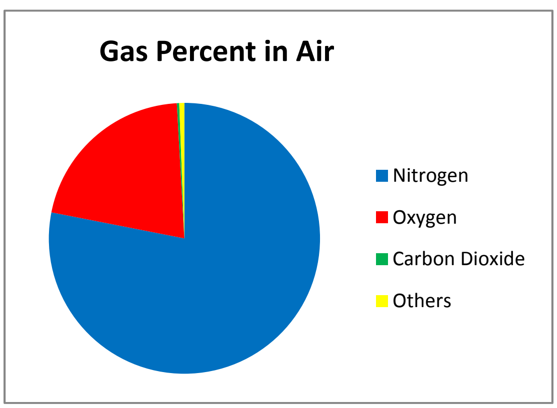
There are three primary gases that make up the air that we breathe: nitrogen, oxygen and carbon dioxide. Our bodies metabolize oxygen in the respiration process and exhale carbon dioxide. The nitrogen gas that we inhale is exhaled as an unreacted, unchanged inert gas.

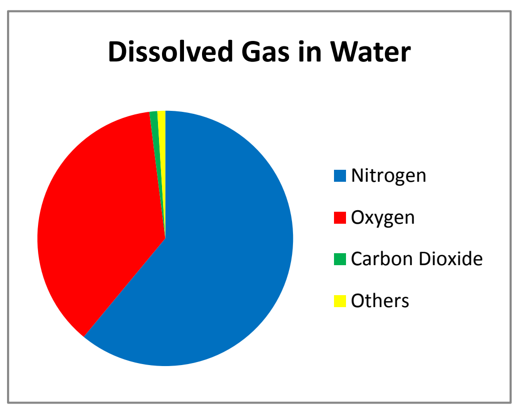
When these three gases come in direct contact with water, a small percentage of each gas will dissolve in the water. For example, at atmospheric pressure and room temperature about 8 – 10 parts per million of oxygen will dissolve in fresh water. The amount of each gas that dissolves in water is affected by four factors:

1. Percentage of the gas in the space above the water
2. Solubility of the gas in water
3. Pressure of the system
4. Temperature of the system

In general, the higher the pressure, the more gas will dissolve in water. Conversely, the higher the temperature, the less gas will remain dissolved in water.

Gas	% Concentration in Air	% Concentration in Water
Nitrogen	78.1	61.0
Oxygen	21.0	37.0
Carbon Dioxide	0.03	1.0
Other Inert Gases	0.06	1.0





Oxygen gas is two times more soluble in water than nitrogen gas and carbon dioxide is many times more soluble than either oxygen or nitrogen. As a result, the ratio of dissolved gases in water changes significantly compared to the composition of the gases in the air. This highlights the impact of solubility on the amount of dissolved gas that can be found in water.

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Solubility of Gases in Water

Gas	Solubility at 68ºF (g/100g H_2O)	Solubility at 104ºF (g/100g H_2O)
Carbon Dioxide	0.170	0.0500
Oxygen	0.004	0.0030
Nitrogen	0.002	0.0015

Dissolved Gases and the Corrosion Process

In order for gases to become available to react with metals in the corrosion process, they **must dissolve** in the water. Water provides the necessary conduit to allow a metal to give up its electrons. In the process the metal is converted into a water soluble ion that leaves the metal surface and dissolves in the water. The metal ion generally reacts with other ions in the water to form a salt. The most common salts that are formed as corrosion by-products are the metal oxides. In fire sprinkler systems the most common iron salt is iron oxide which is commonly known as rust.

Anodic Reaction (corrosion occurs): $Fe^o \rightarrow Fe^{+2} + 2e^-$ iron becomes a water soluble ion

Oxidation of Iron (precipitation of solids):

$2Fe^o + O_2 + 2H_2O \rightarrow 2Fe(OH)_2$
$4Fe(OH)_2 + O_2 \rightarrow 2Fe_2O_3 + 4H_2O$
$2Fe_2O_3 + 2Fe(OH)_2 + O_2 \rightarrow 2Fe_3O_4 + 4H_2O$

As iron is oxidized in water it goes through three transitions from iron II hydroxide $Fe(OH)_2$ to iron oxide Fe_2O_3 (hematite) and finally to iron oxide Fe_3O_4 (magnetite). With each transition the oxygen consumes electrons as iron goes from the zero oxidation state of the base metal to the ferrous oxide state (+2) and finally to the ferric oxide state (+3). All of these oxides of iron are completely insoluble in water and will form a precipitate.

Carbon Dioxide

When **carbon dioxide** (CO_2) dissolves in water, it reacts with the water to form a weak acid called carbonic acid. Carbonic acid in water reacts with metals that the water contacts to initiate a corrosion reaction.

Carbon Dioxide Dissolves in Water: $CO_2 + H_2O \rightarrow H_2CO_3$ carbonic acid

Carbonic Acid Dissolves:

$H_2CO_3 \rightarrow H^+ + HCO_3^-$
$HCO_3^- \rightarrow H^+ + CO_3^=$ yields 2 hydrogen ions

Anodic Reaction: $Fe^o \rightarrow Fe^{+2} + 2e^-$ iron becomes a water soluble ion

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Cathodic Reaction: $2H^+$ (from the acid) + $2e^-$ → H_2 gas evolves

Electrochemical Reaction: $2Fe^o + 2H^+ + O_2 + 2H_2O \rightarrow H_2 + 2Fe(OH)_2\downarrow$ iron hydroxide precipitate

Oxygen

When **oxygen** (O_2) dissolves in water it becomes available to react with metals that come in contact with the water. The dissolved oxygen in the water will immediately react with the free iron (or zinc in the case of galvanized pipe) it contacts on the pipe walls according to the following equations:

Anodic Reaction: $Fe^o \rightarrow Fe^{+2} + 2e^-$ iron becomes a water soluble ion

Cathodic Reaction: $½O_2 + H_2O + 2e^- \rightarrow 2OH^-$ oxygen creates demand for e-

Electrochemical Reaction: $Fe^o + ½O_2 + H_2O \rightarrow Fe(OH)_2\downarrow$ iron hydroxide precipitate

Nitrogen

When **nitrogen** (N_2) dissolves in water it simply exists as a dissolved component in the water. Since it is essentially inert, it does not react with metals, with the water or with any of the soluble components in the water. Nitrogen does not contribute to corrosion of any metal.

Henry's Ideal Gas Law

Henry's gas law states the following:

> **At a constant temperature, the amount of a given gas dissolved in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid.**

By increasing the percentage of nitrogen in the air space over water in a closed pipeline, it is possible to bring about two results:

1. Decrease the percentage of oxygen in the space above the water
2. Reduce the amount of oxygen that is dissolved in the water

In effect, by continuing to increase the percentage of nitrogen in the space over the water, oxygen can actually be stripped out of the water. When this is accomplished, the oxygen is no longer available to corrode the metal surfaces of the pipe. This phenomenon is at the heart of the process of using nitrogen gas to control corrosion in fire sprinkler systems. This approach to corrosion control works in both residual amounts of water that are trapped in dry pipe fire sprinkler systems and with water contained in wet pipe fire sprinkler systems.

The objective of adding nitrogen gas to fire sprinkler piping that contains water is to displace the oxygen and replace it with nitrogen. For each percent of nitrogen that is added to the space above the water, the corresponding amount of oxygen is reduced. If the nitrogen in the space is increased to 97-99% the percentage of oxygen drops proportionately to 1-3%.

If the system is vented during nitrogen addition, the concentration of oxygen in the ***gas phase and in the water phase*** can ultimately be reduced to a point that is equivalent to the concentration of oxygen in the injected gas. Oxygen that is replaced by nitrogen before it reacts with the iron on the pipe walls cannot cause corrosion. Water that has been stripped of its dissolved gases, particularly oxygen and carbon dioxide, is **no longer corrosive**. So even if water remains in the pipe, if it is under an atmosphere that is 97-99% nitrogen it will be essentially non-corrosive water.

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Engineered Corrosion Solutions, LLC is a corrosion management consulting firm that offers fire sprinkler system assessment and analysis coupled with design services and a full suite of corrosion management strategies that include equipment and integrated devices for controlling corrosion in water-based wet, dry, and preaction fire sprinkler systems. We understand the science of corrosion in fire sprinkler systems in a complete variety of different settings from parking structures to warehouses to clean rooms to data centers.

Engineered Corrosion Solutions, LLC offers proprietary dry pipe nitrogen inerting technology (DPNI) and wet pipe nitrogen inerting technology (WPNI), which includes the ECS Protector Nitrogen Generator, Pre-Engineered Skid Mounted Nitrogen Generator, Gas Analyzers, SMART Dry Vent, Two (2) Wet Pipe Nitrogen Inerting Vents and the industry's first real time in-situ corrosion monitoring device the ECS In-Line Corrosion Detector. Finally, we offer the first comprehensive remote corrosion monitoring system that provides live validation of the corrosion control strategy that is in place within your facility.

For complete information about the entire line of corrosion management products and services and the complete list of downloads of White Papers, FAQs, installation schematics and product spec sheets please visit the Engineered Corrosion Solutions website at ecscorrosion.com or contact us at (314) 432-1377 and one of our engineers will assist in personally answering any of your questions.

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