Mercury Seminar

# The Interaction of Mercury with Metal Surfaces – Engineering Implications

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## Presentation Summary

Mercury, in several chemical forms, is a natural component of oil and gas. Reservoir concentrations vary from ppt(w) to ppm(w) depending on geology. In some parts of the world, mercury is present in gas reservoirs at high concentrations. For example, natural gas produced from reservoirs found in the Gulf of Thailand exhibits concentrations of elemental mercury that typically exceed 100 µg/Sm$^3$ and some reservoirs are close to saturation (several hundred µg/Sm$^3$, depending on reservoir pressure and temperature) . The world average for elemental mercury in gas is not known with statistical certainty but thought to be less than 10 µg/Sm$^3$. Historically, high mercury reservoirs have not been seen in the Gulf of Mexico, but that situation may change as deeper reservoirs are brought on stream.

When reservoirs containing mercury are produced, elemental mercury ($Hg^0$), and the other forms that may be present in the reservoir, partition to separated phases (oil, gas and water) and travel throughout production and processing systems. When produced and processed fluids are cooled, mercury can condense to liquid phase in heat exchangers, separators and coolers. Mercury, when present as a vapor component of gas, as a dissolved constituent of oil and condensate or as a liquid metal suspended in produced fluids, interacts with the materials of construction of processing equipment. Detrimental interactions of mercury with aluminum have been known and studied for some time but interactions with steel and stainless steel surfaces have not been carefully investigated. The MTS presentation will summarize the current state of knowledge regarding the interaction of mercury, as found in oil and gas, with engineering alloys.

**Aluminum Heat Exchangers** – Cracking of aluminum welds by mercury is a potential catastrophic failure mechanism for aluminum heat exchangers. Mercury in liquid phase, under certain well-defined conditions, can cause liquid metal embrittlement (LME) of susceptible aluminum metallurgy or amalgam corrosion (AMC) of aluminum heat exchanger core fins. Both modes of attack can lead to sudden loss of pressure containment. Safe operation of aluminum equipment requires a detailed understanding of the mercury/aluminum surface interactions and cognizance of the necessary conditions for crack initiation. Quantitative risk analysis procedures should be applied if aluminum heat exchangers become contaminated by mercury. The risk analysis procedure involves computational prediction of mercury deposition, inspection of critical areas, detailed assessment of metallurgy and fabrication, strain analysis of temperature changes during trips and shutdowns and oxide fatigue analysis. Differentiation of leak and rupture failure modes can be accomplished by calculating amounts of deposition and by locating mercury deposits as determined using a focused inspection.

**Steel Pressure Vessels and Pipelines** – Steel surfaces react with mercury in produced fluids and accumulate significant amounts. Measurements indicate that surface concentrations on the order of 2-10 $g/m^2$ may be possible. The mechanisms by which mercury is absorbed by steel are not known conclusively but reaction with grain boundary elements or compounds is the most likely postulate. Mercury modified steel surfaces display chemical properties that differ from surfaces that do not contain mercury.

Pipelines in Asia sometimes carry gas containing elemental mercury at very high concentrations. Cooling and compression can produce liquid mercury deposits on the bottom of the pipe. The presence of liquid phase elemental mercury in the pipe may be discovered by pigging operations. A question of interest is whether liquid elemental mercury that sits on the bottom of the pipe provides galvanic acceleration of the naturally occurring corrosion processes in the pipeline.

Tanks on ships that carry liquid cargos containing mercury become contaminated by mercury dissolved in the hydrocarbon liquid they carry. The contamination consists of sludge that settles to the bottom of tanks, mercury in the exterior non-metallic surface layers of the tanks (corrosion scale, organic material, sometimes coatings), and by mercury possibly “in” or “on” the steel itself. Simple cleaning and decontamination treatments often suffice to allow safe inspection of a tank but they may not completely retrieve mercury in steel that is available to re-enter the atmosphere or to enter clean (low mercury) cargoes. An important question is what can be done to enhance egress of mercury from contaminated steel. Removal of mercury from steel surfaces can be accomplished but surface treatments may be ineffective to render steel completely mercury-free or decontaminated to the degree needed to prevent contamination of clean cargos.

**Copper Alloys in Refineries** – Running high mercury crudes in refineries can lead to several negative consequences, some of which involve materials. Cracking of Monel trays or overhead components in primary distillations is one example. Cracking of brass heat exchanger tubes is another. Predicting circumstances likely to place liquid mercury on copper alloy components requires understanding the mercury species that may be in crude oil, their distillation behavior and condensation temperatures when fluids cool. Mercury that absorbs into steel piping may present a hazard due to the possibility of worker inhalation of mercury vapor when pipes are welded or cut.

**Mercury on Steel Surface**