Mercury Use in School Classrooms: Summary and Assessment of Non-Mercury Alternatives

Prepared by the Northeast Waste Management Officials' Association (NEWMOA)
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Introduction

The Massachusetts Mercury Management Act prohibits primary and secondary schools from purchasing mercury-added products for classroom purposes but provides exemptions for some uses of mercury products if no feasible alternatives exist. This report, requested and funded by the Massachusetts Department of Environmental Protection (MassDEP) examines the feasibility of the non-mercury alternatives.

Schools are prohibited from purchasing mercury-added products because mercury is a potent neurotoxin that is especially harmful to children. When mercury devices, such as barometers or thermometers break, the mercury is released into the air where it can be breathed by students and school staff. Mercury spills occur frequently in schools and are costly to clean-up properly.

Much of this report is based on NEWMOA's six years of experience working with Massachusetts' schools to remove mercury and mercury-containing products, and replace those products with safer, non-mercury alternatives. NEWMOA has carried out this work under contract with the MassDEP. NEWMOA also spoke with individuals at the Massachusetts Department of Education, the Green Chemistry Program at the University of Massachusetts at Lowell, the Sustainable Hospitals Project at the Lowell Center for Sustainable Production, and many vendors of non-mercury equipment to gather information for this report.

The focus of this report is on mercury use in K-12 classrooms since the Massachusetts law prohibits the purchase of mercury and mercury-added products for use in instruction in all of these schools. However, nurses' offices also use mercury products, such as mercury-added blood pressure units and fever thermometers, as do the facilities' support areas. For example, mercury switches can be used in boilers; fire alarm systems; freezers; and heating, ventilation, and air conditioning (HVAC) control systems. In many cases, mercury switches are not used in these kinds of products that are for sale today. However, the various heating systems and appliances currently in schools were purchased when mercury switches were used in these products.

Energy efficient mercury lighting, such as fluorescent and high intensity discharge (HID) bulbs, are also commonly used in schools. While no non-mercury alternatives are commercially available for energy efficient lighting, fluorescent and HID bulbs should continue to be used and recycled at the end of their useful life.

Mercury products that are common in schools but are not used in classrooms are not addressed in this report, unless the product is used for instructional purposes in a vocational education classroom, such as blood pressure cuff use in programs that teach nursing skills.

Finally, the Massachusetts Mercury Management Act bans anyone from purchasing many mercury-containing measuring devices, including barometers, thermometers, sphygmomanometers, and hygrometers after May 1, 2008. Therefore, teachers and administrators in Massachusetts schools will not be able to legally purchase these items in the state after that date. For more information on these restrictions, visit http://www.newmoa.org/prevention/mercury/imerc/phaseoutinfo.cfm.

Where is Mercury Used in Classrooms?

Mercury is most commonly used in science classrooms and labs, and in vocational classrooms, including home economics, nursing, dental, plumbing, automotive, and HVAC programs. Table 1 summarizes the items commonly found in these classrooms and their non-mercury substitutes, if available. Description of the substitutes follows the Table.

Table 1
REPLACEMENTS FOR MERCURY PRODUCTS COMMONLY FOUND IN SCHOOLS

LOCATION	ITEM	NON-MERCURY SUBSTITUTE
Science Classrooms	Elemental Mercury	There are alternative methods to teach about the unique properties of mercury that do not require that elemental mercury be used in the classroom
	Mercury Lab Thermometer	Alcohol and mineral spirits glass bulbs, digital thermometers
	Mercury Barometer	Aneroid, digital, and liquid-gas silicon
	Mercury Hygrometer	Spirit-filled glass bulb, digital, aneroid
	Mercury Hydrometer	Lead ballast hydrometers are available
	Mercury Vacuum Gauge	Digital, electronic or mechanical gauges that use a needle or Bourdon tube may substitute for certain gases only
	Mercury Spectral Tube	16 alternative gases are available
	Mercury Manometer	U-shaped tubes using any colored liquid, digital manometers

LOCATION	ITEM	NON-MERCURY SUBSTITUTE
Science Classrooms	Mercury Molecular Motion Device	Apparatus for use with overhead projector uses balls on a glass plate
	Mercury Sling Psychrometer	Mineral spirits glass bulb thermometers, some can fit in old frames; digital
	Mercury Compounds: mercury oxide, chloride, sulfate, nitrate, iodide, Zencker's solution, others	Other compounds, depending on experiment
	Mercury Gas Law Apparatus	Charles' Law apparatus
	Sphygmomanometer for Biology classrooms	Aneroid and digital
Home Economics Classrooms	Mercury Cooking Thermometer, Refrigerator Thermometer, Candy Thermometer (with silver liquid)	Spirit-filled glass bulb, digital, bi-metal thermometer
HVAC and Plumbing Classrooms	Mercury Thermostats	Non-mercury sealed switches, programmable and non-programmable electronic thermostats
	Mercury Manometers or U-Tubes	Spirit-filled glass bulb, digital
	Mercury Sling Psychrometers	Spirit-filled glass bulb, digital
	Mercury Gauges	Depends on application
	Mercury Float Control Switches (e.g., used on sump pumps)	Non-mercury switches are available
Nursing Vocational Classroom	Mercury Fever Thermometer	Digital, glass bulb (gallium, indium, tin), or tympanic thermometers
	Sphygmomanometer (blood pressure measuring device) with silver liquid, found in hand-held, mobile, or wall units	Aneroid or digital
Automotive Classroom	Mercury switches for convenience lights	No longer available in cars; various alternatives available
Dental Vocational Classroom	Mercury amalgam capsules	Non-mercury restorative materials

Common Mercury Uses in Science Classrooms & Non-Mercury Alternatives

Alternatives to Mercury Lab Thermometers

Mercury-filled Lab Thermometers

Several types of non-mercury laboratory thermometers are suitable replacements for mercury thermometers, including alcohol and mineral spirit glass bulb, and digital thermometers. These thermometers are widely available from most school scientific supply catalogues.

Red-Alcohol Thermometer

The red- and blue-filled, methyl alcohol thermometers are slightly less expensive than the mercury thermometers, costing $4.00-$5.00 each as compared to a standard mercury thermometer, which average $6.00-$12.00 each. However, many teachers report that they are less accurate than mercury thermometers. Some report that the thermometers can be off by a few degrees; for example, when measuring the temperature of boiling water students can get readings of 98 degrees Celsius with an alcohol thermometer. Teachers requiring precise temperature measurement for their classroom activities may therefore not want to use these thermometers.

The green Enviro-Safe thermometers are nearly as accurate as mercury thermometers. They contain citrus oil with a green non-toxic dye. Like the alcohol thermometers, they are sold in similar temperature ranges as mercury thermometers (e.g., -20 to +110°C, -10 to +260°C, and -20 to +150°C). Depending on the type of thermometer (partial or full immersion) and temperature range, Enviro-Safe thermometers can cost up to 60 percent more than a comparable mercury thermometer, approximately $7.50-$13.50 each, depending on the temperature range. Major vendors, however, are often willing to reduce their price when large quantities of 100 or more are purchased.

Enviro-Safe thermometers are calibrated according to the National Institute of Standards and Technology (NIST) traceable standards, and include a Statement of Accuracy. The guaranteed accuracy is 1° Celsius (C) below 105°C (221°F), 1.5° C above 105°C (221°F), and 2°C above 200°C (392°F).

Enviro-Safe Thermometers with Green Liquid

An issue with Enviro-Safe thermometers is that, unlike mercury thermometers, they must be stored upright or their columns will separate. Storing them in a drawer, which is standard practice in science labs, is not advisable. Schools should purchase an upright holder for the thermometers, which the major vendors offer. The columns can be reunited, however, if separated. See the Appendix for instructions on reuniting separated columns.

Thermometers stored upright in rack

Digital thermometers are more expensive than the glass bulb thermometers, costing between $25.00 and $125.00, which is two to five times as much as a comparable mercury thermometer. Despite their higher cost, they are sometimes the science teacher's preferred choice. First, neither the alcohol nor Enviro-Safe thermometers are available in fractional degrees. For that, a digital thermometer is required. NEWMOA staff has found that at least one of the major vendors sells a digital thermometer that is comparable in price to the fractional degree mercury thermometer. (Note: fractional degree mercury lab thermometers are more expensive than standard mercury thermometers.)

Second, the higher accuracy of digital thermometers often makes them preferable for high school Advanced Placement classes, which can have curriculum requiring a higher degree of precision. Although most of the low-cost digital thermometers are accurate to 1^{o}Celsius, the same as the Enviro-Safe thermometers, a few models are available with 0.3^{o} Celsius accuracy.

High Temp Digital Thermometer

Student Digital Thermometer

For the majority of science classes, however, Enviro-Safe and alcohol thermometers are acceptable non-mercury alternatives.

Alternatives to Mercury Barometers

Close-up of a Mercury-Filled Barometer

Eco-celli liquid-gas silicon Barometer

A barometer is an instrument used for determining the pressure of the atmosphere. Aneroid, digital, and Eco-celli liquid-gas silicon barometers are three suitable and *less costly*, alternatives to the mercury barometer, which can cost upwards of $400.00. The Eco-celli is the best option because it provides the same visual teaching value as a mercury barometer and is also the most accurate of the three. All are available from many school scientific supply catalogues.

The Eco-celli is a liquid-gas barometer with the precision of a mercury barometer in the atmospheric range, 28 to 31 inches mercury. It is similar to a traditional mercury barometer but functions on the basis of compressibility of gasses (Boyle's Law) instead of the weight of liquid mercury. It has a 160 cm-long U-shaped tube filled with a red, non-toxic silicon fluid and gas. The gas reservoir is above the silicon column and provides a constant counter-pressure against the atmospheric pressure. It also has a blue methyl-alcohol thermometer. Temperature fluctuations that can affect pressure readings are corrected using a sliding scale attached to both the thermometer and barometer tubes.

The Eco-celli scale is four times larger than a standard mercury barometer and easy to read. The temperature scale measures in degrees F and C, while the pressure scale measures in both millimeters and inches. A scale that reads in both inches and millibars is also available. Each Eco-celli barometer costs $250.00 ($50.00 rebate with certificate of recycling).

Digital barometers use an electric sensor for measuring the change in air pressure. Accuracy of the models available through school catalogues is about 5 millibars (mbar) of mercury with a resolution of 1 mbar. Digital barometers usually cost $100.00-155.00 each. Over time (5 to 10 years) the less expensive digital barometers can reportedly become less accurate.

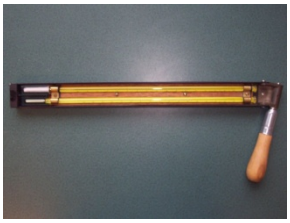
Digital Barometer

Aneroid barometers measure the change in air pressure by means of a mechanical spring and lever system. They contain a metal cell, or capsule, with a small amount of air, or a series of such cells joined together. Increased air pressure causes the sides of the cell or cells to come closer together. A side is fixed to the base of the instrument while the other is connected by means of a system of levers and pulleys that magnify the pressure changes, and cause a pointer to move on a dial, or numbers to change on a digital read-out device. They are far less costly than mercury barometers, $40.00-$90.00 each, but some teachers consider them less precise.

Aneroid Barometer

Alternatives to Mercury Hygrometers/Sling Psychrometers

Mercury Hygrometer



Mercury Sling Psychrometer

Hygrometers are instruments used for measuring humidity. The sling psychrometer is one type of hygrometer. It contains two thermometers, a "dry bulb," or ordinary thermometer, and a "wet bulb" thermometer, which has a bulb that is kept constantly wet. Humidity is computed from the difference in the temperatures shown by the two thermometers.

Non-mercury sling psychrometers with red or blue spirit-filled thermometers are available at a comparable price as mercury sling psychrometers from many school scientific suppliers, usually $80.00-$100.00 each. Buyers should specify non-mercury when ordering. For a discussion on the accuracy of spirit-filled thermometers, see the thermometer section above.

Digital hygrometers are also available from many vendors of school scientific supplies, or from vendors of weather monitoring instruments, in the same price range as mercury sling psychrometers, which is around $42.00 each. The digital devices use electronic sensors that are either capacitive or resistive. The capacitive sensors sense water by applying an alternating current signal between two plates and measuring the change in capacitance caused by the amount of water present. The resistive sensors use a polymer membrane, which changes conductivity according to absorbed water. Temperature must also be measured, as it affects the calibration of all these sensors.

Alternatives to Mercury Hydrometers

Hydrometer

Hydrometers measure the specific gravity of liquids. Historically, mercury has been used in hydrometers as a weight. It is encased in a bulb at one end of a thin glass tube. The tube is sealed and floats upright in the sample liquid like a fishing bobber. Hydrometers may also contain a thermometer for measuring the temperature of liquids. Mercury hydrometers are no longer produced and available for sale.

Replacement non-mercury hydrometers are available from many suppliers of school scientific supplies that use lead as a weight instead of mercury and that contain non-mercury thermometers. However, they are inexpensive – $12.00-$22.00 each. (The price cannot be compared to mercury hydrometers because the mercury devices are not available.)

Soil hydrometers measure particle size distribution in soil suspensions. Non-mercury soil hydrometers are available that also use lead for the ballast.

Alternatives to Mercury Manometers

Mercury Manometer

Manometers measure the pressure of liquids and gases. Mercury manometers are generally U-shaped glass or plastic tubes containing elemental mercury that have one end closed. The difference in the levels of mercury in each side of the tube indicates the pressure of the gas being measured.

U-tubes for measuring the pressure of liquids and gases, using any colored liquid, are available from the major suppliers of school scientific equipment for the same price as mercury U-tubes, which is $79.50.

Digital manometers are also available in a wide price range from suppliers of school scientific equipment and from HVAC distributors. They have a high degree of accuracy; however, they are generally more expensive than tube manometers.

U-tube Manometer filled with Blue Liquid

Digital Manometer

For most applications, tube manometers filled with mineral spirits or water meet the same needs as mercury devices with equal or better accuracy. However, unlike some mercury-filled manometers, water and mineral spirit models cannot measure extremely high pressures. Schools requiring manometers for applications in which very high pressure values are measured may need to replace mercury manometers with digital models.

Alternatives to Mercury Vacuum Gauges

McLeod Vacuum Gauge

Close-up of Mercury Gauge

A vacuum gauge is used for measuring pressure down to very low readings, less than 1 mm of mercury. They are used in conjunction with vacuum pumps. The McLeod vacuum gauges are the types usually found in science classrooms. These do contain mercury. Although they have been considered the standard for vacuum low-pressure measurements and are still used to calibrate other electronic gauges, effective alternatives exist. McLeod gauges are also used for Charles' Law and Boyle's Law gas compressibility measurements.

Digital Vacuum Gauge

Digital vacuum gauges are a non-mercury alternative for vacuum gauges. They are fairly expensive, costing approximately $650.00 each, but they reportedly show better resolution and accuracy than mechanical gauges.

Aneroid or mechanical gauges measure the presence of gas without using mercury. Often these gauges have a Bourdon tube as the sensing element, which coils in response to pressure changes. However, these devices may not be applicable for all experiments/demonstrations. It is important to assess what the vacuum gauge will be used for in order to determine if there is a suitable non-mercury alternative.

As noted before, both of these devices must be calibrated using a mercury pressure gauge (e.g., McLeod vacuum gauge or manometer etc). In some cases, a school may be able to ship a non-mercury gauge back to the scientific supply company for proper calibration for a small maintenance fee. In other instances, schools may be able to keep one mercury gauge onsite to use for calibration purposes only.

Alternatives to Mercury Spectral Tubes

Mercury Spectral Tube in Action

Spectral tubes measure the frequency and intensity of light given off by elements. Sixteen alternative gas tubes are available that are comparable in price to the mercury spectrum tube. These alternative gases include air, argon, bromine vapor, carbon dioxide, chlorine, deuterium, helium, hydrogen, iodine vapor, krypton, neon, nitrogen, oxygen, water vapor, and xenon. While the alternative gases will not display the same spectrum as mercury, they demonstrate the same principles as the mercury spectrum tube.

Spectrum tubes with alternative gases are available from many suppliers of school scientific supplies and cost between $33.00 and $53.00 each.

Alternatives to Mercury Molecular Motion Tube

Molecular Motion Device

Mercury molecular motion tubes demonstrate the kinetic energy of particles. An alternative to the mercury-containing molecular motion tube is a more sophisticated molecular motion demonstrator designed for use with an overhead projector. The device demonstrates not only random motion of molecules, but also diffusion of gases, Brownian motion, Boyle's and Charles' laws, states of matter, and change of state. To simulate the changes in molecules caused by differences in temperature, pressure and volume, the molecular motion demonstrator vibrates a group of balls of various sizes and colors on a glass plate in a mounted metal frame. The speed of the vibrator can be continuously varied by a control knob to show students what happens at "higher" or "lower" temperatures. The device costs $369.00, which is ten times more expensive than the mercury molecular motion tube; however, one demonstrator can be used with an entire class of students in contrast to needing multiple molecular motion tubes to cover the class.

Alternatives to Mercury Boyle's Law Apparatuses

A traditional Boyle's Law Apparatus showing the elasticity of gasses can be replaced with lower cost non-mercury apparatuses. An alternative to the mercury Boyle's Law apparatus is a device that contains two glass cylinders. The outer cylinder is filled two-thirds with water and the inner cylinder is inverted and placed inside the outer cylinder. By reading the depth of the inner cylinder in the water and the air level in the inner cylinder, a plot of depth versus air level can be developed that verifies Boyle's Law.

A second, simpler device consists of a graduated air tight piston containing a measured quantity of gas that is mounted between two wooden blocks. Weights are placed on the wooden platform to increase the pressure and change the volume of gas.

These devices are available from the major suppliers of scientific equipment for schools. The devices cost approximately $12.00 each, and the weights are sold separately for $21.00-$46.00.

Alternatives to Mercury Charles' Law Tubes

The mercury Charles' Law Tube can be replaced with a more sophisticated, but significantly more expensive Charles' Law Apparatus that enables students to determine the volume coefficient of expansion of air throughout a temperature range of almost 100°C. The apparatus

requires sulfuric acid. It contains a specially configured glass U tube with one arm with a funnel top and a second graduated arm that is closed at the end and surrounded by a glass water jacket. The apparatus is available from a few of the vendors listed at the end of this report and costs approximately $365.00.

Alternatives to Use of Mercury Compounds

Mercury compounds were used in the past for a variety of high school science experiments. They are no longer necessary. Many other chemicals may be used in their place. For example, for ionization experiments that have typically used mercuric chloride, any ionizing compound, such as table salt, may be used in place of the mercuric chloride. Furthermore, according to the College Board, which certifies Advanced Placement classes, there are no specific requirements for the use of any particular chemical, such as mercury chloride, in Advanced Placement Chemistry classes.[1]

The Wisconsin Department of Natural Resources[2] lists the following other possible substitutes:

- Magnesium chloride, sulfuric acid, or zinc in place of mercury (II) chloride
- Formalin in place of mercury iodine
- Freeze drying in place of mercury nitrate
- Phenate method in place of mercury oxide
- Ammonia, copper sulfate, neosporin, mycin copper catalyst, silver nitrate, potassium, or chromium (III) sulfate in place of mercury (II) sulfate

Another useful resource for information on non-mercury alternatives to use in place of mercury compounds in science classes is the Lab Safety Institute in Needham, Massachusetts, http://www.labsafety.org, (508) 647-1900.

Elemental Mercury

Elemental Mercury

Many science teaching classrooms have containers of elemental mercury to assist with teaching about mercury's unique properties. Teachers often enjoy showing students the silvery liquid metal that is very dense and heavy. In the past students were encouraged to "play" with the

[1] Personal communication, from David White, Associate Director, Curriculum and Content, AP Science, College Board to Lisa Tyrell, Massachusetts Department of Education, on March 28, 2007

[2] Mercury Sourcebook: Educational Institutions, http://www.epa.gov/glnpo/bnsdocs/hgsbook/ed.pdf

mercury and even clean their coins with it. However, in recent years there have been numerous incidents where elemental mercury has been spilled or accidentally released in schools, and this has caused school evacuations and closures and necessitated costly cleanups. There are many alternative methods to teaching about the unique properties of mercury that no longer require that elemental mercury be present in the classroom. For resources on teaching about mercury, including its toxicity and behavior in the environment, visit http://www.mercuryinschools.uwex.edu/tools/index.htm.

Common Mercury Uses in Nursing Classrooms & Non-Mercury Alternatives

Alternatives to Mercury Fever Thermometers

Mercury Fever Thermometer

Mercury fever thermometers are no longer sold in Massachusetts, unless authorized by a prescription.

Digital, non-mercury liquid, single use, instant read digital, and tympanic thermometers are suitable replacements for mercury fever thermometers and are available from many medical equipment suppliers.

Liquid Gallium-Indium Tin Thermometer

Digital Thermometer

SURE-TEMP Thermometer (For Nursing Programs)

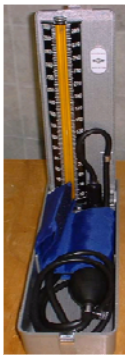
A manufacturer, Geratherm, makes a liquid indium-gallium-tin thermometer that is comparable to a mercury fever thermometer and accurate to 0.1°C. The product comes with dual scale reading, Fahrenheit and Celsius. It is also comparable in price to mercury fever thermometers, both costing approximately $3.00 each.

Geratherm also makes high quality digital fever thermometers that are either solar or battery powered in the same price range as mercury fever thermometers. The battery-powered thermometers cost approximately $3.00 each, while the solar-powered versions cost approximately $7.00 each. Numerous other manufacturers make digital fever thermometers as well.

Instant read and tympanic thermometers are popular with nursing programs because of their widespread clinical use; however they are considerably more expensive than a digital or non-mercury liquid fever thermometer. The SURE-TEMP thermometers are among the highest quality thermometers and cost $195.00-$238.00 each.

Tempa DOT single use thermometers are also available, and these are inexpensive and have the benefit of not requiring sterilization between patients or use of a sanitary sheath.

Alternatives to Mercury Sphygmomanometers



Sphygmomanometer

Standing Sphygmomanometer

Wall-mounted Sphygmomanometer

Sphygmomanometers are instruments that measure blood pressure. Digital and aneroid sphygmomanometers are good replacements for the mercury sphygmomanometer (i.e., blood pressure cuff).

Aneroid sphygmomanometers measure blood pressure using a mechanical, bimetallic spring device; they are comparable to mercury sphygmomanometers in cost and technique. Floor, hand-held and wall-mounted models are available from medical equipment suppliers. Depending on the type or model, aneroid sphygmomanometers costs between $125.00 and $225.00 each.

Aneroid Sphygmomanometer

Like mercurial devices, aneroid sphygmomanometers require regular calibration checks (i.e., at least annually). For aneroid devices, the procedure requires adjusting calibration at several pressure points, not just at zero like a mercury device.

A recent study[3] comparing sphygmomanometer performance in Brazil showed a slight under-reading by aneroid instruments, but concluded the devices were suitable for clinical settings. Digital, mercury, and aneroid blood pressure measurements were taken on 400 South American adults. The aneroid instrument slightly under-read hypertension prevalence (30 percent, compared with 32 percent for digital and mercury); however, the study concluded that the robustness and simplicity of the aneroid instrument make it a suitable alternative to mercury

[3] Geoffrey, G. el al, "Accuracy of aneroid sphygmomanometer blood pressure recording compared with digital and mercury measurements in Brazil," Tropical doctor 2004, vol. 34, n°1, pp. 26-27

sphygmomanometers for clinical settings.

Some clinicians are concerned that aneroid sphygmomanometers are easily damaged during use, resulting in inaccuracy due to the device being dropped or bumped and knocked out of calibration. Concerns about dropping aneroid devices can be alleviated by purchasing aneroid sphygmomanometers as either wall-mounted units or mounted on mobile stands, rather than selecting portable aneroid devices. Welch Allyn, one of the available manufacturers, has addressed these concerns by developing and introducing a gear-free aneroid sphygmomanometer that purportedly can fall 30 inches onto a hard surface and still remain accurate.

Digital sphygmomanometers use the oscillometric technique with proprietary algorithms to determine blood pressure. A range of digital devices are available, from inexpensive models for home-based use to sophisticated models for hospital settings that provide timed print-outs of blood pressure. Some devices have been tested for their validity and accuracy but many have not. For information on the accuracy of particular digital devices, see www.dableducational.org**,** a website developed by a non-profit organization for the purpose of making up-to-date information available on the accuracy and validity of digital blood pressure devices to consumers and the device manufacturing industry. The non-profit organization gathers published validation studies and provides the results and consumer information on many brands of blood pressure measuring devices.

Many of the lower-end, home-based digital devices are in the same price range as mercury and aneroid sphygmomanometers. The digital devices developed for hospital use are considerably more expensive than mercury blood pressure devices.

Common Mercury Uses in Home Economics Classrooms & Non-Mercury Alternatives

Candy Thermometer

Cooking Thermometers

Meat Thermometer

Dial, digital, non-mercury glass bulb, and infrared cooking thermometers are all suitable alternatives to mercury cooking thermometers. They are available from many suppliers of kitchen wares.

Dial thermometers use either "bi-therm" metals or a spring. A bi-therm stem thermometer contains two or more metals that expand at different rates with temperature changes and cause the dial to turn when expansion and contraction occur. Spring thermometers have an actual spring, which similarly expands and contracts, causing the dial to turn. According to http://www.fantes.com, a popular supplier of cooking wares, bi-therm thermometers are more reliable than the spring thermometers, and can usually be re-calibrated. These thermometers are generally low cost, approximately $7.00 each.

Digital cooking thermometers contain a small thermistor at the end of a stainless steel hollow shaft that serves as a sensor. Because of their small sensing element (thermistor), digital thermometers do not need to be inserted as deeply into the food as in the case of the Bi-Therm. Digital thermometers often have memory features that are unavailable in the Bi-Therm thermometers. Depending on the model, they are generally a minimum of twice as expensive as mercury thermometers and cost $12.00-$60.00 each. In general, this class of thermometers has an accuracy of +/-2°F between 50°F and 212°F with a slightly higher tolerance band beyond these ranges.

Infrared surface thermometers use a laser to measure the temperature of a surface without touching it. At $40.00-$90.00 each, they are significantly more expensive than mercury thermometers and not often used in home economics classes.

Non-mercury glass bulb thermometers contain alcohol-based or spirit-based material. Their accuracy relative to mercury thermometers is similar to that of the non-mercury liquid thermometers for science laboratories (see above description). They tend to be slightly more expensive than mercury cooking thermometers, costing approximately $4.00-$14.00 each depending on the model and its use.

Common Mercury Uses in Vocational Classrooms & Non-Mercury Alternatives

Dental Assistant Programs

Non-mercury resin and composite materials are substitutes for mercury amalgam fillings. These include glass ionomer, gold foil, cast gold alloy, and metal ceramic restorative fillings and crowns. However, as long as mercury amalgam fillings are still used in dentistry, vocational programs may still want to teach their dental assistant students how to mix the amalgam capsules.

Automotive Classrooms

Automotive Mercury Switch

Many American-made vehicles manufactured before 2003, and older European models, used mercury switches for convenience lighting in hoods and trunks. A few automobile models also used mercury switches in anti-lock brake systems (ABS).

Vocational teachers may want to replace any mercury switches found in the cars used in their classrooms. Non-mercury switches are readily available as replacements for convenient light switches. Replacing mercury switches in ABS systems, however, is not feasible.

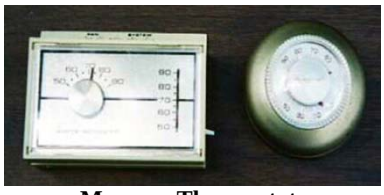
The ball-bearing switch is a suitable alternative to mercury convenience switches. The capsules are identical in size and shape to the mercury switches and generally readily replaceable. They are comparable in price. The ease and cost of replacement depends on whether the plastic components of the light housing must be destroyed during capsule replacement and therefore replaced as well.

Anti-lock brake systems contain two to three mercury switches per unit. The most common non-mercury alternative for antilock brakes uses a computerized system called an analog accelerometer. It is not interchangeable with the mercury ABS switch. Switching from mercury component to a computerized analog accelerometer requires a design change in the vehicles.

For information on removal of ABS switches, see
http://www.cleancarcampaign.org/pdfs/abs_removal.pdf

Heating, Ventilation, and Air Conditioning (HVAC) Classrooms

Alternatives to Mercury Thermostats



Mercury Thermostats

Suitable non-mercury alternatives for thermostats include electromechanical (i.e., air-controlled, reed switch, vapor-filled diaphragm, snap-switch) and programmable electronic. Many are readily available from wholesale and retail heating and plumbing supply stores at a generally comparable price as mercury thermostats. The programmable electronic thermostats are more expensive, however, and can cost $30.00-$200.00.

Both digital and electromechanical thermostats can be as accurate as or more accurate than mercury devices. They can also save energy, by enabling users to automatically adjust the temperature or turn off the HVAC depending on the time of day.

Electronic Thermostat

See manometers in Science Classroom section.

Plumbing Classrooms

Alternatives to Mercury Plumber's Manometers

Mercury Pressure Gauge

Digital, non-mercury-liquid, and aneroid low-pressure non-mercury gauges for testing gas piping, drainage, and vent systems in plumbing classrooms are available from distributors and local plumbing supply companies. Any gauge selected should meet the specifications of ASME B40.100-1998, Standards for Pressure Gauges and Gauge Attachments.

Vendors of Non-Mercury Supplies

Scientific Equipment
Sargent Welch, 800-727-4368, www.sargentwelch.com
Flinn Scientific, 800-452-1261, www.flinnsci.com/
Carolina Biological Supply, 800.334-5551, https://www2.carolina.com
Analytical Scientific, 800-364-4848, www.analyticalsci.com
Allivan Marketing, 978-649-8547, www.allivanmktg.com *eco-celli barometers

Medical Equipment
RG Medical Diagnostics, 888-596-9498, www.rgmd.com

Home Economics Equipment
Fantes Kitchen Wares Shop www.fantes.com

Mention of a company does not imply an endorsement by the Massachusetts Department of Environmental Protection (MA DEP) or the Northeast Waste Management Officials' Association (NEWMOA).

References

Purchasing for Pollution Prevention: Mercury Free Industrial Thermometers, Manometers, Thermostats and Switches Fact Sheet, INFORM, http://www.informinc.org/fact_P3industrialmeters.php

Aneroid Sphygmomanometers, Sustainable Hospitals Fact Sheet http://www.sustainablehospitals.org/HTMLSrc/IP_aneroid_sphygmo.html

Mercury Switch Removal from Motor Vehicles in Maine http://www.maine.gov/dep/rwm/mercury/switch_removal_report.htm

Fantes Kitchen Ware, Thermometers http://fantes.com/thermometers.htm

Appendix:

Instructions for Reuniting Separated Fluid Column of Non-Mercury Thermometer

Heating Method

Heat the thermometers bulb in an upright position away from your face in warm liquid, air, or over a soft flame sufficient to allow the liquid column to rise slowly until the separated portion of the column enters the expansion chamber at the top of the thermometer. Note that over filling the expansion chamber will break the thermometer. Tap the thermometer gently on the surface of a large rubber stopper in an upright position allowing the gas separating in the volume to rise above the column. Allow the thermometer to cool slowly in an upright position.

Cooling Method

Prepare a solution of shaved ice and salt or CO2 (Dry-Ice) and alcohol. Place the thermometer bulb only in the solution. Keep the thermometer upright. Allow the liquid column to retreat into the bulb, swing the thermometer (Bulb Down) in an arc releasing the entrapped gas, permitting it to escape above the column. Allow the thermometer to warm slowly in an upright position.

Reference: Stanford.edu/dept/EHS/prod/enviro/Reuniting_instruct.pdf