Finding the Right Fit for Your Mercury Vapor Detection Needs

AMETEK Arizona Instrument

The toxic effects of mercury vapor on human health have been well documented throughout the years. Agencies such as the Environmental Protection Agency (EPA) regulate and set strict limits on the amount of mercury vapor which can be present in air: 1 µg/m^3 for residential properties and 25 µg/m^3 for industrial properties. To ensure compliance with these regulations, industrial hygienists, environmental agencies, and first responders and clean-up crews rely on portable instrumentation to measure mercury vapor levels on site.

A number of methods have been developed to measure mercury vapor

There are many different technologies which can be used to detect mercury, and some may be more appropriate in certain environments than others. This paper will explain differences between three common methods of mercury detection: gold film sensors, atomic absorption spectroscopy and atomic fluorescence spectroscopy.

Gold film sensors were the first truly reliable instruments for lo and high-end mercury detection with few interferences that can be filtered, while atomic absorption spectroscopy is useful for low level mercury analysis but has many different types of interferences that cannot be filtered. Atomic fluorescence spectroscopy, the most common method used in benchtop mercury analysis, is by far the most reliable with its strict parameters for mercury analysis. By focusing on how these different technologies work, what interferences they have and how sensitive they are, you will gain insight into which method of mercury detection would be most suitable for your unique application.

Gold film sensor analyzers offer portable and fixed-point solutions that are both accurate and precise for low-level mercury vapor analysis

Gold film sensors were the first reliable forms of mercury detectors due to gold's affinity for elemental mercury. Coupling this affinity with gold's inherent electrical conductivity, AMETEK Arizona Instrument created the Jerome 431-X and Jerome J405 mercury vapor analyzers.

When a mercury rich air sample passes over a thin gold film, the mercury deposits on the gold and changes the electrical resistance of the foil. This change in resistance is directly proportional to the mass of mercury vapor taken from a known volume of air, which can be calculated in mg/m^3. If the gold becomes saturated over time, the instrument offers a regeneration feature that bakes the foil at an elevated temperature at which the mercury deposits are vaporized and collected in the scrubber. The schematic to the right demonstrates how this works.

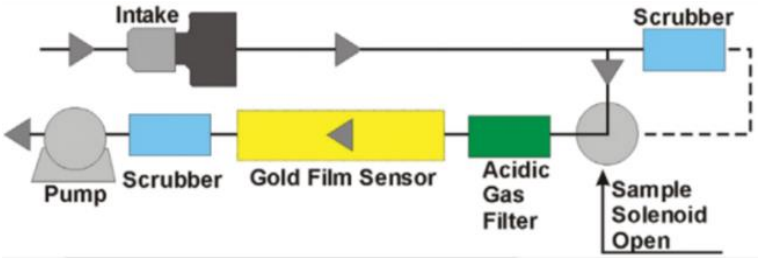

Illustration of Gold Film Sensor Technology

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Jerome J405 and 431-X gold film mercury vapor analyzers

AMETEK Arizona Instrument has been manufacturing its proprietary gold film sensor mercury vapor analyzers for over 30 years, during which time the technology has proven to be effective for diverse applications and detection limits. The Jerome® J405 has many updates from the older 431-X model, but both are useful for different detection limits.

Jerome J405

The Jerome® J405 is the latest gold film analyzer from AMETEK Arizona Instrument. It is equipped with an on-board data logging system that can store up to 20,000 data points and has an optional USB data communication port.


Jerome 431-X

The J405 has a detection range from 0.5 µg/m^3 to 999 µg/m^3 with a resolution of 0.01 µg/m^3. Because it can read below 1 µg/m^3, the J405 allows you to adhere to both industrial and commercial mercury regulations. Both the 431-X and J405 offer continuous modes for surveying potential hot spots in the field and are robust enough to withstand daily use in challenging environments.

The Jerome 431-X has a detection range from 3 µg/m^3 to 999 µg/m^3 with a resolution of 1 µg/m^3. Although this detection limit falls just short of the EPA residential specification, it is well below the industrial specification of 25 µg/m^3. This instrument is well suited for industries concerned with exposing their employees and surrounding residents to harmful mercury vapor.

Interferences

Gold film interferences include hydrogen sulfide, ammonia and chlorine. An internal acidic gas filter eliminates H_2S as an interference. External ammonia and chlorine filters can also be used to reduce the concentration of those gases in the sample before it reaches the sensor, significantly decreasing those interferences.

Environments of potential interference

Since only one external filter can be used during analysis, a gold film sensor mercury vapor analyzer would not be ideal in an environment that is rich in both ammonia and chlorine. Only one of the two would be filtered out, leaving the other to interfere with the test. Another potential environment that may not suitable for gold film sensing technology is one that is completely void of oxygen. However, since most environments that require mercury vapor analysis are also areas where people exist and can be in danger of being exposed, it is unlikely that the environment would be completely devoid of oxygen.

Atomic absorption mercury vapor analyzers are useful for low-level detection but are prone to interference from a number of compounds

Cold Vapor Atomic Absorption Spectroscopy (CVAAS) is another method used for mercury detection. In mercury CVAAS, a light source of known wavelength and intensity (~254nm, middle ultraviolet spectrum) is radiated through a sample of air where the light eventually encounters a detector. If mercury is present, electrons from within the mercury atoms will absorb some of this energy from the light source. The difference between the initial energy of the light source and the energy measured by the detector gives you an indirect

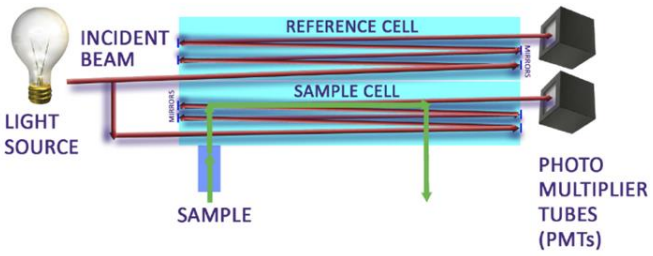

Illustration of CVAAS

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measurement of how many mercury atoms were initially present. The schematic above demonstrates the path of the radiated light. Several mirrors and photo multiplier tubes (PMTs) are used to amplify the signal difference.

Because atomic absorption spectroscopy measures on the atomic level, the sensitivity range is lower. Portable mercury CVAAS analyzers such as the Nippon® EMP-2 and the Lumex® 915 M claim to offer a low-end sensitivity of 0.1 µg/m^3 and 0.002 µg/m^3, respectively, both of which fall below the EPA regulations for residential specifications. However, there are many potential interferences to CVAAS that can skew results. Moreover, the delicate placement of the internal mirror system may not be robust enough to be used in a hazmat situation.

Interferences

Atomic mercury in CVAAS is not the only chemical species to absorb this wavelength. Many other substances, some of which are listed in the chart to the right, also absorb this wavelength and lead to falsely positive readings. It is important to note that 'hydrocarbons' is a very broad description of many different forms of organic compounds that can cause interferences.

CVAAS Interferences	
Inorganic	**Organic**
Chloride/chlorine	Dust
Sulfides	Smoke
Copper	Hydrocarbons*
Tellurium	Some organic solvents
Hydrocarbons*	
Benzene	Acyclic hydrocarbons
Ethylbenzene	Polycyclic aromatics
Toluene	Petroleum hydrocarbons
Xylene	

Along with these interferences, it is also possible for the reflective mirrors within the instrument to become dislodged, soiled by material condensation, including humidity, or degraded by surface corrosion.

Environments of likely interference

When using atomic absorption spectroscopy to detect low levels of mercury contamination, it is imperative that your instrument is detecting a true signal and not just 'noise' from other chemical species. An example of a common low-level mercury analysis application is the process of decommissioning laboratories and hospitals.

When old buildings are abandoned for an extended period of time, they tend to collect a fair amount of dust and construction debris. Before demolition can begin, the entire square footage of the building must be below a certain limit of mercury vapor. It is difficult to confidently measure low-end mercury vapor over dust and smoke if the environment in which you are sampling is substantially contaminated with these particulates.

Mercury analysis in the petroleum processing industry is also quite common. Industrial hygienists must monitor the naturally occurring mercury levels emanating from crude oil wells and processing plants. Common interferences with low-level mercury analysis using CVAAS in this industry are petroleum hydrocarbons. Crude oil aromatic hydrocarbon vapors, along with the toluene/xylene co-solvents used in processing, are major sources of interferences for atomic absorption spectroscopy. Many double bonds and resonance electron structures within these hydrocarbons absorb ultraviolet light and would be measured as mercury vapor. Because of these interferences, atomic absorption spectroscopy is not a suitable fit for mercury vapor analysis in this industry.

Atomic Fluorescence Mercury Vapor Analyzers something something something

Although atomic fluorescence and atomic absorption are related, they are very different. Cold vapor atomic fluorescence spectroscopy (CVAFS) is an improvement upon the traditional CVAAS. When a mercury atom absorbs the energy from the UV wavelength, an electron transitions from a stable ground state to an unstable, excited state. This excitation event describes atomic absorption as discussed in the previous section.

If that energy source is removed, however, the excited electron returns to its ground state and, in doing so, a photon of light is emitted due to a loss of potential energy. This fluorescence of light is often unique for various chemical species. Mercury in particular absorbs light at 254 nm and fluoresces light at the same wavelength. Because the wavelength of light absorbed and emitted are at the same, this form of fluorescence is referred to as resonance fluorescence. Chemicals such as chlorides, sulfides and hydrocarbons, all of which are interferences with CVAAS technology, absorb light at 254 nm but do not fluoresce at 254 nm and are therefore not interferences with the advanced technology of the Jerome J505 CVAFS mercury vapor analyzer.

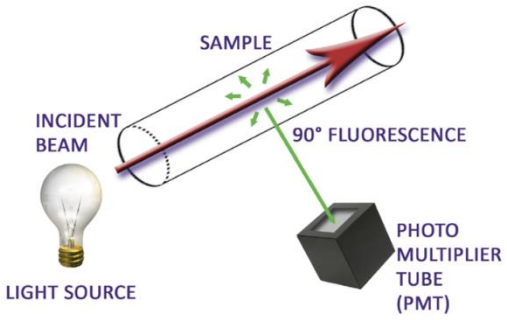

Illustration of CVAFS

Jerome J505 Atomic Fluorescence Spectroscopy Mercury Vapor Analyzer

The Jerome® J505 atomic fluorescence spectroscopy mercury vapor analyzer is the first hand-held instrument of its kind. Utilizing the unique resonance fluorescence of mercury, AMETEK Arizona Instrument designed an instrument that can detect ultra-low concentrations of mercury vapor while minimizing the interferences involved with atomic absorption alone.

The J505 has a detection range from 0.05 µg/m^3 to 500 µg/m^3 with a resolution of 0.01 µg/m^3, which is well below the EPA, OSHA and NIOSH standards for ultra-low mercury vapor specifications. Moreover, the J505 does not share any common interferences with traditional CVAAS technologies.

Jerome J505

The J505 is a robust analytical tool that can be used in a variety of fields. There are no amplifying mirrors such as in CVAAS units and, unlike gold film sensor instruments, no regeneration is ever required. The instrument stores up to 10,000 tests on its internal memory board, which can easily be downloaded from a USB port. Like the J405 and the 431-X, the instrument can perform one-time or continuous sampling and is available for purchase or rent.

Although other chemical species may still absorb the energy from the light source, the J505 only detects the specific wavelength that is fluoresced radially from an air sample. The amount absorbed is inconsequential because the mercury concentration is revealed by the amount of light fluoresced at a 90° degree angle. This technology is a more direct method of analysis since the instrument is quantifying individual photons of excited mercury atoms in a sample. The diagram below outlines how this done without having to amplify the signal through a series of mirrors.

Interferences and environments of likely interference

Because the J505 only measures radial resonance fluorescence of 254 nm, only a chemical species that is excited at 254 nm and then fluoresces at 254 nm will be measured. This stringent criteria eliminates nearly all sources of interference, ensuring you get accurate and repeatable results in the field.

The only positive interference ever to be reported is a high concentration of acetone vapor. Fortunately, most areas of potential mercury contamination are void of such levels of acetone vapor. Industries in which large quantities of acetone are used as a solvent could potentially present environments in which the J505 might have difficulty exclusively detecting mercury vapor. Such environments could potentially be encountered in certain types of chemical processing plants or paints and coatings settings.

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Choosing the correct mercury vapor analysis technology is essential

While several types of technology exists to detect mercury vapor, no single method can be said to be the best for all situations. However, some technologies have clear advantages over others. Understanding how the available technologies behave in your unique application setting is a key factor in making the decision that is right for you.

Gold film sensor analyzers are a proven, reliable form of low-level and high-level mercury detection. They have few interferences and are lightweight, durable and easy to use. Atomic absorption mercury vapor analyzers are useful for low-level analysis, but they are prone to interference from a number of compounds and are less durable than their gold film counterparts. Atomic fluorescence mercury vapor analyzers are rugged, reliable and ideal for a multitude of mercury testing situations. The detection principle eliminates interferences common to other detection methods and increases reliability of results.

If you have any questions or would like to learn more about our Jerome line of mercury vapor analyzers for use in industrial hygiene, hazmat/first response, environmental monitoring or mining, contact us online or give us a call at (602) 313-0839.

Appendix

Elemental mercury (Hg) is the only metal on the periodic table that remains in its liquid phase under standard temperature and pressure (STP), giving it the appropriate nickname of 'quicksilver.' Many of us see mercury as a shiny silver puddle, but it can be found in many other forms in our everyday lives. Fluorescent lighting, antique switches, dental fillings and thermometers are just a handful of items that contain mercury, not to mention its many uses in industrial processing (chlorine, cement, and gold purification). Most of these items and processes are able to minimize mercury exposure, but accidents can and do happen.

Elemental mercury has an unusually high vapor pressure for a metal - 0.0018 mm at room temperature, which corresponds to approximately 2.4 parts per million (ppm). Studies have shown that skin contact and ingestion are dangerous methods of exposure, but inhalation of mercury vapor is perhaps the most lethal. Symptoms of mercury exposure include seizures, dementia and in some cases even death. Because of these risks, regulations have been developed to limit the amount of mercury that people can be exposed to. These regulations also include guidelines for cleaning up mercury, should an accident occur.

Currently, the time weighted average limit for mercury varies depending on regulatory agency. For your convenience, we have listed the exposure limits in the table to the right.

Regulatory Agency	Exposure Limit
OSHA	0.1 mg/m^3
NIOSH and MSHA	0.05 mg/m^3
ACGIH	25 mg/m^3
EPA and ATSDR	0.001 mg/m^3

Because these agencies all differ in application and exposure limit, the Environmental Protection Agency (EPA) has a standard minimum limit of mercury exposure to 1 $\mu g/m^3$ for residential and 25 $\mu g/m^3$ for industrial properties.

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