Test and Measurement Coalition

RoHS Scope Review of Category 9 Products

Mercury Dossier

1. Use of Mercury in test and measurement equipment

1.1 General

There are several uses of mercury and its compounds in electrical and optical equipment because of its special properties including liquid metal state at room temperature and its high electromagnetic frequency of radiation compared to other metals.

- In manometers, which measure and control pressure;
- In thermometers;
- In electrical and electronic switches;
- In fluorescent lamps;
- In batteries (as mercuric dioxide); and
- In sensors

Usage has been reduced considerably in the interest of safety and the environment wherever cost-effective and technically equivalent substitutes have been found for applications of mercury. Mercury in the test and measurement (T&M) sector has been greatly reduced in the last decade and, excluding sensors, is in limited use in switches (including relays) and display lamps. The actual amount in use is small. Five major companies in the T&M sector estimate their products account for no more than 14 grams in switches and 340 grams in display lamps shipped into the EU annually.

Further information on uses of mercury including dental and other medical applications can be found at http://www.chem.unep.ch/mercury/Report/Final%20Assessment%20report.htm

A simple introduction to switches and relays is available at http://www.cougarelectronics.com/pdf/reed_relays.pdf

1.2 Technical characteristics

1.2.1 Lamps:

Mercury has the ability to enable electron/photon interaction processes at much lower energy levels compared to other metals. This property has been used in mercury lamps in education, research and in low energy fluorescent lamps for many years.

Photon energy from a mercury lamp hitting a zinc plate will release electrons from the zinc and this is a common demonstration of the photovoltaic effect due to the photon energy exceeding the work function of the zinc. Tungsten filament lamps will not show the effect independent of their brightness because the photon energy produced is proportional to the electromagnetic frequency of the light. (Mercury electromagnetic frequencies are in the violet/ultraviolet spectrum compared to the lower frequencies of filament lamps.)

Mercury lamps consume lower energy than other lamps for equivalent light output. They are used as lamps for room lighting, backlighting in liquid crystal displays (LCDs), laser printers and photocopiers. LCDs are a common display type in T&M equipment. No other commercially available backlighting technology gives equivalent brightness and contrast ratio. LCDs with lamps having 3-5 milligrams of mercury have largely replaced cathode ray tube displays in our sector. Other new mercury free display lighting possibilities have been announced but we anticipate it will be several years before a cost-effective suitable alternative becomes available. There is great commercial incentive to bring mercury free display lighting to market given the widespread usage of mercury lamps in many domestic and industrial products.

1.2.2 Switches and Relays:

Using the properties of low resistance and surface tension, mercury wetted switches and relays have been used in the past. Generally they have the disadvantage of being directional in operation and are sometimes called tilt switches. Companies in the T&M sector have replaced mercury switches with other types in the majority of applications through mercury reduction programs, however there remain some applications that require no contact bounce, high isolation, low contact resistance or long life (number of operations over expected product lifetime) where mercury switches and relays (activated by mercury switches) are still in limited use.
Application requirements of switches and relays generally include:

Reliable and stable low contact resistance
High operational life
Switching frequencies sometimes into the RF region
Wide range of ambient temperature operation
Switching voltages and currents

1.2.3 Other uses:

There are no products with mercury based manometers or temperature measuring equipment in our companies. One company provides sealed elemental mercury that has no electrical power for temperature standards applications.

1.3 Trends

1.3.1 Our companies have restricted mercury to LCDs, relays and switches in electronic products. The majority of applications for switches and relays do not employ mercury-wetted types which use in the order of 10 milligrams. Equivalent types two decades ago used 20 or more times the quantity or mercury.

1.3.2 Our own reduction of mercury is in-line with reports of world usage of mercury that indicate use of mercury is an order of magnitude less than the amount of mercury used twenty years ago. Further details can be found at http://www.chem.unep.ch/mercury/Report/7.3

2. Substitutes for Mercury

Lamps

In the test and measurement sector LCDs are employed for visual text and graphical representation of measured and derived data with screen sizes much smaller than large screen TVs. Alternative plasma and LED display types are employed where the quantity of information is small and numeric in nature. Our members have no additional information on substitutes for mercury lamps in display backlights that have not been made available to ERA for their review of the first round of RoHS exemptions.

Switches

There are vast numbers of switch/relay technologies available for different applications. Most are electromechanical but there is a growing trend to use solid-state switches and relays in the guise of CMOS or FET devices:

In any electromechanical relay, contact operation relies on an energising element or switch. Depending on the design this can be a purely mechanical device or a magnetic element producing armature movement when energised. The by-product of coil energization is heat. This is not an ideal situation in relays required to offer stable low-level switching since heat generates significant thermal emf voltages across switching contacts.

Different materials and technologies are employed in the following applications:

Power switching (high voltages and currents),
RF (Radio Frequency) switching at high speed and
Low-level signal switching.

Power switches

In power switches the issue to mitigate is arcing of contacts. In most applications power switches do not require large operational life as they change state relatively infrequently (10 times/ hr) and a switch life of 10^5 operations is often more than adequate. To mitigate arching, power switches use cadmium oxide to keep contact resistance low, and may have air evacuated and subsequently sealed to operate in a vacuum, or are filled and sealed with inert gas. Gold plating is an alternative used that improves stability in gas filled relays and switches passing high currents. High voltage switches normally have tungsten or molybdenum contacts that are hard and have high melting temperatures.
Solid-state switches are unable to pass sufficient power without melting. Our companies do not use mercury in power switches and we are not aware of any available.

RF Switches
Operating any relay at radio frequencies to switch analogue or digital signals imposes current and voltage limitations due to the skin effect where current migrates from the centre of a conductor towards its outer surface as frequency increases. This results in localised heating at the surface of the conductor. In many applications at these frequencies a relay life of 10^8 operations or greater is required as it may have to operate many times per second for considerable time. Wherever possible solid-state switches are used however contact resistance is higher than equivalent electromechanical relay switches and they suffer from poor isolation.
Electromechanical RF switches with a lifetime of 10^6 operations without mercury operate at switching speeds up to 50 MHz. Wetting contacts with a small amount of mercury extends lifetime to 10^8 operations and frequency response up to 1 GHz. The quantity of mercury used is in the order of 10 milligrams. The equivalent switches twenty years ago contained 100 milligrams or more of mercury.

Low-level signal switches
For low frequency applications more choices are available to designers. Unless very low contact resistance or high isolation is required, solid-state switches are normally used for their long life in preference to electromechanical switches. In general purpose test and measurement applications wide input signal ranges are specified and where one of several signals is switched (to an analogue to digital converter for example) mercury wetted relay switches are still in use for specialist applications as they give long life and good electrical isolation in applications such as engine testing or monitoring turbo-generators.

With the new arrival of MEMS (micro-electromechanical systems) technology devices, where moving components are etched into a silicon substrate, performance of electromechanical switches is extending to the point where demanding applications like automated test equipment can be implemented to switch RF or low-level signals at internet speeds with low contact resistance and with lifetimes of 10^9 or greater operations.
Types being developed with miniaturised cantilevers have potential lifetimes of around 10^8 as they are limited by wear and oxidation of the solid metal contacts. In the mercury MEMS switches a small (1-5 milligram) slug of mercury is moved from one position to another by a fast heating element within the chip substrate. The slug of mercury sealed by glass over the substrate, is the only moving part in this type of switch. The first switch developed has a frequency response to 12 GHz and has one milligram of mercury. Development is underway to increase frequency bandwidths to 50 GHZ and beyond. Without degrading other performance parameters, these higher bandwidths can only be achieved by increasing the amount of mercury up to 5 milligrams.

Note these switches need very little power to switch and remain on. Once a signal is switched, the control signal can be removed; the switch device contacts stay latched thereby requiring less operating power compared to solid-state switches and electro-mechanical switches (which require power to maintain the on contact position).
The lifetime of a mercury MEMS is only limited by the heater; lifetimes of 10^9 or greater operations have been achieved. In portable battery operated test products, the small size of MEMS switches is an advantage as well as decreased power consumption and long life.

For the application types described above there are no working technically viable alternatives. Potential MEMS developments may eventually substitute mercury with gallium but for the moment this poses insurmountable technical difficulties. To name a few: metal liquid state occurring above room temperature (30 ^{o}C.) and poor surface tension wetting compared to mercury.

3. <u>Impacts of substitution</u>

3.1. Assuming no change to the current RoHS exemptions for mercury in lamps and no new exemptions approved for compliance, one member company would have to eliminate mercury switches in their products.

3.2. Environmental Impacts
As the amount of mercury in switches placed on the EU market by our members is less than 20 grams / year, substitution will have very little environmental impact particularly as thorough recycling procedures already in place for the type of industrial equipment which contain these switches, minimise environmental impact. A closed loop system for controlled take back and treatment means there is virtually no environmental impact from our sector’s products. Substituting these switches with shorter lifetime types will cause increased waste.

3.3. Economic Impact
In respect of conventional mercury wetted tilt switches and relays there is no economic impact to our members since we have recently stopped using them in products due to American legislation.

We are introducing low mercury (up to 5 mg) MEMS switches for high performance switching applications in test equipment for communications and electronic manufacture where no equivalent switches exist. In addition to recovering eight years development costs, industry would be disadvantaged if the new high-performance test equipment were banned from Europe; inevitably development and testing of high-speed communications equipment would migrate to other regions. Elimination of mercury by redesign of such products is not technically possible without degrading product life and performance.

3.4. Health Impacts
Unlike glass mercury thermometers that break easily, there is no risk to health of mercury in LCDs, relays and switches because the mercury is contained in sealed enclosures. Many

LCD lamps have backlighting mercury in cartridges held firmly in display assemblies. Switches or relays are sealed components soldered on printed circuit boards. User access to these components is deliberately difficult and may void product warranty.
In addition drop, shock and vibration testing on our products has proven that no mercury is released during normal or even excessively harsh use.

4. Requests/recommendations

4.1. Exemptions

The existing RoHS exemption for mercury fluorescent lamps is essential for many test and measurement products where they are used extensively in backlights of displays. We are unable to estimate with certainty when alternative compliant displays of equal size and performance will be commercially available.

We request an additional mercury exemption for “switches or relays in monitoring and control equipment not exceeding 5 mg of mercury per switch” on the grounds that there is no substantially equivalent non-mercury alternative technology for the intended use considering all aspects of electrical performance, size, power consumption, cost and product life. In addition we propose that mercury switches used in monitoring and control equipment containing no more than 5 mg of mercury have an identification mark affixed enabling treatment operators to see the devices for removal at end of life. This controlled approach limiting use to industrial products together with removal and treatment mechanisms mitigates risk to the environment without hampering innovation. In context the innovation is the capability to test high-speed electronic products and communications network equipment where there are no technical alternatives.
This new exemption request mirrors a similar exemption granted in California for low mercury switches and relays in monitoring and control equipment since the ban enforced recently - January 2006. It is intended for limited applications where no suitable alternative exists. Our request allows new MEMS technology to address high-speed test applications where no technically equivalent alternatives are available and would drive manufacturers to adopt low or mercury-free solutions in monitoring and control equipment.

4.2. Phase-in period

Assuming exemptions for displays and switches are available when the RoHS Directive is revised, we estimate a transition phase-in period of three years from the entry into force of the revised Directive, is needed in the monitoring and control sector to conduct surveys with suppliers and update products where necessary to ensure compliance. For member companies, this period could be reduced considerably since the parts at risk have been identified by each member company and substitutes implemented where required to comply with American legislation.