This application is focused on measuring hydrogen chloride (HCl) and chlorine (Cl₂), which are corrosive materials. There are many metal alloys such as Inconel®, Hastelloy®, and Monel®, with different corrosion resistant properties that can be considered depending on the application.

**CHLORINE**

Chlorine is a chemical element in the halogen group with a high electron affinity. It is a strong oxidizing agent, which is a concern when measuring chlorine itself or other chemicals, such as water (H₂O), in chlorine. The reaction of chlorine with hydrogen or hydrogen-containing compounds can be considered an oxidation reaction and is likely to produce HCl. The issues associated with HCl sampling and measurements are discussed below.

Chlorine gas is a toxic gas and is used to sterilize drinking water, disinfect swimming pools and to manufacture many consumer products such as paper, dyestuffs, textiles, petroleum products, medicines, antiseptics, insecticides, foodstuffs, solvents and plastics, especially PVC.

100% dry chlorine at temperatures up to 70°C may be used with stainless steels, but moist chlorine is considered unsatisfactory as it removes protective oxide layers from most steels. Therefore, moisture measurement is vital in chlorine plants.

Even titanium is not fully resistant to chlorine. Hastelloy is resistant to a variety of concentrations of moist chlorine. Inconel has been found effective for chlorine gas mixtures at elevated temperatures. Monel (often Monel 400, a copper-nickel alloy) is not so resistant to wet chlorine.

Each application in chlorine environment could be different and has to be looked at on its own metrics. Special metals such as those above are expensive, especially if measuring cells and sample components are both required to be specially manufactured. So, compromise solutions, where occasional replacement of less resistant materials will be necessary, may be more customer-acceptable.

When measuring chlorine or other gases excluding moisture, use a sample chiller to dry the gas if the water concentrations are in percent or high parts-per-million (ppm) levels. For longer lifetimes of metal sample system components, reduce moisture even further by using chemical driers such as a molecular sieve.

In chlorine plants, moisture measurements are often made to ensure they do not rise above (typically) 15 ppmv, because significant corrosion may occur above this level.

Where possible, using halogenated plastics such as PVDF for sample tubing is recommended.

Significant levels of ammonia, acetylene, hydrogen, or fuel gas may react explosively with chlorine.
CHLORINE MEASUREMENT

Chlorine, being a symmetric molecule, does not absorb in the infrared, but can be measured in the UV spectrum where AMETEK IPS-4 analyzers have been used for measuring Cl₂ in gas mixtures, as well as ethylene dichloride (EDC).

HYDROGEN CHLORIDE

Hydrogen chloride is a diatomic molecule, consisting of a hydrogen and a chlorine atom connected by a single covalent bond. Since the chlorine atom is much more electronegative than the hydrogen atom, the covalent bond between the two atoms is quite polar. Consequently, the molecule has a large dipole moment with a negative partial charge δ⁻ at the chlorine atom and a positive partial charge δ⁺ at the hydrogen atom, which make HCl highly polar and soluble in water and other polar solvents.

Upon contact, H₂O and HCl combine to form hydronium cations H₃O⁺ and chloride anions Cl⁻ through a reversible chemical reaction:

\[ \text{HCl} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^- \]

The resulting solution is called hydrochloric acid and is a strong acid. Even in the absence of water, hydrogen chloride can still act as an acid. Because of its acidic nature, hydrogen chloride is corrosive in the presence of moisture.

Dry HCl is not generally a concern to us from a sampling viewpoint. It will react easily with water to form hydrochloric acid, which is a problem when it condenses. It is important to keep a sample containing both HCl and H₂O above the acid dew point which means heating the sample lines and parts in contact with the sample, efficiently.

SUMMARY

Where HCl and moisture are present, the sample in the gas phase should be kept above the acid dew point temperature. Temperatures above 100°C will usually be more than adequate.

Condensed HCl reacts with most metals forming hydrogen (and denaturing the metal to a salt). Stainless steel is not resistant to hydrochloric acid. Hastelloy C is largely resistant but, for long-term reliability, the concentration of HCl should be as low as possible. As with chlorine, plastics are much more resistant than metals, including PP, PVC, PTFE, PVDF, and PFA.

CONCLUSION

The issue with these measurements is potential corrosion of the analyzer and sample conditioning system. Clearly, the lifetime of these components is a primary customer question and varies depending on the concentrations, and stream operating conditions. The table below summarizes the solutions AMETEK recommends for analyzing some of the more common corrosive materials.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry chlorine</td>
<td>UV Photometer</td>
</tr>
<tr>
<td>Wet (&gt;15 ppm H₂O) Cl₂</td>
<td>Use corrosion-resistant plastics or metals where possible - UV</td>
</tr>
<tr>
<td>Dry HCl</td>
<td>IR Photometer (Note that low ppm levels are difficult)</td>
</tr>
<tr>
<td>Wet (&gt;15 ppm H₂O) HCl</td>
<td>Either dry or raise above acid dew point temperature Corrosion-resistant materials will extend lifetime IR Photometer (Note that low ppm levels are difficult)</td>
</tr>
<tr>
<td>Water in chlorine</td>
<td>Sampling as for wet chlorine IR Photometer</td>
</tr>
<tr>
<td>Water in HCl</td>
<td>Raise above acid dew point temperature Corrosion-resistant materials will extend lifetime IR Photometer</td>
</tr>
</tbody>
</table>

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