An Investigation of Alternatives to Mercury Containing Products

January 22, 2003

Prepared for
The Maine Department
of Environmental Protection

by
Catherine Galligan
Gregory Morose
Jim Giordani

Table of Contents

Executive Summary

The Maine Department of Environmental Protection (DEP) will issue a report on January 1, 2003 that will include a comprehensive strategy to reduce the mercury content of products. To assist in gathering information for this report, the Maine DEP commissioned the Lowell Center for Sustainable Production of the University of Massachusetts Lowell to conduct a study of alternatives to mercury containing products.

Mercury's chemical and physical properties have been applied to meet the requirements of thousands of products and applications including: dental amalgams, scientific instruments, electrical components, batteries, lamps, and medical devices. These mercury containing products are widely used in residential, commercial, industrial, military, marine, and medical environments.

Mercury from these products can be released to the environment during various stages of the product life cycle including production, transportation, manufacturing, use, and disposal. Once released, the mercury can transform to organic forms, and can readily disperse in the environment through the air, soil, and water. Mercury is persistent in the environment, and also accumulates in concentration as it biomagnifies within the food chain. Mercury is highly toxic to humans; exposure can damage kidneys and the central nervous system. The fetus is particularly sensitive to mercury's toxic effects. Mercury also has adverse effects on wildlife including early death, weight loss, and reproductive issues.

In February 2002, the Interstate Mercury Education and Reduction Clearinghouse (IMERC) was formed under the auspices of the Northeast Waste Management Officials' Association (NEWMOA). IMERC is an umbrella organization designed to assist the eight northeast states in their implementation of mercury reduction laws and programs aimed at getting mercury out of consumer products, the waste stream, and the environment.

The LCSP study included a review of the mercury product notification data submitted by manufacturers to IMERC. The notification data included a description of mercury added components, number of components, amount of mercury per unit, amount of mercury in total domestic sales, and purpose of mercury in the product. At the time of the review, this included seventy-six manufacturers reporting 390 mercury containing products. The LCSP study also included discussions with mercury product experts, discussions with manufacturers of mercury products, review of responses to a May 1, 2002 State of Maine letter to mercury product manufacturers (see Appendix 4), review of published mercury product studies, and review of pertinent data available on the internet.

Since there are thousands of products that contain mercury, a prioritization effort was needed to focus on a core set of products that could then undergo further detailed study. The criteria for this prioritization included: amount of mercury released to the environment, amount of mercury contained within the product, total amount of mercury reported for all product sales, product coverage by current regulation, and the availability of non-mercury alternatives. Products and components were reviewed as part of the prioritization process. Components are typically sold to original equipment manufacturers to be incorporated within a product. For example, the mercury tilt switch is a component that is incorporated in automobiles, vending machines, cranes, wheelchairs, and numerous other products.

The priority products selected for further detailed study included sphygmomanometers, gastrointestinal tubes, manometers, non-fever thermometers, barometers, hygrometers, psychrometers, hydrometers, flow meters, pyrometers, and thermostats (industrial and manufacturing only). The priority components selected for further detailed study included float switches, tilt switches, pressure switches, temperature switches, displacement relays, wetted reed relays, mercury contact relays, and flame sensors.

After the priority products and components were selected, detailed research and analysis was

then conducted. The findings from this research include:

- Description of how the mercury product/component operates
- Typical applications of the mercury product/component
- Non-mercury alternatives available
- Cost range for the mercury product/component and non-mercury alternatives
- Advantages and disadvantages of the mercury products/components and their non-mercury alternatives
- Manufacturer information for non-mercury alternatives
- Summary of findings for each mercury product/component

In general, cost competitive non-mercury alternatives were identified that meet the functionality requirements for most priority mercury products. Therefore, these products could be targets for mercury reduction efforts. The two products where alternative replacements cannot be recommended are the gastrointestinal tubes and the industrial thermostats.

For the following components there are cost competitive non-mercury alternatives available for new products and applications: flame sensors, float switches, tilt switches, temperature switches, and pressure switches. However, non-mercury relays can cover most, but not all, combinations of design parameters for new relay products or applications.

Certain retrofit situations for mercury switches and relays exist where the non-mercury alternative is not cost competitive. Efforts to reduce the sale of mercury switches and relays for retrofitting existing products or applications should take this into consideration.

There are many opportunities for substituting non-mercury alternatives for mercury containing products and components. Many alternatives are not simple drop-in substitutions. Although a non-mercury alternative may ultimately achieve the same desired functionality, such as providing an accurate measure of blood pressure or sensing a flame, there are often design considerations or different techniques or practices that must be first learned and communicated.

1.0 Introduction

The Maine Department of Environmental Protection (DEP) will issue a report on January 1, 2003 that is required under *An Act to Phase Out the Availability of Mercury Added Products*, PL 2001, c. 620. The report will include a summary of mercury product data and a comprehensive strategy to reduce the mercury content of the products.

To assist in gathering information for this report, the Maine DEP commissioned the Lowell Center for Sustainable Production (LCSP) to conduct a study of alternatives to mercury containing products. This report summarizes the findings of the LCSP investigation.

The LCSP develops, studies and promotes environmentally sound systems of production, healthy work environments, and economically viable work organizations. The LCSP is based at the University of Massachusetts Lowell, where it works closely with the Massachusetts Toxics Use Reduction Institute (TURI) and the Department of Work Environment.

Because of its persistent, bioaccumulative and toxic nature, the management of mercury presents a hazard to the environment that should be addressed and minimized wherever feasible. Reducing mercury exposure can be accomplished by source reduction, by minimizing uses that disperse the material into the environment, and by diverting and reclaiming any mercury containing products prior to disposal. While regulations on use and waste diversion strategies are necessary, an effective and economically efficient strategy would be, wherever possible, to substitute mercury containing products with products containing less hazardous materials.

The objective of this study is to accomplish the following:

- Investigate mercury product information in the public domain.
- Identify priority products for investigating non-mercury alternatives.
- Identify non-mercury alternatives to the products identified.
- Conduct a qualitative evaluation of viable alternatives, including their cost and performance.

The research methodology undertaken to complete this study included:

- Telephone communication and meetings with Northeast Waste Management Officials' Association (NEWMOA) and Maine DEP personnel were conducted to understand the information received on mercury-containing products.
- An internet search was conducted to obtain data and understand the flow of mercury associated with products. This data provided a reference against which the NEWMOA and DEP mercury product submissions could be compared.
- Telephone interviews of mercury reduction experts were held to gain insight on their perspectives and to reinforce or challenge conclusions drawn by the researchers.
- An internet search and phone interviews were conducted to identify the function of mercury in products and to identify alternatives for mercury containing components and products.
- Telephone interviews were conducted with manufacturers to develop information on the alternatives, their applications, and their advantages and disadvantages.
- Interviews were held with users of medical products to understand what made a product preferable from the user's perspective.
- A search and review of literature in the public domain was conducted to provide data on mercury products and components and their performance.

2.0 Mercury Notification Data Review

The Maine statutes (see 38 MRSA § 1661-A) prohibit the sale of mercury-added products unless the manufacturer has provided written notification disclosing the amount and purpose of the mercury. New Hampshire, Rhode Island, and Connecticut have passed similar mercury notification laws.

In February 2002, the Interstate Mercury Education and Reduction Clearinghouse (IMERC) was formed. IMERC is an umbrella organization designed to assist the eight Northeast states in their implementation of mercury reduction laws and programs aimed at getting mercury out of consumer products, the waste stream, and the environment.

Launched under the auspices of the Northeast Waste Management Officials' Association (NEWMOA), IMERC has coordinated regional mercury reduction efforts and assisted state environmental agencies in developing and implementing specific legislation and programs for manufacturer notification, labeling, collection, and eventual phase-out of products that contain mercury.

IMERC has consolidated the mercury notification information obtained by the individual states prior to February 2002, and has served as the clearinghouse for all mercury notification information received since that time for Maine, New Hampshire, Rhode Island, and Connecticut. IMERC has used two notification forms to collect this data:

> *Mercury Added Product Notification Form*: The term "mercury added" is used to indicate that the mercury was intentionally added to the product. This form requests manufacturer contact information, as well as information pertaining to the mercury in the product such as description of mercury added components, number of components, amount of mercury, and purpose of mercury in the product.
>
> *Total Mercury in all Mercury Added Products Form*: This form requests manufacturer contact information, as well as total amount of mercury in all units sold in the United States for a particular product.

Approximately 700 letters in December 2001 and 1,100 letters in June 2002 were sent to manufacturers to request such information for mercury containing products. IMERC has reviewed the received mercury notification forms for adherence to the requested information. The majority of notification forms received require follow-up communications with the manufacturer to address missing or erroneous data. Once the review of the notification forms has been finished and has been considered complete, the information is entered into an IMERC electronic database.

For this study, the mercury notification information in the IMERC electronic database was reviewed in June and July of 2002. At that time, the database contained notification information for seventy-six manufacturers reporting 390 mercury containing products. The total amount of mercury for all units sold in the United States was available for ninety-eight of these products. Substantially more mercury data has been provided to IMERC since the LCSP completed its review.

The following table illustrates the distribution of IMERC data for the various product types:

Table 2.1: IMERC Data

Product	Number of Products Reported
Barometer	1
Battery	16
Gas plasma display	7
Lamp	16
Lamp – cold cathode	1
Lamp – fluorescent	32

Product	Number of Products Reported
Lamp – HID	36
Lamp – LCD	115
Lamp – mercury xenon	18
Lamp – ultraviolet	1
Manometer	7
Relays	2
Sensor – flame	52
Sphygmomanometer	3
Switch – float	15
Switch – pressure	2
Switch - temperature	1
Switch - tilt	36
Thermometer	9
Thermostat	20
Total:	390

Source: NEWMOA Database, July 2002

The IMERC mercury product data were one of several important sources of data for this report. IMERC information was valuable for the prioritization process discussed in section 3, and for identifying the initial manufacturers to be contacted for further information. Other sources of mercury product information included discussions with mercury product manufacturers and experts, review of mercury product reports, and review of relevant data available on the internet.

3.0 Mercury Product Prioritization

A broad search was conducted to determine the scope of products that contain mercury. The intent of this search was not to develop a comprehensive list of products, but rather to develop background information on:

- How is mercury being used in products?
- Why is mercury being used in products?
- How much mercury is in various products?
- What are common mercury components for various products?
- Are non-mercury alternatives available for these mercury containing products?

These questions were investigated through discussions with mercury product experts, discussions with manufacturers of mercury products, review of IMERC mercury notification results, review of responses to a May 1, 2002 State of Maine letter to mercury product manufacturers (see Appendix 4), review of published mercury product studies, and review of pertinent data available on the internet.

This review has shown that for most mercury-added products, the mercury is found in a number of common components. For example, tilt switches are a common component in hundreds of products and applications such as building security systems, automobile trunk lights, scanners, and robotics. This is also true for batteries, relays, and fluorescent lamps which are each used in hundreds of products and applications.

The universe of products that use mercury is extensive. Mercury's chemical and physical properties have been applied by design engineers to meet the needs of thousands of diverse products and applications. The following table illustrates examples of products that employ some of these properties.

Table 3.1: Properties of Mercury

Product Example	Property of Mercury
Mercury wetted reed relays	Electrical conductivity
Position sensing products such as level sensors	Liquid at ambient conditions
Barometer	Precise movement in response to air pressure differential
Thermometer	Precise expansion/contraction in response to temperature change
Dental amalgam	Easily alloys with many metals such as gold, silver, and tin.
Gastrointestinal tubes	Density
Fluorescent lights	When energized, mercury in vapor form emits ultraviolet energy
Tilt switches utilize both the electrical conductivity and liquid at ambient conditions properties	Combination of properties

Since there are thousands of products that contain mercury, the research effort focused on identifying a core set of priority products or common components that could then undergo further detailed study. For the purpose of this report, the terms product and component will be defined as followed:

Product: A product is predominately sold to the consumer in its final product state. For example, a thermometer is sold to the consumer for temperature measuring purposes.

Component: A component is predominately sold to an original equipment manufacturer to be incorporated within another product. For example, the tilt switch is sold to automobile manufacturers to be incorporated into an automobile.

The following five criteria were selected as the basis for this prioritization:

1. What is the contribution of the product category to the total mercury released to the environment for all product categories?

   Only limited data is available on mercury released on an individual product basis. More information is available on mercury released by product category. Thus, total mercury released by product category was chosen as a screening criterion. The more mercury released by a product category, the more likely that products in that category would be a priority for further research.

   The following report was selected as a basis to support this criterion: "Substance Flow Analysis of Mercury in Products" prepared by Barr Engineering Company for the Minnesota Pollution Control Agency on August 15, 2001. (Barr, 2001) This report was chosen because it provided a comprehensive review of total mercury releases from numerous product categories, it included mercury releases to each environmental media (land, air, and water), and it was recently published. The releases by product category from this report have been categorized as high for releases greater than 20% of total releases, medium for releases from 5% to 20% of total releases, and low for releases less than 5% of total releases.

2. What is the amount of mercury within the product?

   The higher the amount of mercury contained within a product, the more likely it would be a priority for further research. Various sources were used to obtain this information including: discussions with manufacturers of mercury products, review of IMERC mercury notification results, review of published mercury product studies, and review of pertinent data available on the internet.

3. What is the total amount of mercury reported for all sales of a specific type of product in the U.S.?

   The higher the total amount of mercury reported for all U.S. product sales, the more likely it would be a priority for further research. The primary source for this data was a review of IMERC mercury notification results. However, this information was reported and available for only a few product types at the time of this study. Also, since all manufacturers had not yet reported at that time, the value of the highest product sales amount reported from a single manufacturer for a particular product was used in Table 3.3.

4. Is the product addressed by existing mercury regulations?

   Mercury-added products already regulated by either the State of Maine or federal Environmental Protection Agency (EPA) were eliminated as a priority for further study as part of this report. The Maine statutes on mercury-added products, 38 MRSA §1661 et seq., as well as pertinent EPA regulations were used as sources for this information.

5. Have readily available non-mercury alternatives been identified?

   If non-mercury alternatives are available in the marketplace, then the product is more likely to be a priority for further

study. The data sources for this effort included discussions with mercury product experts, discussions with manufacturers of mercury products, review of published mercury product studies, and review of pertinent data available on the internet.

Certain mercury products did not fall into a product category. For many of these products very limited information was available about their current use, manufacture, and mercury content. This included counterweights, jewelry, and advanced mercury alloys used in products such as convertors, oscilloscopes, semiconductors, solar cells, satellites, and infrared sensors. These products were therefore not considered a priority for this project.

As a result of applying these five criteria to mercury containing products, the following products and components were selected for further study as part of this report:

Table 3.2: Priority Products and Components

Products

- Sphygmomanometers
- GI tubes
- Manometers
- Thermometers (non-fever)
- Barometers
- Hygrometers
- Psychrometers
- Hydrometers
- Flow meters
- Pyrometers
- Thermostats (industrial and manufacturing)

Components

- Float switches
- Tilt switches
- Pressure switches
- Temperature switches
- Displacement/plunger relays
- Wetted reed relays
- Mercury contact relays
- Flame sensors

The results of applying these five criteria are summarized on the following page in Table 3.3 Priority Product Selection. The shaded cells indicate the priority products selected.

LCSP notes that the Maine DEP has prepared a summary of IMERC data as of December 2002. This more recent review of the IMERC data supports the priorities identified by LCSP based on the amount of mercury in the products and the total amount of mercury in domestic product sales.

Table 3.3: Priority Product Selection

Product	Product Category Releases[1]	Mercury Content (mg)[2]	Total Mercury Use By Single Manufacturer (g)[3]	Addressed in Existing Legislation[4]	Alternatives Identified	Priority
Sphygmo - manometers	Other measurement & control devices (High)	> 1,000	1,815,000	No	Yes	Yes
Manometers		> 1,000	6,956	No	Yes	Yes
GI Tubes		> 1,000	Not Available	No	Yes	Yes
Flame sensors		> 1,000	1,267,000	No	Yes	Yes
Thermometers (non-fever)		> 1,000	765,443	No	Yes	Yes
Barometers, hygrometer, psychrometer, hydrometer, flow meter, pyrometer		> 1,000	Not Available	No	Yes	Yes
Permeter, barostat, oscillator, gyroscope, otoscope, sequential multiple analyser, phanotron, ignitron		Not Available	Not Available	No	No	No
Amalgam	Dental (High)	> 1,000	Tytin Alloy: 8,811,270	Yes	Yes	No
Fever Thermometers	Fever Thermometers (Medium)	100 – 1,000	Not Available	Yes	Yes	No
Fluorescent Lamps	Fluorescent Lamps (Medium)	Predom-inately < 100	2,092	No	No	No
Float switch	Other Relays & Switches (Medium)	> 1,000	1,914,418	No	Yes	Yes
Tilt switch		100 to 1,000 > 1,000	11,329	No	Yes	Yes
Pressure Switch		> 1,000	Not Available	No	Yes	Yes
Temperature Switch		> 1,000	Not Available	No	Yes	Yes
Displacement/plunger relay		10 to 50, 50 to 100 100 to 1,000 > 1,000	16,174,300	No	Yes	Yes
Wetted reed relay		10 to 50, 50 to 100 100 to 1,000 > 1,000	2,400	No	Yes	Yes
Other mercury contact relays		0 to 5, 5 to 10 10 to 50 100 to 1,000 > 1,000	Not Available	No	Yes	Yes
Manufacturing and industrial thermostats	Thermostats (Medium)	100 – 1,000 > 1,000	2,162	No	Yes	Yes
HID & Other Lamps	HID & Other Lamps (Low)	Predom-inately < 100	16,051	No	No	No

Product	Product Category Releases[1]	Mercury Content (mg)[2]	Total Mercury Use By Single Manufacturer (g)[3]	Addressed in Existing Legislation[4]	Alternatives Identified	Priority
Batteries	Batteries (Low)	Predom-inately < 100	50,085	No	No	No
Bulk Liquid Mercury	Bulk Liquid Mercury (Low)	Not applicable	Not Available	Yes	No	No
Chlor-alkali products	Chlor-alkali products (Low)	Misc-ellaneous ppm/ppb	Not Available	No	Yes	No
Pharmaceuticals	Pharmaceuticals (Low)	Misc. ppm/ppb	Not Available	No	No	No
Latex Paint	Latex Paint (Low)	Misc. ppm/ppb	Not Available	Yes	Yes	No
Fungicides	Fungicides (Low)	Misc. ppm/ppb	Not Available	No	Yes	No
Film	Film	0 - 5	164	No	No	No
Convertor, oscilloscope, semiconductors, solar cells, satellites, infrared sensors	Advanced Materials (HgCdTe, HgTe, HgSe)	Not available	Not Available	No	No	No
Cleaners, detergents, catalysts, reagents, pigments, cosmetics, other industrial/laboratory use	Chemical Compounds	Misc-ellaneous ppm/ppb	Not Available	No	No	No
Jewelry, counterweights	Miscellaneous	Not available	Not Available	No	No	No

[1] Source: "Substance Flow Analysis of Mercury in Products" Prepared for the Minnesota Pollution Control Agency, August 15, 2001. Film, advanced materials, chemical compounds, and miscellaneous were not explicit product categories within this report. High: greater than 20% of total releases, Medium: 5% to 20% of total releases, Low: less than 5% of total releases.

[2] From IMERC database, IMERC paper files, and other miscellaneous sources.

[3] Total amount of mercury used in all products sold in calendar year 2001 as reported to IMERC. The value in the table indicates the highest amount reported from a single manufacturer for a particular product. Total amounts have not yet been reported by all manufacturers.

[4] The Maine statutes restricting the sale and use of mercury-added products, 38 MRSA §1661 et seq., as well as pertinent EPA regulations were used as sources.

4.0 Findings

Once the prioritization process was completed and accepted by the Maine Department of Environmental Protection, the analysis of the priority products and components was initiated. After conducting research and analysis of the priority products and components, the findings were prepared. The findings of this study are here presented in the following format:

Description
This section includes an overview of how the product/component operates, background information on the product/component, and typical applications of the product/component.

Alternatives
This section identifies the non-mercury product/component available to replace the function and performance characteristics of the mercury containing product/component.

Costs
The costs in this section are often provided in a range. The range includes only list prices available on the internet or by manufacturer inquiry as part of this study. The range does not necessarily include every model or every manufacturer listed for a particular technology. The prices for a specific model may vary considerably based upon options required, quantity ordered, customer discount, and other factors. The price ranges are only presented to provide a gross cost comparison between the various technologies.

Advantages/Disadvantages
This section compares the effectiveness of the non-mercury alternative product/components to the mercury containing products or components. The function of the mercury containing product/components will be considered, and the merits and shortcomings of the alternatives will be presented.

Manufacturers
This section lists in table format the manufacturers of mercury containing products/components and manufacturers of the non-mercury alternatives. This table also provides product/component name, manufacturer phone number, and manufacturer website information.

Format
There are two formats used in this report to present findings. The priority products are covered in sections 4.2 through 4.11 utilizing the following format:

Description

Alternatives

Costs

Advantages/Disadvantages

Manufacturers

Summary

The priority components are covered in sections 4.12 through 4.17 utilizing a slightly different format. Since the components are used in a wide variety of products and applications, the description, costs, advantages/disadvantages, and manufacturers information will be provided for each non-mercury alternative identified. Also, the manufacturers of both mercury and non-mercury manufacturers are provided. The following is the format for priority components:

Description

Costs

Advantages/Disadvantages

Manufacturers

Summary

4.1 Costs of Using Mercury

Traditionally the cost of using mercury has been focused on the purchase price of the device. What is often not recognized are the other costs that go along with the use of mercury. These other costs include potential for costly spills, adverse health effects, liability, regulatory compliance costs and maintaining equipment and trained personnel to handle mercury releases.

Tellus Institute's report "Healthy Hospitals: Environmental Improvements Through Better Environmental Accounting" proposes that environmental costs and benefit information can be incorporated into accounting practices to attain a more meaningful cost. It considers environmental costs, which are defined as "impacts, both monetary and non-monetary, incurred by a firm or organization resulting from activities affecting environmental quality. These costs include conventional costs, potentially hidden costs, and less tangible costs." (Tellus Institute, 2000)

Table 4.1: Mercury Costs

Potentially Hidden Costs	Less Tangible Costs
• Up-front: site preparation, permitting, installation • Back-end: site closure, disposal of inventory, post-closure care • Regulatory: training, monitoring, recordkeeping	• Liability: Superfund, personal injury, property damage • Future regulatory compliance costs • Employee safety and health compensation • Organizational image

Source: Tellus Institute, 2001

The same report provides a case study of Kaiser Permanente's mercury minimization efforts. Kaiser Permanente is the largest not-for-profit Health Maintenance Organization (HMO) in the United States. Kaiser considered the costs in addition to the purchase price of mercury thermometers and sphygmomanometers that could be avoided by using alternative non-mercury products. For sphygmomanometers, Kaiser found that "the aneroid alternative is significantly more expensive to purchase on a unit basis. When associated lifecycle costs are included … total costs per unit drop to about 1/3 the total costs of the mercury unit." The findings of the LCSP study indicate that in 2002, the purchase cost of mercury and aneroid sphygmomanometers are now comparable. This further reduces the lifecycle costs for the non-mercury sphygmomanometers.

Kaiser's mercury minimization efforts reduced costs avoidance by reducing the incidence of spills, exposure incidents and liability, and staff toxics training, as detailed in the Table 4.2. Kaiser's estimates suggest that for every $1 spent on spill response, there is potentially another $1.75 for training, fines, and treatment of exposure. (Tellus Institute, 2000)

Although clean up costs are not well documented in the literature, an internet search revealed numerous reports that provide insight into the financial impact of a mercury spill. A summary of these reports is presented in Appendix 2.

While the LCSP study does not present the full life cycle costs for each of the mercury and non-mercury products, the costs delineated in this section should be considered when evaluating these products.

Table 4.2 : Kaiser Permanente Case Study

Avoided Cost Category and Amount	Sources of cost avoidance estimate
Spill preparation and response $20,000/year	The cost of a mercury spill kit is known, as is the cost of a spill response by Kaiser Permanente's contractor. These costs, combined with the average historical number of spill incidents from broken devices in a year, permit an avoided cost estimate to be made.
Compliance and liability $15,000/year	Use of mercury-containing devices necessitates staff spill/exposure training. Further, given staff training, careful use and appropriate spill procedures, the presence of mercury-containing devices gives rise to the possibility of fines from facility inspections or spill incidents. The probabilistic costs of mercury related penalties were estimated using representative statutory and regulatory penalties multiplied by the probability of a fine being assessed for any particular violation.
Treatment of exposure	A probabilistic cost. Even assuming very high standards of appropriate and careful use, some small number of mercury exposures from broken devices are likely when mercury-containing devices are employed throughout the Kaiser system. Cost is determined from the expected yearly cost of long-term treatment of a single pediatric exposure case ($100,000-plus), and the probability of an exposure incident within a given year.
Additional soft savings (environmental staff were aware of these costs, but they were not quantified)	"Soft cost" savings were not estimated, but could, include: environmental contamination from mercury release, subsequent health impact, and negative media attention.

Source: Tellus Institute, 2000

4.2 Sphygmomanometers

Description

Blood pressure is generated by the activity of the heart and blood vessel system and is widely accepted as a measure of cardiovascular performance. Therefore blood pressure levels and variations are considered to be a valid indicator of cardiovascular function and overall health.

Most blood pressure devices use an air filled cuff to temporarily block blood flow through the artery, then apply a particular technique to obtain blood pressure data while the cuff deflates. The two most common techniques for pressure measurement are the auscultatory method (listening for characteristic blood flow sounds) or oscillometric technique (using a pressure transducer).

The two main considerations for this discussion of blood pressure devices are 1) how the blood pressure is sensed (e.g. by ear or by using a pressure transducer) and 2) the gauge or indicator for the pressure value (mercury column, dial gauge, or microprocessor/digital display). A mercury column is the traditional method of indicating blood pressure.

Alternatives

In the field, two alternatives to mercury are widely marketed for clinical blood pressure measurement. They are aneroid (mechanical dial) sphygmomanometers and low-end professional electronic blood pressure monitors. There are other non-mercury blood pressure monitors available as well, including home monitors, ambulatory blood pressure monitors, and high-end vital signs monitors. These are not covered in this report because they are generally not considered direct replacements for mercury sphygmomanometers.

Auscultatory Sphygmomanometers (mercury and aneroid)

Mercury and aneroid sphygmomanometers rely on the auscultatory technique, in which a clinician determines systolic and diastolic blood pressures (SBP and DBP) by listening for Korotkoff sounds, or sounds that characterize different stages of blood flow during cuff deflation. At certain points in the sound pattern, the clinician reads the pressure using a column of mercury or the dial of an aneroid (mechanical) gauge. This technology is the most widely used because of its low cost and simplicity.

The familiar mercury sphygmomanometer uses a column of mercury (manometer) to provide the pressure readout. Mercury's liquid state and its precise expansion and contraction in response to pressure are very suitable for pressure indication. The manometer reads from 0 to 300 mmHg.

A common aneroid gauge consists of a dial that reads in units of 0 to 300 mmHg and a thin brass corrugated bellows inside. There is a shaft which connects two pins at right angles to each other; one of these rests on the bellows, the other is inside a concave sided triangle which meshes with a pinion connected to the dial pointer. A thin coiled spring (known as a hair spring) is also connected to the pinion and returns the pointer to zero when the pressure is released. The gauge is connected to a blood pressure cuff around the patient's arm. As the pressure in the cuff rises, the pin resting on the expanding bellows is lifted. This movement is transmitted by the other pin which moves the triangle and therefore the pinion and pointer. (Yeats, 1993)

Welch Allyn has recently introduced the Dura Shock aneroid sphygmomanometer that utilizes a new internal design. The new concept results in a sphygmomanometer that is lighter in weight, considerably lower in cost, and more shock resistant than a conventional aneroid sphygmomanometer. Further research is warranted to understand the internal design.

Oscillometric Blood Pressure Monitors

The oscillometric blood pressure monitor uses a pressure sensor and a microprocessor in place of the ear and simple gage. During cuff deflation, a pressure sensor transmits an electric signal representing the distention of the artery. Within the microprocessor, this signal is translated to systolic and diastolic blood pressure (SBP and

DBP) using empirically derived algorithms. Manufacturers spend considerable effort validating their algorithms for accuracy.

In addition to SBP and DBP, this type of device can display more comprehensive information about blood pressure patterns, which can be useful for diagnostics. Because of its higher cost and technical sophistication, this type of device is not as prevalent as the auscultatory devices. The cost of these devices has dropped significantly over the past few years and companies are now marketing these to hospitals based on the breadth of information they can provide.

Electronic equipment using the oscillometric technique is common in two types of equipment:

1. A mid-price blood pressure monitor, designed to compete with auscultatory devices. In the past few years several companies have begun promoting this type of device and as their cost has decreased, use is becoming more widespread.
2. Vital signs monitors – This class of device is often found in hospital settings where simultaneous monitoring of multiple vital signs (e.g. temperature, blood pressure, heart rate, blood oxygen level) is desirable or critical for patient outcomes. The instrument's electronic box includes multiple modules, each for measuring a different sign. They are available from several device manufacturers. These devices, though relatively common in hospitals, are not considered further because they are not considered a one-for-one replacement for a mercury sphygmomanometer.

Cost

Most manufacturers of auscultatory devices offer both mercury and aneroid sphygmomanometers. A sampling of prices for mercury and aneroid devices revealed essentially no difference between the two, as shown in the following table.

Table 4.3 Cost of Comparable Mercury and Aneroid Sphygmomanometers

Manufacturer & Style	Type	List or Suggested price[1]	Model
Welch Allyn Wall unit	Mercury	$132	5097-26
	Aneroid	$134	5091-38
Welch Allyn Mobile unit	Mercury	$258	5097-29
	Aneroid	$253	5091-41
Welch Allyn Pocket unit (portable)	Mercury	Not available[2]	
	DuraShock[3] aneroid	$59	DS45-11
	Aneroid	$162	5098-02
ADC Wall Unit	Mercury	$111	952B
	Aneroid	$105	750W
ADC Mobile Unit	Mercury	$204	972
	Aneroid	$204	750M
Trimline Mobile Unit	Mercury	$299	0103N
	Aneroid	$264	4103N
Trimline Wall Model	Mercury	$120	0303N
	Aneroid	$137	4303N
Trimline Desk Model	Mercury	$148	0403N
	Aneroid	$151	4203N
Trimline Hand-held	Mercury	Not available[2]	
	Aneroid	$98	2273N

[1] These prices were obtained by contacting each manufacturer and/or their websites and requesting pricing on comparable mercury and aneroid units.

[2] No comparable unit because Hg column must be rigidly mounted in perfectly vertical position; incompatible with hand-held or portable units.

[3] The DuraShock is a new product for Welch Allyn that is more resilient than a traditional aneroid. This design also results in a significantly lower cost.

Oscillometric blood pressure monitors are considerably higher in price, as shown in the following table.

Table 4.4 Cost of Oscillometric Blood Pressure Monitors

Manufacturer & Style	List or Suggested price	Model
Pulse Metric	$995	DynaPulse Pathway
VSM MedTech Ltd.	$645	BP Tru
Welch Allyn Medical Products	$805	Spot Vital Signs™

Advantages/Disadvantages

From the perspective of clinicians and hospital systems, the considerations for blood pressure devices include cost, accuracy, ease of use, maintenance and calibration, and environmental impact. One needs to consider the merits and shortcomings of the following two aspects of blood pressure devices:

1. The method of pressure sensing; i.e. auscultatory (listening to sounds) versus oscillometric (using pressure transducers).
2. The pressure readout mechanism; i.e. mercury manometer, aneroid gauge, or microprocessor with digital display.

Auscultatory devices (mercury and aneroid) rely on the human ear to detect and distinguish sounds and there is a possibility for measurement error due to individual skill and levels of auditory acuity and sensitivity. Auscultatory devices allow measurement of just SBP and DBP. In contrast, the oscillometric monitors are less dependent on operator technique and many offer a greater breadth of baseline data including mean arterial pulse (MAP) and pulse rate. Some monitors also allow addition of modules for other vital signs (temperature, pulse oximetry), pulse waveforms, and data analysis. One manufacturer's technical representative reported that he continues to learn about the utility of the oscillometric device as doctors phone in and describe how they are using the data for diagnostics. In short, the breadth of information may allow doctors to better understand and manage a patient's condition.

Mercury gauges are familiar, have a long history of use, are on the low end of the cost spectrum and they have the unique advantage of being perceived as the gold standard for blood pressure. The primary disadvantages of the mercury gauge are associated with the toxicity of mercury. Mishandling may result in a mercury spill and there is potential for a costly mercury cleanup. Even with proper handling and maintenance, mercury gauges eventually require either handling of elemental mercury during maintenance or disposal of mercury as a hazardous waste. For the clinician, mercury gauges require positioning one's head at the proper, but often awkward, angle to read the glass tube's mercury meniscus.

Aneroid gauges are familiar, have a long history of use, are on the low end of the cost spectrum, are easy to read, and the clinician can easily perform a rudimentary function check by observing the zero resting point and the smoothness of dial rotation. Mishandling may result in damage to the gauge. Aneroid gauges have been maligned in the press recently, and there is an unsubstantiated perception that accuracy of aneroid gauges is inferior to mercury columns. The calibration is different from, but comparable in complexity, to proper calibration of the mercury devices.

The electronic monitors on the oscillometric devices are easy to use and provide an easy-to-read digital display of the DBP and SBP. The devices go through a self-calibration routine on start up. In addition to SBP and DBP, many of the devices display comprehensive data that provides greater insight into patient health; as the devices are used more widely it is likely that the full utility of features will be better recognized and reported. Some disadvantages of the electronic blood pressure monitors are initial cost and the need for A/C power or a battery pack.

Manufacturers
The following are manufacturers of alternative sphygmomanometers:

Mercury and Aneroid Sphygmomanometers

Manufacturer Name	Product	Phone Number & Website
American Diagnostic Corporation	ADC Sphygmo-manometer	613-273-9600 www.adctoday.com
Trimline Medical Products	Trimline Sphygmo-manometer	800-526-3538 www.trimlinemed.com
W.A. Baum Co. Inc.	Baum Aneroid Sphygmomanometer	631-226-3940 www.wabaum.com
Welch Allyn Medical Products	WelchAllyn Tycos sphygmo-manometer	315-685-4100 www.welchallyn.com

Oscillometric Blood Pressure Monitors

Manufacturer	Product	Phone Number & Website
Pulse Metric	DynaPulse Pathway	866-3962-78573 www.pulsemetric.com
VSM MedTech Ltd.	BpTRU™	913-307-9527 www.vsmmedtech.com
Welch Allyn Medical Products Vital Signs Products	Spot Vital Signs™	800-535-6663 www.welchallyn.com

Summary
Research on sphygmomanometers suggests that there are numerous good alternatives to mercury sphygmomanometers. Aneroid sphygmo-manometers are cost competitive, have a long history in the field, and have been found acceptable by many hospitals. Blood pressure monitors are more costly, but are becoming more popular as costs are dropping and medical practitioners are seeing advantages to their ease of use and the breadth of information provided.

The Mayo Medical Center in Rochester, Minnesota is an example of a facility that has successfully converted to non-mercury sphygmomanometers. Since 1993, Mayo Clinic replaced approximately 1,500 mercury sphygmomanometers with wall-mounted aneroid devices. At the same time a maintenance protocol was developed to ensure proper function and accuracy of these devices. In March 2001, Mayo published the results of an internal study in which they concluded that the aneroid sphygmomanometers provide accurate pressure measurements when properly maintained. (Canzanello et al, 2001) Appendix 5, Aneroid Sphygmomanometers, includes further discussion and addresses some commonly held perceptions about the use of aneroid sphygmomanometers.

4.3 Esophageal Dilators (Bougies) and Gastrointestinal Tubes

Esophageal Dilators (Bougies)

Description
An esophageal dilator, also called a bougie, is a long, weighted flexible tube that is passed down a patient's esophagus to dilate a narrowed area. In the past, mercury was commonly used in the bougie. Its density and liquid state made mercury ideal as a flexible weight that assisted passing the tube down the throat into the esophagus, conforming to the shape of the esophagus and exerting the pressure needed to enlarge the narrowed section. The mercury-filled devices have a thick latex outer coating that contains about two pounds of mercury. Esophageal dilators may be found in thoracic surgery, otolaryngology, and the medical procedure units.

Alternatives
The alternatives to mercury bougies use a tungsten gel to provide the flexible weight. Because tungsten is a solid at room temperature, the tungsten within the device is a powder suspended in a gel. This allows the dilator to flex and conform to the shape of the esophagus, have a "feel" similar to the density of mercury, and to

apply the proper pressure to enlarge the narrow area of the esophagus.

Cost

Mercury bougies are no longer widely available. Of the three manufacturers that were identified, only one company still offers mercury bougies at a cost of $3,395 for a full set. The cost of a set of replacement tungsten gel bougies listed in the range of $3,000 to $4,400. At the $4,400 end of the range, one manufacturer was offering 10% discounts and a free mercury bougie take-back option.

Advantages/Disadvantages

Bougies have an expiration date, due to the potential for degradation of the outer rubber casing. At the end of its useful life, a mercury bougie must be disposed of as a hazardous material. Mercury containing esophageal dilators have been known to rupture during handling or use causing potential environmental, patient, and employee hazards. The FDA Medical Device Report (MDR) system includes reports of bougies rupturing and leaving mercury inside the patient as well as in the room. Examples of MDRs for ruptured bougies are included in Appendix 1.

The tungsten bougie is considered to be a safer, more environmentally benign alternative. The tungsten gel filled bougies perform like mercury filled bougies, so there are no changes in technique required. At the end of its useful life, a tungsten filled bougie can be disposed of in the trash. Tungsten bougies have either a silicone covering or a PVC covering. An advantage of the silicone surface is that it is non-slip when dry and slippery when wet, making handling easier. Some healthcare facilities are moving away from PVC because of a concern that when PVC is incinerated as waste, there is potential for the formation of dioxins during incineration.

Manufacturers

The following are manufacturers of non-mercury and mercury esophageal dilators:

Manufacturer	Product	Phone Number & Website
Medovations, Inc	Weightright™ Bougie	800-558-6408 www.medovations.com
Pilling	Bougie Tubes (Maloney style and Hurst style bougies are weighted with tungsten gel)	800-523-6507 www.pillingsurgical.com
Rusch	Bougie Tubes (Maloney style and Hurst style bougies are tungsten filled)	800-524-7722 www.myrusch.com

Summary

Phone interviews with manufacturers and medical practitioners suggest that tungsten filled bougies are widely available and well received as alternatives to mercury containing bougies. For example, a seasoned practitioner in a hospital in the northwest suburbs of Boston who was interviewed recalled her hospital's much earlier use of mercury bougies. Her recollection was that the hospital had been using tungsten filled bougies for years and the non-mercury devices performed just fine.

Gastrointestinal Tubes

Description

Another family of tubes, including Miller Abbott, Blakemore, and Cantor tubes, are used for addressing intestinal obstructions. Historically these tubes used mercury as a flexible weight to guide the tube into place through gravity.

This family of products represents a data gap in this report. Research suggested that these devices are no longer widely used and no manufacturers of mercury-containing devices were identified. Unweighted tubes are available, and although the manufacturers do not supply mercury they believe some customers add their own mercury.

Alternatives
Two manufacturers were identified that described their products as viable alternatives for this type of application. Andersen offered unweighted and tungsten weighted tubes that they described as alternatives for Miller-Abbott and Cantor tubes. Rusch's Product Manager suggested that practitioners can add sterile water to the Cantor tube, as a weight to help move the tube.

Cost
A cost comparison is not relevant since mercury products were not located. However, the cost of the non-mercury Miller Abbott and Cantor tubes were approximately $300 to $400.

Advantages/Disadvantages
One manufacturer reported that sterile water can be used as a weight for the cantor tube, in the place of mercury. The disadvantage is that the tube passes much more slowly, a disadvantage that translates to a longer medical procedure time.

Manufacturers
The following are manufacturers of gastro-intestinal tubes for which the buyer must provide the weighted liquid:

Manufacturer	Product	Phone Number & Website
Andersen	Miller Abbott & Cantor Tubes	800-523-1276
Rusch	Cantor Tubes	800-524-7722 www.myrusch.com

Summary
Research on gastrointestinal tubes suggests that this family of products is no longer widely used in hospitals. It is unclear whether mercury is still used in settings where gastrointestinal tubes have not become obsolete and if so, whether an alternative practice or product might be acceptable.

Dartmouth Hitchcock Medical Center reported that in 1995 they eliminated the use of mercury in Miller Abbott Tubes by replacing the mercury with water and a contrast media. When the change was implemented, there was a concern that because water is not as heavy as mercury, the procedure might take longer than with mercury. However the Safety and Environmental Programs office did not receive complaints from clinicians about the replacement. It was reported that the nursing and housekeeping staff were pleased with the elimination of mercury because they were responsible for mercury spills.

4.4 Manometers

Description
Manometers are used to measure air, gas, and water pressure. The mercury in manometers responds to air pressure in a precise way that can be calibrated on a scale. Manometers are used in laboratories, the dairy industry milking process, and for calibrating outboard motors and motorcycle carburetors. Manometers are also used by HVAC contractors for testing, balancing, and servicing equipment.

Alternatives
The three alternatives to a mercury manometer include the needle/bourdon gauge, the aneroid manometer, and the digital manometer. The needle/bourdon gauge operates under a vacuum with a needle indicator as a method to measure pressure. The aneroid manometer operates in a similar fashion to the needle/bourdon gauge. The digital manometer uses a digital computer programmed memory and gauges to measure the pressure.

Cost
Many digital manometers are manufactured for various purposes and most pressure-sensing units can be used interchangeably for different applications. Digital manometers can range in price from $100 to $700 depending on the

application it is being used for. Needle/bourdon gauges range from $50 to $200 depending on the application and manufacturer.

Advantages/Disadvantages

Digital manometers, mercury manometers, and needle/bourdon gauges require calibration. This calibration ensures the accuracy of the instrument reading. A digital manometer can be more precise than the mercury manometer if properly calibrated.

Manufacturers

The following are manufacturers of non-mercury manometers.

Manufacturer Name	Product	Phone Number & Website
Mannix	Digital manometer	516-887-7979 www.mannix-inst.com
Testo	Digital manometer	973-252-1720/1-800-227-0729 www.testo.com
Extech Instruments	Digital manometer	781-890-7440 www.extech.com
Carbtune	Aneroid manometer	011 44 28 9023 9007 www.carbtune.com
Alnor	Digital manometer	1-800-424-7427 www.alnor.com
Dwyer Instruments	Digital manometer, Needle/ bourdon gauge	219-879-8000 www.dwyerinstruments.com

Summary

It appears that the alternatives to a mercury manometer are cost competitive, reliable, and widely manufactured and used throughout the United States. An example of a successful mercury manometer replacement project is the effort undertaken for dairy farms in Wisconsin with a $40,000 grant from the EPA. Dairy equipment service providers participated in this program by collecting the mercury manometers used on dairy farms and replacing them with non-mercury manometers. Under this program, more than 100 manometers have been removed from Wisconsin dairy farms. (Wisconsin Department of Natural Resources, 2002) A similar program in Maine has resulted in the replacement of twenty-five mercury manometers from dairy barn milking machines. (Maine DEP)

4.5 Thermometers (non-fever)

Basal Thermometers

Background

An individual's basal body metabolism is reflected in basal metabolic temperature, or the lowest normal body temperature of a person immediately on waking in the morning. Day-to-day variations in basal temperature are indicative of the body's cyclical changes. For example, basal temperature is a useful index for evaluating ovulation.

This baseline temperature is measured with a basal thermometer, which is more sensitive than a conventional fever thermometer. The smallest division on a basal thermometers is 0.1 degree, compared with 0.2 degree on a conventional fever thermometer.

Mercury basal thermometers are similar in function to mercury fever thermometers. A column of mercury within a glass tube expands with increasing temperature and registers a reading at the peak temperature.

Alternatives

Alternatives to basal thermometers are galinstan-in-glass (liquid in a glass tube) and compact digital thermometers.

Galinstan basal thermometers are sold under the brand name Geratherm. Like mercury thermometers, the Geratherm thermometer consists of silvery liquid in a glass tube. The liquid is a mixture of gallium, indium, and tin that expands with temperature to provide a reading. These are similar to Geratherm fever thermometers.

Battery-powered digital basal thermometers are the most common option for basal

thermometers. These are similar in appearance and function to digital fever thermometers.

Cost

Basal thermometers are fairly inexpensive and technologies are readily available for under $15. The cost of devices is historically lowest for mercury basal thermometers, mid-range for Geratherm, and highest for digital devices.

A data gap exists for the cost of mercury basal thermometers as our research was unable to easily identify a current manufacturer. Becton Dickenson, a large medical manufacturer, reported that they no longer offer mercury basal thermometers. Pharmacies in the researchers' local area have also eliminated mercury basal thermometers, although anecdotal information suggests that mercury basal thermometers are still available in other geographic locations.

According to one manufacturer, their list price for the Geratherm basal thermometer is $7.69-$7.99. Another manufacturer reported that the average list price for its digital basal thermometer is $12.

Advantages/Disadvantages

The primary selling points for mercury are cost and familiarity. The disadvantages of mercury basal thermometers are: lengthy dwell time to peak temperature (3-5 minutes), shake down is required between readings, difficulty reading the column of mercury, fragile glass structure, and mercury basal thermometers may not be widely available.

The Geratherm liquid-in-glass thermometer is comparable in function to mercury. That is, it consists of a glass tube containing a silvery liquid that rises in a column with increasing temperature. The Geratherm is lower in cost than digital thermometers. Galinstan thermometers have several disadvantages: the toxicity of the gallium-indium-tin mixture is not well researched or understood, the silvery liquid may be mistaken for mercury, the fragile glass structure can break easily, and the Geratherm is slightly larger than a mercury basal thermometer.

Digital basal thermometers appear to be the most commonly available alternative to mercury devices. There are a number of reasons that the digitals are easily accepted: the time for taking a temperature is approximately 1 minute (vs. ~4 minutes for mercury), the thermometer provides beeps to signal when peak temperature is reached, and there is a memory chip that recalls the last reading. The main drawback of a digital thermometer is that it uses a battery, which requires proper recycling/disposal at the end of its useful life. The digital basal thermometers are also more expensive than either mercury devices or Geratherm thermometers.

Manufacturers

The following are manufacturers of basal thermometers:

Manufacturer	Product	Phone Number & Website
Becton Dickinson	Digital basal thermometer	201-847-6800 http://www.bd.com
Mabis Healthcare	Digital basal thermometer	800-728-6811 http://www.mabis.net
Omron Healthcare, Inc.	Digital basal thermometer	800-231-3434 http://www.omronhealthcare.com
R.G. Medical Diagnostics (U.S. Distributor)	Geratherm basal thermometer (Galinstan liquid-in-glass thermometer)	888-596-9498 http://www.rgmd.com

Summary

Based on discussions with manufacturers and visits to local pharmacies, it appears that suitable alternatives are readily available for mercury basal thermometers.

Other Thermometers (non-fever)

Description

Non-fever thermometers are used for various industrial, laboratory, and commercial applications including food preparation, freezers, laboratory refrigerators, and testing. The protocol for certain lab requirements and food preparation codes require that the thermometers be of a high quality.

Alternatives

The colored-liquid in glass thermometer (also called "liquid thermometer") is the most common replacement to the mercury thermometer. Its appearance and structure are similar to mercury in glass; it consists of a cylindrical tube containing a liquid that expands and contracts with increasing and decreasing temperature. The liquids used in such glass thermometers include common organic liquids such as alcohol, kerosene, and citrus extract based solvents that are dyed blue, red or green. Some manufacturers offer liquid thermometers described as non-toxic or environmentally friendly. Digital, bi-metal or infrared thermometers are also alternatives to mercury thermometers and are used in many of the same applications.

Cost

The costs of a thermometer can vary based upon the requirements of a particular application. The following table illustrates these cost differences.

Table 4.5: Thermometer Costs

Application	Thermometer Type	Cost
Food Preparation	Mercury	$10 - $40
	Bi-metal	$13 - $138
	Digital	$14 - $20
	Liquid filled	$2 - $28
Industrial	Infrared	$92 - 270
Laboratory	Mercury	$15 - $60
	Digital	$20 - $100
	Liquid filled	$20 – $60
	Infrared	$92 - $270
Freezer/ Refrigeration	Bi-metal	$6 - $15
	Liquid filled	$2 - $28

Advantages/Disadvantages

The benefits of using a digital or infrared thermometer are that they are very accurate and easy to read. Infrared thermometers are much more costly than digital thermometers but in some applications the use of an infrared thermometer is necessary. All thermometers, whether they are mercury, digital, bi-metal or organic liquid, do need to be re-calibrated at least annually. Re-calibration is required due to the gradual relaxation of residual mechanical strains in the glass that can affect the volume of the bulb.

A disadvantage of all liquid thermometers is the possibility of column separation. When a separated column occurs, the thermometer cannot be used until the column is rejoined and recalibrated.

Evidence provided by manufacturers indicates that most alternatives to mercury thermometers are as effective and reliable as the mercury thermometer with regular calibration. The most common barrier to change is the widespread use of mercury thermometers as the "standard" for all temperature sensing devices.

Manufacturers

The following are manufacturers of alternatives to mercury thermometers.

Manufacturer Name	Product	Phone Number & Website
ICL Calibration Laboratories	Liquid filled, Digital thermometer	www.icllabs.com
Ertco (ever ready thermometers)	Liquid filled, Digital thermometer	1-800-453-7826 www.ertco.com
Comark	Liquid filled, Digital Thermometer	1-800-555-6658 / 503-643-5204 www.comarkltd.com
Miller Weber	Liquid filled (Performather m), Digital, Bi-metal thermometer	718-821-7110 www.millerweber.com
Taylor	Liquid filled, Digital, Bi-metal thermometer	630-954-1250 www.taylorusa.com
Weiss Instruments	Liquid filled, Digital, Bi-metal thermometer	631-207-1200 www.weissinstruments.com
Cooper Instrument Corporation	Liquid filled, Digital thermometer	860-349-3473 www.cooperinstrument.com

Manufacturer Name	Product	Phone Number & Website
Becton Dickenson	Liquid filled, Digital thermometer	201-847-6800 www.bd.com
Mannix	Infrared, Digital thermometer	516-887-7979 www.mannix-inst.com

Summary

It is apparent that there are many alternatives to mercury thermometers that are cost effective and acceptable. However, a Food and Drug Administration procedure for food processing was identified that requires at least one mercury-in-glass thermometer for each retort. This requirement is outlined in the Code of Federal Regulations under: 21 CFR Ch. 1 Part 113 – Thermally Processed Low-acid Foods Packaged in Hermetically Sealed Containers.

An example of a successful mercury thermometer replacement program is the "Mercury Thermometer Swap" program undertaken by the University of Vermont. More than 1,400 mercury thermometers were replaced with non-mercury alternatives under this program. The majority of these replacements occurred in laboratories within the chemistry department. (Winkler, 1999)

4.6 Barometers

Description

Barometers are used to measure the atmospheric pressure. The barometer is a long cylindrical tube filled with mercury. The mercury is displaced by the atmospheric pressure. When the mercury level rises in a barometer it indicates increasing air pressure; when the mercury level is decreasing it indicates decreasing air pressure.

Alternatives

The aneroid barometer is more compact and consists of an evacuated metal diaphragm linked mechanically to an indicating needle. As atmospheric pressure increases or decreases the diaphragm compresses or expands, causing the indicating needle to show the change in pressure. The digital barometer contains a sensor with electrical properties (resistance or capacitance) that change as the atmospheric pressure changes. These sensors are considered to be just as accurate as a traditional or an aneroid barometer. Additional electronic circuitry converts the sensor output into a digital display. There is also a device called a water barometer that is similar to a traditional mercury barometer. Changes in air pressure cause the water to rise and fall in the spout. Low water level indicates high pressure and fair weather. The water level rises as the air pressure falls.

Cost

The digital barometer can cost between $50 - $300 depending on the manufacturer and the other applications the digital barometer can perform. Because mercury barometers and aneroid barometers are often considered collector's items, their prices are much higher, ranging from $100 to over $1000.

Advantages/Disadvantages

Aneroid barometers have been used for approximately 200 years and are considered just as accurate as the traditional mercury barometer. The digital barometer is programmable and is considered to be as accurate as the mercury barometer.

Manufacturers

The following are manufacturers of alternatives to mercury barometers.

Manufacturer Name	Product	Phone Number/ Website
Howard Miller	Aneroid barometer	www.howardmiller.com
Weems & Plath	Aneroid barometer	410-263-6700 www.weems-plath.com
Bacharach	Digital barometer	724-334-5000/1-800-736-4666 www.bacharach-inc.com
Kestrel	Digital barometer	610-447-1555 www.nkhome.com

Summary
The aneroid and digital barometers are cost effective, in use, and acceptable alternatives to the mercury barometer.

4.7 Psychrometers/Hygrometers

Description
A hygrometer is an instrument used to measure the moisture content of air or any gas. The most common type of hygrometer is the "dry and wet-bulb psychrometer." The psychrometer is best described as two mercury thermometers, one with a wetted base, and one with a dry base. The water from the wet base evaporates and absorbs heat causing the thermometer reading to drop. Using a calculation table, the reading from the dry thermometer and the reading drop from the wet thermometer are used to determine the relative humidity.

The sling psychrometer is also used to determine relative humidity and is reliably measured by both digital and alcohol type psychrometers. The sling psychrometer is basically a thermometer encased in a swiveling mechanism that is swung around rapidly to record an accurate reading for relative humidity. Psychrometers function the same as a hygrometers, however the names are different due to the applications for which they are used. For example, the hygrometer is used to monitor the moisture in the storage area for cigar tobacco used by manufacturers and cigar aficionados. Atmospheric scientists and weather enthusiasts use the psychrometer to monitor outdoor humidity and moisture content.

Alternatives
Spirit-filled thermometers can be used in psychrometers instead of the mercury thermometers and provide equally accurate results. Another alternative is the digital hygrometer that uses electronic sensors and a digital program to measure the humidity of the air. Both the digital hygrometer and spirit filled hygrometer are relatively inexpensive, are readily available, and currently in use.

Cost
The spirit-filled sling psychrometer and the spirit-filled hygrometer are both similar in pricing when compared to mercury versions of the same product. The digital psychrometer was found to be more expensive than the spirit filled version, but the digital hygrometer was found to be less expensive than the spirit filled version, ranging from $15 to $60.

Advantages/Disadvantages
The digital hygrometer and digital psychrometer provide much more accurate results when properly calibrated because the possibility of human error is eliminated.

Manufacturers
The following are manufacturers of alternatives to mercury psychrometers and hydrometers:

Manufacturer Name	Product	Phone Number & Website
Bacharach	Spirit filled psychrometers	1-800-736-4666 www.bacharach-inc.com
Testo	Digital psychrometers	973-252-1720/1-800-227-0729 www.testo.com
Miller Weber	Digital hygrometer	718-821-7110 www.millerweber.com
Mannix	Spirit filled psychrometers	516-887-7979 www.mannix-inst.com
Tramex	Digital hygrometer	353-1-282 3688 www.tramexltd.com

Summary
The spirit filled psychrometers and digital hydrometers appear to be acceptable, cost effective alternatives to mercury filled devices.

4.8 Hydrometers

Description
A hydrometer is a device that measures the density or specific gravity of a liquid. Hydrometers are calibrated based upon the

specific gravity of water at 60°C being 1.000. Liquids denser than water will have a higher specific gravity, while liquids less dense will have a lower specific gravity. The hydrometer is used for many applications. For example it is used in the petroleum and dairy industries, as well as in amateur wine and beer making.

Alternatives
An alternative to a mercury hydrometer is the spirit filled hydrometer. The spirit filled hydrometer comes customized to suit individual applications. The manufacturer should be consulted to use the most appropriate hydrometer.

Cost
The cost of a mercury hydrometer ranges from $12 to $30, or about $2 less on average than a spirit filled hydrometer.

Advantages/Disadvantages
The accuracy of a spirit filled hydrometer is considered to be comparable to a mercury hydrometer.

Manufacturers
The following are manufacturers of alternatives to mercury hydrometers:

Manufacturer Name	Product	Phone Number Website
Miller Weber	Alcohol/spirit filled hydrometer	718-821-7110 www.millerweber.com
Ertco (ever ready thermometers)	Alcohol/spirit filled hydrometer	1-800-453-7826 www.ertco.com
ICL Calibration Laboratories	Alcohol/spirit filled hydrometer	www.icllabs.com

Summary
The spirit filled hydrometer is cost effective, in use, and an acceptable alternative to the mercury hydrometer.

4.9 Flow meters

Description
Flow meters are used in many areas for measuring the flow of gas, water, air, and steam. They are used in water treatment, sewage plants, power stations, and other industrial applications.

Alternatives
The manufacturers contacted stated that they did not use mercury in the manufacturing of new flow meters. However, most older flow meters still in use contain mercury. Non-mercury alternatives include digital and ball actuated flow meters.

Cost
The cost associated with flow meters depends on the application. Some flow meters are custom designed for certain applications, which can increase the cost. The manufacturers contacted declined to provide a price range because they felt it would be misleading.

Manufacturers
The following are manufacturers of alternatives to mercury containing flow meters:

Manufacturer Name	Product	Phone Number Website
Eldridge Products, Inc	Digital and ball actuated flow meters	1-800-321-3569 www.epiflow.com
Flow Technology	Digital and ball actuated flow meters	602-437-1315 www.ftimeters.com
Alloborg Instruments & Controls	Digital and ball actuated flow meters	1-800-866-3837 www.aalborg.com
John C. Ernst	Digital and ball actuated flow meters	973-989-0300 www.johnernst.com
Lake Monitors	Digital and ball actuated flow meters	1-800-850-6110 www.lakemonitors.com

Manufacturer Name	Product	Phone Number Website
Universal Flow Monitors	Digital and ball actuated flow meters	248-542-9635 www.flowmeters.com
Digiflow Systems	Digital flow meters	419-756-1746 www.digiflowsys.com
Primary Flow Signal, Inc.	Digital and ball actuated flow meters	877-737-3569 www.primaryflowsignal.com

Summary
It appears that mercury flow meters are no longer being manufactured, and alternatives to older mercury flow meters are in use, cost effective, and acceptable.

4.10 Pyrometers

Description
Pyrometers are used to measure the temperature of extremely hot materials, and are used primarily in foundry applications. No manufacturers were identified that currently provide mercury pyrometers. Some pyrometers still in use do have mercury within the temperature-sensing device.

Alternatives
There are two alternatives available, the optical pyrometer and the digital pyrometer. An optical pyrometer is a device that allows temperature to be measured by using incandescence color. The theory behind an optical pyrometer is that when a substance is heated to about 700°C, it begins to glow a deep red color. This indicates that the object is emitting enough energy in the visible portion of the spectrum for detection. As the temperature increases, the object changes from red to orange to white, with concurrent dramatic increases in brightness. The hot target is viewed through an optical system that contains a lamp filament whose brightness can be adjusted until it equals that of the target, and gives you an already known temperature that has been measured and recorded into the pyrometer. Digital pyrometers are also available, and use a thermocouple with a digital output screen that relays the temperature.

Cost
The cost of an optical pyrometer is in the range of $3000. The cost of a digital pyrometer is less than an optical pyrometer, and can cost between $180 to $300 depending on the manufacturer. No manufacturers of a mercury pyrometer could be located, and therefore a price for a mercury pyrometer could not be determined. Manufacturers of the alternatives would not speculate about the cost of a mercury pyrometer.

Advantages/Disadvantages
Optical pyrometers are used in applications of extreme heat and are extremely accurate. The digital pyrometers are also considered to be functional and reliable for temperature reading but not as accurate as an optical pyrometer at higher temperatures.

Manufacturers
The following are manufacturers of alternatives to mercury pyrometers:

Manufacturer Name	Product	Phone Number Website
EDL	Optical/digital pyrometers	1-800-342-5335 www.edl-inc.com
MIFCO	Digital pyrometer	217-446-0941 www.mifco.com
Spectrodyne	Optical/ pyrometers	215-977-7780 www.spectrodyne.com
Precision Pyrometer	Optical/ pyrometers	1-800-468-7976 www.pyrometer.com

Summary
It appears that the mercury pyrometer is no longer being manufactured, but may be in use in some locations. The digital and optical pyrometers are reliable technologies which function as alternatives to the mercury pyrometer.

4.11 Thermostats (industrial and manufacturing)

Description
Industrial thermostats provide temperature control in manufacturing and industrial settings. The mercury thermostat uses a mercury switch to activate the heating/cooling device. The mercury in the switch is part of an electric current relay which relies on an electric current to activate and deactivate the heating/cooling device when the mercury in the switch is tipped.

Alternatives
Digital electronic thermostats are available for industrial type workloads and temperature control. Digital thermostats use a simple device called a thermistor to measure temperature. A thermistor is a resistor whose electrical resistance changes with temperature. The microcontroller in a digital thermostat can measure the resistance and convert that number to a temperature reading.

Costs
Manufacturers were unable to provide specific price quotes because industrial thermostats are often custom tailored to meet the requirements of a specific application. The price is then derived on an application specific basis. Manufacturers believed it would be misleading to provide a price range of industrial thermostats they had previously manufactured for specific applications.

Advantages/Disadvantages
Digital thermostats have limits that should be researched by the buyer to determine the type of thermostat best suited for an industrial purpose. Many industrial thermostats are needed to regulate higher temperatures than household thermostats. Industrial thermostats are created to be more durable and withstand higher temperatures and harsher environments. Manufacturers who supply digital thermostats for light industrial purposes report that they may not meet the most demanding applications. Situations in which digital thermostats would not perform as well as mercury products are cases of extreme environmental conditions and areas at risk of explosions or fire.

Manufacturers
The following are manufacturers of industrial thermostats:

Manufacturer Name	Product	Phone Number & Website
Chromalox	Thermostats	412-967-3800 http://www.mychromalox.com/
Honeywell International	Thermostats	612-951-1000 www.honeywell.com
Kelvin Technologies	Thermostats	1-800-458-5246 www.kelvintech.com

Summary
It appears that no functional alternatives to mercury thermostats for industrial settings with harsh environmental conditions are available.

4.12 Float Switches

There are two basic types of float switches: 1) a float switch can be located in a buoyant float housing and is actuated based upon rising and falling liquid levels, or 2) a float switch can be stationary and is actuated by the presence or absence of liquid. Float switches are used for liquid monitoring and control in tanks, wells, chambers, drillings, and other containers. Float switches are used to actuate alarm and control circuits. Float switches have been used for monitoring various liquids including, among others, water, sewage, wet sludge, oil, chemicals, grease, and liquid nitrogen.

A float switch is a versatile component used to meet the needs of thousands of varied products and applications. A float switch can be incorporated into a product (e.g. bilge pumps,

automobiles, etc.), or can be purchased as a component to be used in a customer specific application (e.g. waste treatment plant). Listed below are examples of products and applications that use float switches. Many of these products and applications may already use non-mercury float switches. :

- Pump control: bilge, sump, utility, shower, effluent, waste, lubrication, etc.
- Equipment Control: magnetic valve, cooling equipment, motors, etc.
- Alarm/Outputs: programmable logic controllers, distributed control systems, supervisory control and data acquisition, etc.
- Industrial/manufacturing: processing liquids, waste treatment, air conditioners, semiconductor manufacturing, automatic plating machinery, etc.
- Residential: sump pumps, septic tanks, hot water heaters, automatic plumbing fixtures, etc.
- Marine: bilge pumps, shower pumps, ocean liner sewage disposal, balance tank on ships, etc.
- Automobile: fuel tank, windshield wash reservoir, etc.
- Municipal: pumping stations, waste water treatment, sewage plants, etc.
- Commercial: boilers, vending machines, electrical equipment such as liquid insulated transformers, etc.
- Miscellaneous: food processing, irrigation systems, petrochemical processing, laundry tray, food warmers, steam cookers, mineral processing, hydraulic equipment, water filters, pharmaceutical processes, food processing, power stations, etc.

There are numerous design parameters that affect the specification and selection of a float switch for a particular product or application. Float switch design and product options vary greatly by manufacturer. The design requirements have a significant impact on technology selection, manufacturer selection, product model selection, product option selection, and ultimate product cost. The following is a concise listing of some of the more critical design parameters:

- Switch points: number of control points, number of alarm points, field adjustable points, etc.
- Level detection: point level, continuous level
- Accuracy: tolerances, calibration requirements
- Liquid environment: viscosity, conductivity, foam, bubbles, turbulence, contaminants, debris, etc.
- Mounting: side, bottom, or top of enclosure, free standing/suspended cable, pipe mount, stem mount, etc.
- Output contact rating: inductive load, resistive load, current, voltage, power, etc.
- Buoyancy: ball, counterweight, specific gravity, etc.
- Life expectancy: switch, controlled equipment, etc.
- Regulatory approval: Underwriters Laboratories, Canadian Standards Association, etc.

- Operating parameters: differential between control/alarm points, angle of operation, etc.

- Environmental conditions: temperature, pressure, explosiveness, shock, vibration, corrosiveness, moving equipment, etc.

- Input power requirements: 115 Volts AC, 230 Volts AC, 24 Volts DC, 12 Volts DC, other

- Switch: number of poles, number of throws, normally open, normally closed, relay, etc.

- Other parameters: signal time delay (to compensate for wave action), float switch enclosure material, intrinsically safe, cleaning requirements, space available for operation, etc.

Mercury Float Switch

Description

A mercury float switch is typically located in a buoyant float housing and is actuated based upon the rising and falling liquid levels. The mercury float switch contains a small tube with electrical contacts at one end of the tube. As the tube lifts, the mercury collects at the lower end, providing a conductive path to complete the circuit. When the switch is tilted back the circuit is broken. The mercury float switch operates in a similar fashion to the mercury tilt switch. The mercury content reported to IMERC for float switches was in the range of greater than 1,000 mg/switch.

Cost

The cost of a mercury float switch is approximately $15 to $150 depending upon product type or application requirements. Two manufacturers were identified that have both mercury and non-mercury float switches with the same functionality. These manufacturers charge the same price for the mercury float switch and the non-mercury mechanical float switch. One manufacturer was identified that provides the non-mercury mechanical float switch at a cost less than the mercury float switch for the same functionality.

One manufacturer charged more for a metallic ball float switch than for a mercury float switch with comparable functionality.

Advantages/Disadvantages

The mercury float switch has high reliability and long operational life because it has few components and is not subject to arcing. Life-cycle testing has been conducted for more than one million cycles. The mercury float switch can handle a high inductive load, has a quiet operation, has no bounce on contact, and can be hermetically sealed to provide increased protection from various environmental factors (e.g. dust, moisture, etc.). The mercury float switch can use one float for both on and off functions.

The mercury float switch requires a swing area to properly operate. If the application is in a tight location (e.g. windshield washer reservoir), then a magnet/reed float switch may be more appropriate. Because the switch contains mercury, it is becoming less desirable for many applications, including the food and beverage industry.

Manufacturers

The following are manufacturers of mercury float switches.

Manufacturer Name	Product	Phone Number & Website
Advanced Control Technology, Inc.	7000 Series	888-340-8820 www.actsensors.com
Comus International	Numerous models	973-777-8405 www.comus-intl.com
Conery Manufacturing Inc.	2900 Series	419-289-1444 www.conerymfg.com
Contegra Inc.	FS 96	651-905-0900 www.contegra.com

Manufacturer Name	Product	Phone Number & Website
Electro-sensors, Inc.	MLS Series	800-328-6170 www.electro-sensors.com
ITT Industries McDonnell & Miller	E-8, 80, 65, and 165 series	773-267-1600 www.mcdonnellmiller.com
ITT Industries Rule Industries	Models 35, 37, & 40	978-281-0440 www.rule-industries.com
Mercury Displacement Industries Inc.	A, B, C, & D Series	616-663-8574 www.mdius.com
Scientific Technologies Inc.	FG Series	888-525-7300 www.levelandflow.com
Septronics, Inc.	4701, 4704 Series	888-565-8908 www.septronicsinc.com
Signal Systems International Inc.	FS121, CW101 Series	732-793-4668 www.signalsystem.com
S.J. Electro Systems Inc.	Numerous Models	888-342-5753 www.sjerhombus.com

Alternative 1: Mechanical Switch

Description

A mechanical float switch is typically located in a buoyant float housing and is actuated based upon the rising and falling liquid levels. The mechanical switch can be a snap switch or micro-switch that can be actuated using a variety of methods. The most common method is that the lever arm is actuated by a metallic rolling ball that changes position based upon gravity and the position of the buoyant float housing.

Cost

The cost of a mechanical float switch is approximately $10 to $150 depending on product or application requirements. Two manufacturers were identified that have both mercury and non-mercury float switches with the same functionality. These manufacturers charge the same price for the mercury float switch and the non-mercury mechanical float switch. One manufacturer was identified that provides the non-mercury mechanical float switch at a cost less than the mercury float switch for the same functionality.

Advantages/Disadvantages

The mechanical float switch has high reliability, long operational life, can handle high inductive loads, and can be hermetically sealed to provide increased protection from various environmental factors (e.g. dust, moisture, etc.). Mechanical switches are often designed to have an operational life in excess of one million cycles. The mechanical float switch can use one float for both on and off functions.

The mechanical float switch typically needs a swing area to properly operate. However, this is not the case for mechanical float switches that use magnets in a vertical stem to activate the micro-switch.

Manufacturers

The following are manufacturers of mechanical float switches:

Manufacturer Name	Product	Phone Number & Website
Advanced Control Technology, Inc.	7300 Series	888-340-8820 www.actsensors.com
Aggressive Systems, Inc.	AMF Series	248-477-5300 www.aggressivesystems.com
Contegra Inc.	FS90 Series	651-905-0900 www.contegra.com
Dwyer Instruments, Inc. (Mercoid)	L6, L8 Series	219-879-8000 www.dwyer-inst.com
ITT Industries Jabsco	FS20	949-609-5106 www.jabsco.com
ITT Industries Rule Industries	ECO-Switch Model 39	978-281-0440 www.rule-industries.com

Manufacturer Name	Product	Phone Number & Website
Kari-Finn (Finland) U.S. Rep: STI Automation Sensors Division	Numerous models	Scientific Technologies Inc.: 888-525-7300 www.kari-finn.fi
Kobold	NGS series	800-998-1020 www.kobold.com
Lovett Marine	Models 3208 and 3209	800-673-5976 www.lovettmarine.com
Mercury Displacement Industries Inc.	Numerous models	616-663-8574 www.mdius.com
MJK Automation (Denmark) Danfoss – U.S. Representative	7030 Series	Danfoss: 800-621-8806 www.us.water.danfoss.com
Nivelco (Hungary) Hitech – U.S. Representative	Nivofloat and NivoMag MK-200 Series	Hitech 215-321-6012 www.nivelco.com
Scientific Technologies Inc.	FT, FTN, and MLS Series	888-525-7300 www.levelandflow.com
Septronics, Inc.	SD and HD models	888-565-8908 www.septronicsinc.com
Zoeller	Numerous models	800-928-7867 www.zoeller.com

Alternative 2: Magnetic Dry Reed Switch

Description

Permanent magnets are embedded in the float housing that move vertically along the tubing or stem. The reed switches are embedded in the stem. The magnets activate the reed switches in the stem at pre-determined levels for control or alarm purposes.

Cost

The magnetic dry reed float switch cost is approximately $6 to $500 depending on product or application requirements.

Advantages/Disadvantages

The magnetic dry reed switch is ideal for use in small or narrow enclosures. The magnetic dry reed switch has a long operational life.

The magnetic dry reed switch cannot handle a high inductive load, and therefore has a low contact rating. The magnetic dry reed switch must be used in a clean environment, because debris collected on the stem will impair proper functioning. The reed switch can have its contacts welded together when exposed to high voltage sources.

Manufacturers

The following are manufacturers of magnetic dry reed switches:

Manufacturer Name	Product	Phone Number & Website
Advanced Control Technology, Inc.	Numerous models	888-340-8820 www.actsensors.com
Aggressive Systems, Inc.	AOE model	248-477-5300 www.aggressivesystems.com
Barksdale, Inc.	BLS Series	800-835-1060 www.barksdale.com
Clark Reliance Corporation Jerguson Gage and Valve Division	Magnicator II Model RS-2	281-240-4243 www.clark-reliance.com
Comus International	Numerous models	973-777-8405 www.comus-intl.com
Crydom Magnetics (UK)	RSF Series	619-210-1600 www.crydom.co.uk
Dwyer Instruments, Inc.	F7 Series	219-879-8000 www.dwyer-inst.com

Manufacturer Name	Product	Phone Number & Website
Flowline Liquid Intelligence	Numerous models	562-598-3015 www.flowline.com
Innovative Components	LS and SM Series	860-621-7220 www.liquidlevel.com
Kobold	Model N	800-998-1020 www.kobold.com
K-Tech Industrial Products Inc.	Numerous models	905-840-7106 www.process-controls.com/KTech
Nivelco (Hungary) Hitech – U.S. Representative	NivoPoint	Hitech 215-321-6012 www.nivelco.com
Scientific Technologies Inc.	FCN, LF, FL, SLS, and TLS Series	888-525-7300 www.levelandflow.com
Signal Systems International Inc.	Numerous models	732-793-4668 www.signalsystem.com

Alternative 3: Optical Float Switch

Description

The optical float switch utilizes optical principles to detect the presence or absence of a liquid as compared with air. The sensor contains a small infrared LED and a phototransistor light receiver to detect the presence of liquid.

Cost

The cost of an optical float switch is approximately $120 to $400 depending on product or application requirements.

Advantages/Disadvantages

The optical sensor is unaffected by liquid color or density. The optical float switch has very slight hysteresis, high repeatability, and is highly chemical resistant.

The optical float switch has a higher price range than other float switch technologies.

Manufacturers

The following are manufacturers of optical float switches:

Manufacturer Name	Product	Phone Number & Website
Com connection	Fiber Optic Float Switch	954-600-1962 http://comconnection.tripod.com
Dwyer Instruments, Inc.	OLS Series	219-879-8000 www.dwyer-inst.com
Kobold	OPT Series	800-998-1020 www.kobold.com
Pulnix America Inc.	FL, FLH Series	800-445-5444 www.pulnix.com
Scientific Technologies Inc.	OPL Series	888-525-7300 www.levelandflow.com

Alternative 4: Conductivity

Description

The conductivity float switch uses electrodes to measure conductivity and sense the presence or absence of a liquid. It relies on the conducting properties of liquids to complete an electrical circuit between electrodes, or between an electrode and the metal tank.

Cost

The cost of a conductivity float switch is approximately $40 to $800 depending on product or application requirements.

Advantages/Disadvantages

The conductivity float switch has no moving parts and is therefore very reliable and can be used in vessels with moving equipment that may damage other types of float switches. The conductivity sensor can sense the presence of different liquids. For bilge pump applications, it

can detect gas, oil, and diesel fuel in bilge water that can trigger an automatic shutdown of the pump. This prevents pumping of contaminants into waterways.

The conductivity float switch must be used in a conductive liquid for proper operation.

Manufacturers

The following are manufacturers of conductivity float switches:

Manufacturer Name	Product	Phone Number Website
Advanced Control Technology, Inc.	Numerous models	888-340-8820 www.actsensors.com
Aggressive Systems, Inc.	IPF model	248-477-5300 www.aggressivesystems.com
ITT Industries McDonnell & Miller	LPC series	773-267-1600 www.mcdonnellmiller.com
Kari-Finn (Finland) U.S. Rep: STI Automation Sensors Division	Numerous models	STI: 888-525-7300 www.kari-finn.fi
Kobold	NEH, NEW Models	800-998-1020 www.kobold.com
MJK Automation (Denmark) Danfoss – U.S. Representative	Conduct-ivity Level Switch 501	Danfoss : 800-621-8806 www.us.water.danfoss.com
Nivelco (Hungary) Hitech – U.S. Representative	NivoCont K Series	Hitech 215-321-6012 www.nivelco.com
Product Innovators	Bilge Buddy	845-796-4526 www.411web.com/P/PRODUCTINNOVATORS/Default.htm
Scientific Technologies Inc.	ELS Series	888-525-7300 www.levelandflow.com

Alternative 5: Metallic Ball

Description

A rolling metallic ball is used to make or break the actual electrical connection for a circuit. The metallic ball moves based on the float movement as the liquid level rises and falls.

Cost

One manufacturer reported that the cost of their metallic ball switch is about 10 – 15% higher than their mercury float switch with similar functionality.

Advantages/Disadvantages

The metallic ball float switch can have a long life if it is only used for small rated loads.

The metallic ball float switch is not suitable for applications subject to shock or vibration because it can experience false contacts due to bounce. The metallic ball float switch requires a swing area for proper operation. The metallic ball can become welded to the electrical contacts due to overheating or arcing. The metallic ball float switch cannot handle loads greater than two amps without experiencing arcing issues.

Manufacturers

The following is a manufacturer of metallic ball float switches:

Manufacturer Name	Product	Phone Number Website
Comus International	Numerous models	973-777-8405 www.comus-intl.com

Alternative 6: Sonic/Ultrasonic

Description

The sonic/ultrasonic float switch utilizes a sensor containing a piezoelectrical crystal. The crystal excites oscillations, allowing the liquid level to be measured by oscillation frequency. As the

probe tip becomes immersed in liquid, the crystals acoustically couple and the switch changes state.

Cost

The cost of a sonic/ultrasonic float switch is approximately $150 to $600 depending on product or application requirements.

Advantages/Disadvantages

The sonic/ultrasonic float switch is highly accurate and can be used for non-conductive liquids as well as highly viscous liquids. The sensor can be quickly removed for cleaning as required by the food, beverage, and pharmaceutical industries.

The sonic/ultrasonic sensor needs to be rigid mounted for proper operation.

Manufacturers

The following are manufacturers of sonic/ultrasonic float switches:

Manufacturer Name	Product	Phone Number & Website
Advanced Control Technology, Inc.	ELC - 8	888-340-8820 www.actsensors.com
Cosense Inc.	LL Series	631-231-0735 www.cosense.com
Dwyer Instruments, Inc.	GS Series	219-879-8000 www.dwyer-inst.com
Flowline Liquid Intelligence	Numerous models	562-598-3015 www.flowline.com
Kobold	NWS Model	800-998-1020 www.kobold.com
MJK Automation (Denmark) Danfoss – U.S. Representative	MJK 7005	Danfoss : 800-621-8806 www.us.water.danfoss.com
Ohmart Vega	Vegaswing Series	800-367-5383 www.ohmartvega.com
Scientific Technologies Inc.	DFN-30 Series	888-525-7300 www.levelandflow.com
Siemens Milltronics	ULS 200 Series	817-277-3543 www.milltronics.com

Alternative 7: Pressure Transmitter

Description

The pressure transmitter float switch utilizes one of two technologies:

1) The float switch is actuated by a piezo-recitative mechanism that senses the hydrostatic pressure within a container.
2) The float switch is actuated by compression of a captive air column in the detecting pipe beneath a diaphragm.

Cost

One manufacturer sells one of its pressure transmitter models for $825. A cost range for all available models was not determined, but will depend on product or application requirements.

Advantages/Disadvantages

The piezo-recitative technology provides highly reliable results. The diaphragm technology can be used in applications where electrical power is not available or hazardous conditions exist.

Manufacturers

The following are manufacturers of pressure transmitter float switches:

Manufacturer Name	Product	Phone Number & Website
Dwyer Instruments, Inc.	PLT Series	219-879-8000 www.dwyer-inst.com

Manufacturer Name	Product	Phone Number & Website
MJK Automation (Denmark) Danfoss – U.S. Representative	MJK 7050, 7060	Danfoss: 800-621-8806 www.us.water.danfoss.com
Scientific Technologies Inc.	NLS Series	888-525-7300 www.levelandflow.com

Alternative 8: Alloy

Description

A gallium indium alloy replicates the fluid and electrical properties of mercury. This alloy is used as a direct replacement of mercury within the switch.

Cost

The alloy float switch has limited commercial usage and is still in the early development stage. The cost of an alloy float switch is significantly higher than a mercury switch, ball contact switch, or magnetic/reed switch.

Advantages/Disadvantages

The gallium indium alloy functions as a direct replacement for mercury within the switch and therefore provides similar advantages such as quiet operation, high reliability, and long operational life. This alloy eliminates bounce problems and false contacts associated with the metallic ball contact device.

The gallium indium alloy cannot be used in applications less than 20 degrees Fahrenheit. This precludes its use for many non-water applications. The gallium indium alloy is difficult to handle, will oxidize easily, and is potentially toxic.

Manufacturers

The following are manufacturers of alloy float switches:

Manufacturer Name	Product	Phone Number Website
Comus International	Alloy float switch	973-777-8405 www.comus-intl.com

Alternative 9: Thermal

Description

The thermal float switch utilizes the thermal dispersion principle of the dissipation of heat by a liquid to detect the presence or absence of a liquid as compared with air. The sensor typically contains a resistor in the form of a thermistor. A thermistor is a semiconductor material that detects heat and converts heat into an electrical signal. The switch is actuated when heat generated by the thermistor is dissipated by a liquid.

Cost

The cost of a thermal float switch was obtained for one model from one manufacturer for $87. A range of values was not available at the time this report was completed.

Advantages/Disadvantages

The thermal float switch can be used for caustic liquids such as acids and alkalines. Light to moderate buildup on the sensor will not affect thermal dispersion performance.

The thermal float switch is not suited for high temperature applications, and cannot be used for high viscosity liquids.

Manufacturers

The following are manufacturers of thermal float switch sensors:

Manufacturer Name	Product	Phone Number & Website
JC Controls	SN Series	877-837-6677 www.ln2.net
Scientific Technologies Inc.	TDL Series	888-525-7300 www.levelandflow.com

Alternative 10: Capacitance

Description
The capacitance level float switch is typically comprised of two electrodes separated by an insulating medium. Air provides a reference capacitance value, and when the probe is covered by liquid the resultant capacitance change causes a signal to actuate the switch.

Cost
The cost of a capacitance float switch is approximately $150 to $500 depending on product or application requirements.

Advantages/Disadvantages
The capacitance float switch contains no moving parts, has extremely high chemical resistance, and moderate vibration resistance.

The capacitance float switch cannot be used for highly viscous liquids.

Manufacturers
The following are manufacturers of capacitance float switches:

Manufacturer Name	Product	Phone Number Website
Dwyer Instruments, Inc.	CLS Series	219-879-8000 www.dwyer-inst.com
Flowline Liquid Intelligence	Numerous models	562-598-3015 www.flowline.com
Kobold	NTS Series	800-998-1020 www.kobold.com
Robertshaw	Model 304B	865-981-3100 www.robertshawindustrial.com
Scientific Technologies Inc.	CP30 Series	888-525-7300 www.levelandflow.com

Summary
There are numerous non-mercury alternative technologies currently in use for float switch products and applications. It appears that these non-mercury alternatives are cost competitive and can meet the functional requirements for new float switch products and applications. However, these non-mercury alternatives may not meet the requirements for retrofitting all existing float switch products and applications.

4.13 Tilt Switches

Tilt switches sense changes in position or rotation and actuate a switch based upon these changes. The tilt switch can be used to activate alarms, control equipment, turn on lights, or accomplish other functions.

A tilt switch is a versatile component used to meet the needs of hundreds of position monitoring/control products and applications. A tilt switch can be incorporated into a product (e.g. video cameras, motion detectors, etc.), or can be purchased as a component to be used in a customer specific application (e.g. mining operations). Listed below are examples of products and applications that use tilt switches. Many of these products and applications may already use non-mercury tilt switches.

- Test & Laboratory Equipment: precision measuring devices, plotters, power supplies, etc.
- Heavy equipment: construction vehicles, cranes, hoists, chutes, scissor lifts, static platforms, etc.
- Industrial: processing equipment, conveyor controls, extruders, speed controls, foot pedals, coal level monitoring, etc.
- Marine: rudder controls, deep sea manipulators, salt water platforms, ship & barge leveling etc.

- Medical equipment: x-ray machines, MRI scanners, position controls, wheelchairs, etc.

- Robotics: analog inputs, remote operated vehicles, creature animation, etc.

- Agriculture: tractors, conveyor controls, food processing, bins, silos, grain level monitoring, etc.

- Other: signaling alarms, lights, interfacing with programmable logic controllers, personnel digital assistants, cell phones, computer security, anti tamper devices, utility metering, pump control, digital cameras, video cameras, portable space heaters, pinball game machine, swimming pools, payphones, survey leveling equipment, gyroscopes, steam irons, anti-locking brake systems, digital compass correction, submarines, virtual reality equipment, oil rig leveling, laser instruments, geophysical monitoring, laser leveling, grading, continuous casting, weapons platform leveling, wheel alignment, land navigation, auto security, RVs, exercise equipment, automobiles, glove compartments, video cameras, commercial popcorn poppers, electric organs, space heaters, oil well pump control, machine tools, fishing lures, greenhouses, motion detectors, pneumatic tube communication, man-lifts, antenna positioning, mining, aircraft, transportation, etc.

There are numerous design parameters that affect the specification and selection of a tilt switch for a particular product or application. Tilt switch basic design and product options vary greatly by manufacturer. The design requirements have a significant impact on technology selection, manufacturer selection, product model selection, product option selection, and ultimate product cost. The following is a concise listing of some of the more critical design parameters:

- Measurement requirements: tilt or rotation angle, number of axes, etc.

- Switch points: number of control points, number of alarm points, field adjustable points, etc.

- Accuracy: tolerances, calibration requirements

- Output contact rating: inductive loading (amps, voltage, power), resistive loading (amps, voltage, power)

- Life expectancy: switch, controlled equipment, etc.

- Regulatory approval: Underwriters Laboratories, Canadian Standards Association, etc.

- Operating parameters: differential between control/alarm points, angle of operation, etc.

- Environmental conditions: temperature, pressure, explosiveness, shock, vibration, corrosiveness, moving equipment, etc.

- Input power requirements: 115 Volts AC, 230 Volts AC, 24 Volts DC, 12 Volts DC, other

- Switch output: single pole single throw, double pole double throw, normally open, normally closed, relay, etc.

- Other parameters: display requirements, enclosure material, intrinsically safe, cleaning requirements, space available for operation, signal time delay, etc.

Mercury Tilt Switches

Description

Mercury tilt switches are small tubes with electrical contacts at one end of the tube. As the

tube lifts, the mercury collects at the lower end, providing a conductive path to complete the circuit. When the switch is tilted back the circuit is broken. The mercury content reported by manufacturers to IMERC for tilt switches ranged from 400 mg to 71,000 mg/switch.

Cost
The cost of a mercury tilt switch is approximately $2 to $300 depending on product or application requirements.

Advantages/Disadvantages
The mercury tilt switch has high reliability and long operational life because it has few components and is not subject to arcing. Life cycle testing has been successfully conducted for more than one million cycles. The mercury tilt switch can handle a high inductive load, has a quiet operation, has no bounce on contact, and can be hermetically sealed to provide increased protection from various environmental factors (e.g. dust, moisture, etc.).

The mercury tilt switch contains mercury, which is becoming less desirable for many applications including the food and beverage industry.

Manufacturers
The following are manufacturers of mercury tilt switches.

Manufacturer Name	Product	Phone Number & Website
Abra Electronics	Model 35-760	800-717-2272 www.abra-electronics.com
Celduc Relais (France) Laube Technology – US Representative	IB600099 Series	Laube Technology: 805-388-1050 www.celduc-relais.com
Comus International	Numerous models	973-777-8405 www.comus-intl.com
Electro-Sensors, Inc.	MTS Series	800-328-6170 www.electro-sensors.com
George Risk Industries	4561 Series	800-523-1227 www.grisk.com
Kahl Scientific Instrument Corporation	Series 03EA	619-444-2158 www.kahlsico.com
Siemens Milltronics	Mill-tronics Tilt Switches	817-277-3543 www.milltronics.com
Signal Systems International Inc.	Series 3004	732-793-4668 www.signalsystem.com

Alternative 1: Metallic Ball

Description
A rolling metallic ball is used to make the actual electrical connection. The metallic ball moves based on the movement of the tilt switch housing, or can be moved by actuator magnets using the principle of spherical magnetism.

Cost
The cost of a metallic ball tilt switch is approximately $1 to $11 depending on product or application requirements.

Advantages/Disadvantages
The metallic ball tilt switch is suited for applications with high levels of electromagnetic interference (EMI) such as generators and motors, or high stress applications that require a robust switch. The metallic ball tilt switch can have a long life if it is only used for small rated loads.

The metallic ball tilt switch is not suitable for applications subject to shock or vibration because it can experience false contacts due to bounce. The metallic ball can become welded to the electrical contacts due to overheating or arcing. The metallic ball tilt switch cannot handle loads greater than two amps without experiencing arcing issues.

Manufacturers
The following are manufacturers of metallic ball tilt switches:

Manufacturer Name	Product	Phone Number Website
Comus International	Numerous Models	973-777-8405 www.comus-intl.com
Magnasphere Corp.	Magna-sphere Switch	262-792-1306 www.magnaspherecorp.com
Signal Systems International Inc.	NM 1001, NM 2001, NM 3001, NM 4001	732-793-4668 www.signalsystem.com

Alternative 2: Electrolytic

Description
The electrolytic tilt sensorcontains multiple electrodes and is filled with an electrically conductive fluid. As the sensor tilts, the surface of the fluid remains level due to gravity. The conductivity between the electrodes is proportional to the length of electrode immersed in the fluid. Electrically, the sensor is similar to the potentiometer, with resistance changing in proportion to tilt angle. The electrolyte material can vary in conductivity and viscosity to meet different design parameters. The voltage output from the electrolytic tilt sensor can be used for certain tilt switch applications.

Cost
The cost of an electrolytic tilt sensor is approximately $5 to $50 depending on product or application requirements.

Advantages/Disadvantages
Electrolytic tilt sensors provide excellent repeatability, stability, and accuracy. These sensors are rugged and can be used in environments of extreme temperature, humidity, and shock. Electrolytic tilt sensors have low power consumption.

Electrolytic tilt sensors are complex devices due to their sensitivity to internal circuitry and external environmental influences.

Manufacturers
The following are manufacturers of electrolytic tilt sensors:

Manufacturer Name	Product	Phone Number Website
Fredericks Company	Numerous models.	215-947-2500 www.frederickscom.com
Nanotron, Inc.	Ultimate I and II Series	480-966-9006 www.nanotronusa.com
Spectron Glass and Electronics, Inc.	The SP5000 and AU6000 series	631-582-5600 www.spectronsensors.com

Alternative 3: Potentiometers

Description
Potentiometers consist of a curved conductive track with a connection terminal at each end and a moveable wiper connected to a third terminal. As the shaft of the potentiometer is rotated, the length of the electrical path and resistance changes proportionally. Potentiometers can be used to detect linear motion as well as single turn or multiple turn rotation.

Cost
Potentiometers were found to range from approximately $0.25 for simple, high volume applications to $300 for high quality audio applications.

Advantages/Disadvantages
Potentiometers are inexpensive, reliable, and have long operational life, often greater than 20

million cycles. Potentiometers are also available in micro-miniature size for space saving design requirements.

Manufacturers
The following are manufacturers of potentiometers:

Manufacturer Name	Product	Phone Number & Website
ETI Systems	LCP8, SP12B, Series	760-929-0749 www.etisystems.com/singledesign.htm
Precision Electronic	RV4, RV6 Series	416-744-8840 www.precisionelectronics.com
Tocos America, Inc.	G3, G4 Series	847-884-6664 www.tocos.com
Vishay	249, 357, 533 Series	402-563-6866 www.vishay.com

Alternative 4: Mechanical Switch

Description
The mechanical tilt switch can be a snap switch or micro-switch that can be actuated in a variety of methods. The most common method is that the lever arm is actuated by a metallic rolling ball that changes position based upon gravity and the changing position of the switch housing.

Cost
The cost of a mechanical tilt switch is approximately $100 to $350 depending on product or application requirements.

Advantages/Disadvantages
The mechanical tilt switch has high reliability, long operational life, can handle high inductive loads, and can be hermetically sealed to provide increased protection from various environmental factors (e.g. dust, moisture, etc.). Mechanical tilt switches are often designed to have an operational life in excess of one million cycles. The mechanical tilt switch requires only a small amount of pressure to actuate the switch action. The mechanical tilt switch can be used as a limit switch to detect the position of some moving part. Numerous limit switches can be used to sense multiple positions.

Manufacturers
The following are manufacturers of mechanical tilt switches:

Manufacturer Name	Product	Phone Number & Website
Binmasater	BM-T Series	800-278-4241 www.binmaster.com
Monitor Technologies LLC	TC Series	800-601-6302 www.monitortech.com
Omron Electronics	D7E Series	847-882-2288 www.omron.com

Alternative 5: Solid-State

Description
The solid-state tilt switch is often referred to as an inclinometer or accelerometer depending upon the application. Various operational methods are used including:

- Using a Hall effect integrated circuit sensor that provides a voltage output ratio as a function of the mechanical angle of the shaft
- Using a highly stable silicon micro-machined capacitive inclination sensor element
- Using force balance accelerometer technology

Cost
The cost of a solid-state tilt switch is approximately $100 - $250 depending on product or application requirements.

Advantages/Disadvantages

The solid-state tilt switch offers high resolution, accuracy, fast response, and maintains its accuracy over temperature ranges. The solid-state tilt switch requires a low supply voltage and has a long operational life, often greater than ten million cycles. The solid-state tilt switch can be used in strong vibration and shock environments.

The initial cost is higher than mercury, potentiometer, or electrolytic tilt switches.

Manufacturers

The following are manufacturers of solid-state tilt switches:

Manufacturer Name	Product	Phone Number & Website
Clarostat Sensors and Controls	HRS100 Series	800-872-0042 www.clarostat.com
Columbia Research Labs	SI-701 Series	800-813-8471 www.columbiaresearchlab.com
Crossbow	CXTA and CXTLA Series	408-965-3300 www.xbow.com
Jewell Instruments LLC	LSO Series	800-227-5955 www.jewellinstruments.com
Omron Electronics	D6B Series	847-882-2288 www.omron.com

Alternative 6: Capacitive

Description

The capacitive tilt switch utilizes a capacitive based sensor that produces output directly proportional to the relative tilt. The sensor is typically composed of hermetically sealed capacitive domes with a high dielectric constant fluid that fills the space between the domes.

Cost

The cost of a capacitive tilt switch is approximately $80 to $250 depending on product or application requirements.

Advantages/Disadvantages

The capacitive tilt switch has high accuracy, high long-term stability, and low power requirements. The capacitive tilt switch is suitable for applications requiring high measurement accuracy with low linearity deviations, and for measurement of relatively large inclination angles.

Manufacturers

The following are manufacturers of capacitive tilt switches:

Manufacturer Name	Product	Phone Number & Website
Measurement Specialties	Accustar and Accuswitch Series	800-745-8008 www.schaevitz.com
Rieker Inc.	N Series and NG Series	610-534-9000 www.riekerinc.com
Seika (Germany) Reiker Inc. – U.S. Representative	NG2, NG3, and NG4 Series	Reiker Inc. 610-534-9000 www.seika.de

Summary

There are numerous non-mercury alternative technologies currently in use for tilt switch products and applications. It appears that these non-mercury alternatives are cost competitive and can meet the functional requirements for new tilt switch products and applications. However, these non-mercury alternatives may not meet the requirements for retrofitting all existing tilt switch products and applications.

An example of a successful tilt switch replacement program is the “Switch the Switch” program initiated by the Michigan based Clean Car Campaign. Mercury tilt switches in hood lights and trunk lights were replaced with non-mercury tilt switches in automobiles across the nation. This was a simple, drop-in exchange that

took about ten minutes per switch to accomplish. Across the United States, thirteen tilt switch replacement events took place. Some participating dealerships replaced mercury switches in vehicles on their lots, while other dealerships offered the service, free of charge, to their customers. The participating municipal and state agencies replaced the mercury tilt switches in their fleets of vehicles. (Clean Car Campaign, 2002)

4.14 Pressure Switches

A pressure switch is a device that converts a pressure change into an electrical switching function. The pressure change might be measured as pressure, vacuum, or differential between two pressure inputs. In every case, the pressure switch will employ a diaphragm, piston, or other pressure-responsive sensor, which has been coupled to actuate a mechanical switch, mercury switch, or transistor. Examples of pressure responsive sensors used in pressure switches include:

- Diaphragm: A diaphragm actuated pressure switch has a large surface area and very flexible diaphragm material. This type of sensor is able to convert a relatively small amount of pressure or vacuum into sufficient mechanical force to actuate a snap-action switch. In a pressure switch, positive pressure pushes the diaphragm. In a vacuum switch, negative pressure pulls the diaphragm. In a differential switch, both sides of the switch housing are linked to two pressure sources, and the diaphragm responds to the resulting net force.

- Piston: A piston actuated pressure switch uses a metal piston as the sensor. Its robust design and stronger materials enable this type of sensor to work at high pressures, or in hostile media.

- Bellows: A bellows actuated pressure switch uses a bellows elastic element that expands and contracts axially with changes in pressure. Changes in the measured pressure cause the bellows to work against an adjustable spring. This spring determines the pressure required to actuate the switch. Through suitable linkage, the spring causes the contacts to open or close the electrical circuit automatically when the operating pressure falls below or rises above a specified value.

- Flex Circuit: A flex circuit diaphragm is a small metal diaphragm etched from one layer of a circuit board. This diaphragm is able to make contact with another layer, combining sensor and switch. The advantage of this device is that it can open and close at a very high frequency over a very long duty cycle.

Each type of sensor provides performance tradeoffs that must be evaluated for each particular application. For example, bellows actuated pressure switches have excellent sensitivity, however they are subject to metal fatigue in rapidly cycling applications.

A pressure switch is a versatile component used to meet the needs of hundreds of pressure monitoring/control products and applications. A pressure switch can be incorporated into a product (e.g. boiler, air conditioner, vacuum cleaner, etc.), or can be purchased as a component to be used in a customer specific application (e.g. semiconductor processing). Listed below are examples of products and applications that use pressure switches. Many of these products and applications may already use non-mercury pressure switches.

- Heating, ventilation, and air conditioning: electrostatic air cleaners, filter indicators, reservoir level, gas fired heating, ventilation, utility heaters, heat pumps, furnaces, flue gas, fuel delivery, etc.

- Medical: respiratory sensors, therapy tent nebulizers, automated blood pressure systems, sip and puff movement controls, anesthesia leak detection, saline pumps, tourniquet systems, reverse osmosis purification systems, dental aspirator pumps, respiratory therapy, disposable surgical vacuum systems, etc.

- Automotive: tire pressure, emission control, manifolds, air conditioning, engine crankcase pressure, air brakes, lumbar seat pressure, exhaust gas re-circulation, etc.

- Appliance: commercial dish washers, floor scrubbers, vacuum cleaners, food storage sealers, air conditioners, commercial fryers, hot water dispensers, hot water heaters, etc.

- Other: fire pump controllers, scrubbers, venting hoods, construction equipment, tape braking systems, tape tension controls, door safety, spa pumps, machine tools, automated test equipment, packaging machinery, pulp digesters, boilers, well heads, polymerization reactor vessels, mine gas samplers, garage doors, industrial gas pressure sensing, vacuum radon detection, missile guidance applications, spray painting equipment, semiconductor process equipment, injection water systems, submarine navigation control, robotics, organs, pump control, automobiles, pressurized air systems, bioprocess applications, sanitary systems, hydraulic systems, sprayers, pressurized tanks, altitude sensing, portable test equipment, fire protection systems, and waste treatment plants.

There are numerous design parameters that affect the specification and selection of a pressure switch for a particular product or application. Pressure switch basic design and product options vary greatly by manufacturer. The design requirements have a significant impact on technology selection, manufacturer selection, product model selection, product option selection, and ultimate product cost. For example, sensor selection is a key determinant of range, sensitivity, accuracy, life expectancy, and cost of a pressure switch. The following is a concise listing of some of the more critical design parameters:

- Variable measured: pressure, vacuum, differential

- Operating parameters: set-point, dead-band, factory set, field adjustable

- Enclosure: general purpose, weather resistant, explosion proof, etc.

- Regulatory approval: Underwriters Laboratories, Canadian Standards Association, etc.

- Switch type: mercury, snap switch, micro-switch, transistor, etc.

- Switch: number of poles, number of throws, amperage, voltage, hermetically sealed, etc.

- Load: resistive, inductive, other

- Accuracy: repeatability, calibration requirements

- Monitoring: local, remote

- Mounting: vertical, horizontal

- Materials: enclosure, sensor, switch, etc.

- Visual display: status, power on, etc.

- Sensor type: diaphragm, bellows, piston, bulb & capillary, etc.

- Pressure: range to be measured, maximum operating pressure, etc.

- Life expectancy: time in service, number of cycles
- Electrical connection: terminal block, conduit, etc.
- Physical: size, weight, etc.
- Power input: 120/240Volts AC, 12/24Volts DC, current, etc.
- Environmental conditions: shock, vibration, explosion, corrosiveness, temperature, humidity, radio frequency interference, etc.
- Other: pressure surge protection, test button, reset button, etc.

Mercury Pressure Switches

Description
The mercury pressure switch typically uses a piston, diaphragm, or bellows acting as the pressure sensor to actuate the mercury switch. The mercury content reported by manufacturers to IMERC for pressure switches was in the range of greater than 1,000 mg.

Cost
The cost of a mercury pressure switch is approximately $150 to $170 based on pricing obtained for only two product models. The range could be much greater depending on various product and application requirements. One manufacturer provides comparable pricing for mercury pressure switches and mechanical pressure switches with similar functionality.

Advantages/Disadvantages
The mercury pressure switch has high reliability and long operational life because it has few components and is not subject to arcing. Life cycle testing has been successfully conducted for more than one million cycles. The mercury float switch can handle a high inductive load, has a quiet operation, has no bounce on contact, and can be hermetically sealed to provide increased protection from various environmental factors.

The mercury pressure switch contains mercury, which is becoming less desirable for many applications including the food and beverage industry.

Manufacturers
The following is a manufacturer of mercury pressure switches.

Manufacturer Name	Product	Phone Number & Website
Dwyer Instruments (Mercoid)	PQ, PR, BB, DP, and DA Series	219-879-8000 www.dwyer-inst.com

Alternative 1: Mechanical Pressure Switches

Description
The mechanical pressure switch typically uses a piston, diaphragm, bellows, or combination piston/diaphragm as the pressure sensor. The sensor can either 1) directly actuate the switch, or 2) use a pushrod, lever, or compression spring to actuate a snap acting micro-switch.

Cost
The cost of a mechanical pressure switch is approximately $40 to $600 depending on product or application requirements.

Advantages/Disadvantages
Mechanical pressure switches have high reliability, a long operational life, and can also provide high accuracy when used with a diaphragm sensor. Certain models of the mechanical pressure switch use a diaphragm and negative rate Belleville spring that provides superior resistance to shock and vibration.

Manufacturers
The following are manufacturers of mechanical pressure switches:

Manufacturer Name	Product	Phone Number & Website
Barksdale, Inc.	D1, B1, E1S, C9612 Series	800-835-1060 www.barksdale.com
Custom Control Sensors, Inc.	6800 and 6900 Series	818-341-4610 www.ccsdualsnap.com
Dwyer Instruments (Mercoid)	PG, DP, APS, AVS, and DS-7300 Series	219-879-8000 www.dwyer-inst.com
Emerson Electric Co., Alco Controls Division	Numerous models	314-569-4500 www.alcocontrols.com
Hobbs Corporation (Invensys Company)	Series 3000 and 5000, Series III and V	217-753-7752 www.hobbs-corp.com
Kobold	KPH 8000 and KPH 8200 Series	800-998-1020 www.kobold.com
Micro Pneumatic Logic, Inc. (MPL)	MPL 500 Series	954-973-6166 www.pressureswitch.com
Neo-dyn/ITT Industries	100P, 152P, 160P, 142P, and 182P Series	661-295-4000 www.neodyn,com
Potter Electric Signal Company	ADPS Model	800-325-3936 www.pottersignal.com
SOR Inc.	Series 20	800-676-6794 www.sorinc.com
Tecmark Corporation	Series 3000	440-205-7600 www.tecmarkcorp.com
Texas Instruments	Numerous models	888-438-2214 www.ti.com
United Electric Controls	Spectra 10, Deltapro 24, and Spectra 12 Series	617-926-1000 www.ueonline.com
Weed Instrument	Model GR2/4	800-880-9333 www.weedinstrument.com

Alternative 2: Solid-State Pressure Switches

Description

Solid-state pressure switches contain one or more strain gauge pressure sensors, a transmitter, and one or more switches all in a compact package. In addition to opening or closing the pressure switch circuit, they can provide a proportional analog or digital output. Diffused silicon piezoresistive sensors are widely used in solid-state pressure switches. The sensor contains homogeneous silicon measuring cells containing two vacuum-welded silicon plates. The piezoresistive effect causes element resistance to change proportionally with measured pressure. Thin film strain gauges can also be used as the pressure sensor. A microprocessor is used to process the strain gauge sensor information and actuate the switching element. The switching element is typically a transistor.

Cost

Solid-state pressure switches cost approximately $200 - $350 depending on product or application requirements. This is higher than the cost for mechanical or mercury pressure switches. Solid-state pressure switches become more cost effective when monitoring more than one point and other of its various features are needed.

Advantages/Disadvantages

Solid-state pressure switches provide higher accuracy than mechanical switches. Solid-state pressure switches can improve process quality, resulting in reduced scrap and waste. Solid-state pressure switches have long life at rated loads that can often be ten million cycles or greater. Solid-state sensors usually have built-in temperature compensation to ensure accuracy over a wide temperature range. The solid-state pressure switch can provide proportional analog or digital output. The electronic control unit can be mounted remotely from the sensor. Solid-state pressure sensors often have a built-in keypad and display to simplify setup and ongoing

field adjustments. Solid-state pressure switches provide a wide range of set-point and dead-band adjustment. The transistor switch is highly reliable, has no contact bounce, accommodates fast switching, and has no arcing.

The transistor is usually restricted to low-level direct current voltage applications. High temperatures or transient pressure spikes can damage a solid-state pressure sensor.

Manufacturers

The following are manufacturers of solid-state pressure switches:

Manufacturer Name	Product	Phone Number & Website
Barksdale, Inc.	PS Series	800-835-1060 www.barksdale.com
Kobold	PDD Series	800-998-1020 www.kobold.com
SOR Inc.	SGT Series	800-676-6794 www.sorinc.com
United Electric Controls	One Series	617-926-1000 www.ueonline.com

Summary

There are numerous non-mercury alternative technologies currently in use for pressure switch products and applications. The use of pressure switches in fire pump controllers is illustrative. The fire pump controller is used to control diesel and electric pumps that provide water for fire suppression in large buildings.

Two fire pump controller manufacturers were identified that discontinued use of mercury pressure switches, and instead use non-mercury pressure switches for their fire pump controllers. One manufacturer uses non-mercury pressure switches for both its diesel and electric fire pump controllers. One manufacturer converted its electric fire pump controller line to non-mercury switches in 2003, and will convert their diesel pump controllers to non-mercury pressure switches in 2004.

These fire pump controllers using non-mercury pressure switches are Underwriters Laboratories (UL) listed, Factory Mutual (FM) approved, and comply with National Fire Protection Association (NFPA) standards. According to the manufacturers, these fire pump controllers have achieved high customer satisfaction and acceptance. The fire pump controllers with non-mercury switches are considered as reliable as the fire pump controllers that use mercury switches. In addition, the two manufacturers can now avoid the high costs of shipping replacement mercury pressure switches that are considered a hazardous material.

The following are manufacturers of fire pump controllers that use non-mercury pressure switches:

Manufacturer Name	Product	Phone Number & Website
Joslyn Clark Controls	Fire Pump Controller	800-476-5463 www.joslynclark.com
Metron	Fire Pump Controller	303-592-1903 www.metroninc.com

It appears that these non-mercury alternatives are cost competitive and can meet the functional requirements for new pressure switch products and applications. However, these non-mercury alternatives may not meet the requirements for retrofitting all existing pressure switch products and applications.

4.15 Temperature Switches

A temperature switch is a device that converts a temperature change into an electrical switching function. The temperature switch uses a temperature responsive sensor that is coupled to a switch. The switch can be a mercury switch, solid state, micro-switch, or snap switch. The following are examples of temperature sensors commonly used in temperature switches:

Thermocouple: A thermocouple is comprised of two wire strips of dissimilar metals. These metal wires are joined at one end and the voltage is measured at the other end. Changes in the temperature at the juncture induce a

change in electromotive force at the other end. As the temperature goes up, the output electromotive force of the thermocouple rises. There are many different types of thermocouples made of different types of wire with very different properties.

Resistance Temperature Detectors (RTD): An RTD is based on the fact that the electrical resistance of a metal changes as its temperature changes. The resistance will rise more or less linearly with temperature. RTDs use a length of conductor (platinum, nickel, iron or copper) wound around an insulator. Newer styles use a thin film of the conductor deposited on a ceramic substrate. RTDs are stable and have a fairly wide temperature range, but are not as rugged and inexpensive as thermocouples. Since they require the use of electric current to make measurements, RTDs are subject to inaccuracies from self-heating.

Thermistor: A thermistor is also based on the fact that the electrical resistance of a material changes as its temperature changes. Thermistors rely on the resistance change in a ceramic semiconductor, with the resistance dropping non-linearly with a temperature rise. Thermistors tend to be more accurate than RTDs and thermocouples, but they have a much more limited temperature range because of their marked non-linearity. Thermistors can be a low cost solution to temperature measurement. They tend to have large signal outputs and their small size permits fast response to temperature changes.

Integrated Circuit Sensor: The newest type of temperature sensor on the market is the integrated circuit temperature transducer. Integrated circuit sensors can be designed to produce either voltage or current output and are extremely linear. Integrated circuit sensors are a very effective way to produce an analog voltage proportional to temperature. They have a limited temperature range and are used to measure temperatures from -50° to 300° F.

A temperature switch is a versatile component used to meet the needs of hundreds of temperature monitoring/control products and applications. A temperature switch can be incorporated into a product (e.g. food warming trays, hot water boilers, etc.), or can be purchased as a component to be used in a customer specific application (e.g. plastics injection molding process). Listed below are examples of products and applications that use temperature switches. Many of these products and applications may already use non-mercury temperature switches.

> Ovens, sterilizers, moulding machines, heat exchangers, labelling machines, water baths, heat sealers, refrigerating equipment, ventilating equipment, alarm systems, bearings, gear reducers, bucket elevators, hammer mills, generators, conveyors, dryer bearings, mechanical drives, grinders, pumps, motors, presses, mixers, appliances, vending machines, platens, plastic laminating presses, dental equipment, popcorn machines, hot stamping, food warming trays, hydraulic laminating presses, livestock applications, hot water boilers, hot water storage tanks, heavy oil pre-heaters, watering fountains, label adhesive applicators, paint drying equipment, typesetting machines, hot stamp printers, vending machines, deep fat cookers, and textiles.

There are numerous design parameters that affect the specification and selection of a temperature switch for a particular product or application. Temperature switch basic design and product options vary greatly by manufacturer. The design requirements have a significant impact on technology selection, manufacturer selection, product model selection, product option selection, and ultimate product cost. For example, sensor selection is a key determinant of range, sensitivity, accuracy, life expectancy, and cost of a temperature switch. The following is a concise listing of some of the more critical design parameters:

- Operating parameters: Set-point, dead-band, factory set, field adjustable
- Enclosure: general purpose, weather resistant, explosion proof, etc.
- Regulatory approval: Underwriters Laboratories, Canadian Standards Association, etc.
- Switch type: mercury, snap switch, micro-switch, transistor, etc.
- Switch: number of poles, number of throws, amperage, voltage, hermetically sealed, etc.
- Load: resistive, inductive, other
- Accuracy: repeatability, calibration requirements
- Monitoring: local, remote
- Mounting: vertical, horizontal
- Materials: enclosure, sensor, switch, etc.
- Visual display: status, power on, etc.
- Sensor type: RTD, integrated circuit, thermistor, thermocouple, etc.
- Temperature: range to be measured, maximum operating temperature, storage temperature, etc.
- Life expectancy: time in service, number of cycles
- Electrical connection: terminal block, conduit, etc.
- Physical: size, weight, etc.
- Power input: 120/240VAC, 12/24VDC, current, etc.
- Environmental conditions: shock, vibration, explosion, corrosiveness, temperature, humidity, RFI, etc.
- Other: temperature surge protection, test button, reset button, etc.

Mercury Temperature Switches

Description

The temperature switch employs a temperature responsive sensor, which is coupled to the mechanical means of actuating a mercury switch. The temperature responsive sensor is typically either a thermocouple, resistance temperature detector (RTD), or gas actuated bourdon tube. The mercury content reported by manufacturers to IMERC for temperature switches was in the range of greater than 1,000 mg.

Cost

The cost of a mercury temperature switch is approximately $150 to $250 depending on product or application requirements. For one manufacturer, the cost of a temperature switch with a snap action switch is less than the cost of a mercury temperature switch with the same functionality.

Advantages/Disadvantages

The mercury temperature switch has high reliability and long operational life because it has few components and is not subject to arcing. Life cycle testing has been successfully conducted for more than one million cycles. The mercury temperature switch can handle a high inductive load, has a quiet operation, has no bounce on contact, and can be hermetically sealed to provide increased protection from various environmental factors.

The mercury temperature switch contains mercury, which is becoming less desirable for many applications including the food and beverage industry.

Manufacturers

The following table lists a manufacturer of mercury temperature switches.

Manufacturer Name	Product	Phone Number & Website
Dwyer Instruments (Mercoid)	M-51, FM, DA-36, DA-37 Series	219-879-8000 www.dwyer-inst.com

Alternative 1: Mechanical Temperature Switches

Description

The mechanical temperature switch employs a temperature responsive sensor, which is coupled to the mechanical means of actuating a mechanical switch. The temperature responsive sensor can typically be a thermocouple, bulb and capillary, resistance temperature detector (RTD), welded alloy, or gas actuated bourdon tube.

Cost

The cost of a mechanical temperature switch is approximately $8 to $600 depending on product or application requirements. For one manufacturer, the cost of a temperature switch with a snap action switch is less than the cost of a mercury temperature switch with the same functionality.

Advantages/Disadvantages

The mechanical temperature switch has high reliability, long operational life, and can handle high inductive loads. The reliability and accuracy of a mechanical temperature switch is largely dependent on the sensor technology used. The mechanical temperature switch provides similar functionality to the mercury temperature switch without the attendant mercury management issues.

Manufacturers

The following are manufacturers of mechanical temperature switches:

Manufacturer Name	Product	Phone Number & Website
Barksdale, Inc.	THR, TPR, T1X, L1X Series	800-835-1060 www.barksdale.com
Chromalox	AR, ARR, and 3000 Series	800-443-2640 www.chromolox.com
Custom Control Sensors, Inc.	6900 and 604 Series	818-341-4610 www.ccsdualsnap.com
Dwyer Instruments (Mercoid)	RRT, D-7435, DA-36, and DA-37 Series	219-879-8000 www.dwyer-inst.com
Kidde-Fenwal, Inc.	Series 15000, 16000, 17000, and 18000	508-881-2000 www.fenwalcontrols.com
Kobold	TWR and TRS Series	800-998-1020 www.kobold.com
Neo-dyn/ITT Industries	Series 100T and 132T	661-295-4000 www.neodyn,com
Selco	S200 and SIO Series	800-257-3526 www.selcoproducts.com
United Electric Controls	55 Series C54S-103 B54-103	617-926-1000 www.ueonline.com
Weed Instrument	Model PR7 Series	800-880-9333 www.weedinstrument.com

Alternative 2: Solid State Temperature Switches

Description

The solid-state temperature switch utilizes temperature coefficient thermistors, RTDs, or integrated circuits sensor to monitor temperature, and a semiconductor for the switching output.

Cost
The cost of a solid-state temperature switch is approximately $350 to $600 depending on product or application requirements. The cost of a solid-state temperature switch is generally higher than the cost of a mercury or mechanical temperature switch.

Advantages/Disadvantages
The use of solid-state technology provides improved accuracy, repeatability, and reliability as compared with mechanical or mercury temperature switches. Switching point, hysteresis, and other parameters are often field programmable. Solid-state temperature switches provide tighter control that can increase the life of controlled equipment. Solid-state temperature switches operate with low voltage and low current consumption. Solid-state temperature switches do not require calibration.

Solid-state temperature switches usually have a higher initial cost than mechanical or mercury temperature switches.

Manufacturers
The following are manufacturers of solid-state temperature switches:

Manufacturer Name	Product	Phone Number & Website
Kobold	TDD – 2, TDD - 4	800-998-1020 www.kobold.com
Maxitronic	HB Series	800-659-8520 www.maxitronic.com
Seiko Instruments USA	S-8130AC Series	310-517-7771 www.seiko-usa-ecd.com
United Electric Controls	D1C2L1N, D1C2L2A, D1A2L1N	617-926-1000 www.ueonline.com

Summary
There are numerous non-mercury alternative technologies currently in use for temperature switch products and applications. It appears that these non-mercury alternatives are cost competitive and can meet the functional requirements for new temperature switch products and applications. However, these non-mercury alternatives may not meet the requirements for retrofitting all existing temperature switch products and applications.

4.16 Relays

A relay is an electrically controlled device that opens or closes electrical contacts to effect the operation of other devices in the same or another electrical circuit. Relays are often used to switch large current loads by supplying relatively small currents to a control circuit. There are two general families of relays: electro-mechanical and semiconductor. Electro-mechanical relays include mercury displacement, mercury wetted reed relay, mercury contact relay, dry reed relay, and other miscellaneous electro-mechanical relays. Semiconductor relays include solid-state relays and silicon controlled rectifiers.

A relay is a versatile component used to meet the needs of hundreds of varied products and applications. A relay can be incorporated into a product (e.g. copiers, heaters, conveyors, etc.), or can be purchased as a component to be used in a customer specific application (e.g. petrochemical processing). Listed below are examples of products and applications that use relays. Many of these products and applications may already use non-mercury relays.

- Commercial aircraft: power control, master power switches, motor control switching, heavy current load switching, instrument panel, generator switching, alternator power switching, antenna changeover, channel selection, etc.

- Air conditioning and heating equipment: compressor motors, fan motors, coolant pump motors, duct heaters, etc.

- Lighting controls: street lamps, dimmer controls, parking lots, scoreboards, high intensity lamps, traffic signals, tungsten lamps, etc.

- Telecommunications: trunk switching, test panels, telecomm circuit boards, load switches, radio base stations, ground start, input/output cards, control panel exchanges, antenna switches, loop current test, etc.

- Hospitals: surgical equipment, X-ray machine control, energy management systems, surgical lighting, etc.

- Food Industry: food processing, deep fryers, pizza ovens, baking ovens, electric grills, dishwashers, etc.

- Office equipment: copiers, computer power supplies, blue print machines, etc.

- Manufacturing: injection molding machines, kilns, ink heating, vacuum forming, soldering systems, semiconductor processing, programmable logic controllers, etc.

- Production test equipment: component testers, cable testers, circuit testing, etc.

- Laboratory test instruments: voltmeters, ohmmeters, recorders, environmental chambers, etc.

- Machine tool control: solenoid operated valves, heavy motor starting, signal lights, etc.

- Miscellaneous: mining equipment, pool heaters, dry cleaning equipment, notebook computers, ceramic heaters, industrial furnaces, alarm systems, battery chargers, farm incubators, chemical tank heaters, film packaging, glass furnaces, engraving equipment, plastic extruders, steam generators, automobiles, printing machines, silicon carbide heaters, controlled rectifiers, graphite heaters, infrared dryers, book binding machines, trucks, conveyors, appliances, missiles, aerospace, petrochemical processing, coin operated machines, ships, laboratory baths, flask heaters, robotics, packaging machines, pharmaceutical processes, textiles, paper & pulp drying, infrared ovens, high temperature materials processing, electric ranges, multiplexers, communication modules, modems, data access arrangement circuits, etc.

The global market for relays was $4.658 billion in 2001 revenues. Approximately 89.1% of these revenues were for electromechanical relays and 10.9% was for semiconductor relays. The three largest industry applications were telecommunications (25.3%), transportation (18.4%), and industrial automation (12.4%).

There are numerous design parameters that affect the specification and selection of a relay for a particular application. The following is a concise listing of some of the more critical factors:

- Mounting: printed circuit board, din rail, bracket/flange mount, socket/plug-in style, surface mount, etc.

- Reliability: failure rate, mean cycles before failure (MCBF), etc.

- Enclosure: open, National Electrical Manufacturers Association (NEMA), hermetically sealed, etc.

- Pole specifications: single pole, double pole, triple pole, etc.

- Throw specifications: single throw, double throw, etc.

- Isolation: optically isolated, etc.

- Contact ratings: maximum switching current (amps), maximum switching voltage, maximum switching power

- Contacts: normally open, normally closed, contact material, etc.

- Materials: contacts, insulation, soldering fluxes, finishes, etc.
- Regulatory approval: Underwriters Laboratories, Canadian Standards Association, etc.
- Resistance: contacts, coil, insulation
- Voltage: Direct current or alternating current
- Load types: inductive, motor, lamp, etc.
- Load characteristics: inrush current, step up, ramp up, soft start, etc.
- Life expectancy: electrical components, mechanical components, controlled equipment, etc.
- Physical: weight, size, noise level, etc.
- Coil ratings: voltage range, resistance range, nominal power, etc.
- Performance specifications: make/operate time, break/release time, contact chatter, contact bounce, time delay, etc.
- Environment: operating temperature, shock, vibration, acceleration, humidity, etc.
- Control panel: space available, natural convection available, etc.
- Output device for solid-state relays: metal oxide semiconductor field effect transistor (MOSFET), silicon controlled rectifier, bipolar transistor, triac, etc.
- Other features: time delay, instrinsically safe, visual indicators, sealed enclosure, test button, latching controls, energy efficiency, etc.

Original equipment manufacturers that use relays as a component within their products or equipment were interviewed by Venture Development Corporation. They were asked to identify the most important criterion for their selection of relays in their products. The following table illustrates the results:

Table 4.6: Most Important Relay Product Selection Criteria

Product Selection Criteria	Percent of OEM Respondents Citing as Most Important
Reliability/Quality/Durability	41.4%
Contact Current Specifications	27.6%
Physical Characteristics	27.6%
Lifespan/Cycles	24.1%
Coil/Control Specifications	19.0%
Resistance Parameters	15.5%
Ease of Maintenance & Replacement	13.8%
Isolation Parameters	15.5%
Regulatory/Customer Requirements	10.3%
Energy Efficiency	3.4%
Other	12.1%

Source: Venture Development Corporation

4.16.A Mercury Displacement Relay

Description

The mercury displacement relay uses a metallic plunger device to displace mercury. The plunger is lighter than mercury so it floats on the mercury. The plunger also contains a magnetic shell or sleeve, so it can be pulled down into the mercury with a magnetic field. The plunger provides the same functionality in a mercury displacement relay as an armature in a mechanical relay. When the coil power is off, the mercury level is below the electrode tip and no current path exists between the insulated center electrode and the mercury pool. When coil power is applied the plunger is drawn down into the mercury pool by the pull of the magnetic field and the plunger centers itself within the current path. Upon removing the coil power, the buoyancy force of the mercury causes the plunger assembly to again rise to the starting

position. This drops the level of the mercury and breaks the current path through the center electrode and the mercury pool.

The amount of mercury in mercury displacement relays varies considerably based on number of poles, current rating, termination requirements, and other factors. The mercury content reported by manufacturers to IMERC for relays was in the range of greater than 1,000 mg. The mercury can be released to the environment during product use. For example, if the load is short circuited, the MDR can burst. Some manufacturers offer free take-back programs for their mercury relays.

Mercury displacement relays are used in high current, high voltage applications such as industrial process controllers, power supply switching, resistance heating, tungsten lighting, welding, high current/voltage lighting, flood lights, copiers, battery chargers, energy management systems, and industrial ovens.

Cost

The cost of a mercury displacement relay is approximately $20 to $150 depending on product or application requirements. The cost of a mercury displacement relay is comparable with other electromechanical relays. The cost of a mercury displacement relay is less than a solid state relay for low current applications, but cost becomes comparable for higher current applications.

Advantages/Disadvantages

Mercury displacement relays have hermetically sealed contacts that provide internal and external protection from arcing and environmental abuse. The mercury rewets the contact electrode providing a new contact surface with each actuation, so the surface does not pit or weld. Mercury displacement relays can cycle faster than a mechanical relay, and have low contact resistance because large electrodes and surrounding mercury volume creates large contact mating areas. Mercury displacement relays have quiet operation because acoustical noise from rebounding contacts is eliminated. Mercury displacement relays have long life because they contain one moving part and no pivots, hinges, pins or mechanical linkages resulting in limited wear. Mercury displacement relays last on average between 1,000,000 to 10,000,000 cycles. Factors that affect the longevity of the relay include: voltage being switched, ratio of line voltage to rated voltage, and number of cycles per hour. Mercury displacement relays have bounce free operation because the mercury surface tension enable the mercury to bridge the contacts during the plunger settling time.

Mercury displacement relays need to be mounted in a specific orientation in order for the mercury to function properly. Mercury displacement relays can burst, causing an on-site hazardous waste problem, if the relay is overheated due to rapid cycling or if the load is short-circuited. In addition, disposal of worn out contactors can be expensive. Control of equipment is limited compared with solid-state relays. Thermal shock can occur for the equipment being controlled by the relay.

Manufacturers

The following are manufacturers of mercury displacement relays:

Manufacturer Name	Product	Phone Number & Website
Chromalox	HGR series	800-443-2640 www.chromolox.com
Magnecraft & Struthers-Dunn	WM and WML Series	843-393-5778 www.magnecraft.com
Mercury Displacement Industries Inc.	Numerous models	616-663-8574 www.mdius.com
Watlow Electronic Manufacturing Company	HG Series	507-454-5300 www.watlow.com

4.16.B Mercury Wetted Reed Relay

Description

A mercury wetted reed relay is a type of electro-mechanical relay that employs a hermetically sealed reed switch. The reeds are thin flat

ferromagnetic blades that serve as a contact, spring, and magnetic armature. The mercury wetted reed relay consists of a glass encapsulated reed with its base immersed in a pool of mercury and the other end capable of moving between two sets of contacts. The mercury flows up the reed by capillary action and wets the contact surface of the reed and the stationary contacts. The mercury wetted reed relay is usually actuated by a coil around the capsule.

Wetted mercury reed relays are typically small circuit controls that are used in electronic devices for switching or signal routing functions. Reed relays are primarily used in test, calibration, and measurement equipment applications where stable contact resistance over the life of the product is necessary.

Cost

Prices for the mercury wetted reed relay ranged from approximately $10 for printed circuit board mounted low amperage devices, to $40 for larger 5 amp devices. For one manufacturer, the cost of mercury wetted relay was the same as a dry magnetic reed relay for a similar device. For another manufacturer, the cost of a mercury wetted relay was double the cost of a dry magnetic reed relay for a similar device. Overall, prices for mercury wetted relays appear to be comparable to prices for dry reed relays. However, life cycle costs are higher for the mercury wetted reed relay due to the higher costs associated with shipping, management, and disposal of the mercury containing device.

Advantages/Disadvantages

Hermetically sealed contacts in a clean atmosphere are unaffected by dust, corrosion, or oxidation, and also eliminate the opportunity for sticking, binding, or wearing of hinged joints. With proper circuitry, magnetic reed relays can offer a life span in excess of one billion operations. The mercury wetted reed relay can operate in the millisecond range. Although slower than solid-state relays, reed relays are sufficiently faster than other electro-mechanical relays and therefore can be used in high speed switching applications. When compared to solid-state relays, the necessary coupling circuitry between the logic and input and output devices is less complicated and less expensive for reed relays. The mercury wetted reed relay has the following advantages over a dry reed relay: no contact bounce, longer life, and lower contact resistance.

Reed relays used for inductive loads such as motors, relay coil, solenoids, etc., are subject to high induced voltages during opening of the load circuit contacts. This high transient voltage may cause damage to the reed switch or significantly reduce its life. Reed relays used for capacitive loads such as capacitors, incandescent lamps or long cables, are subject to high surge/inrush current. Therefore, protective circuits such as surge suppressors or current limiting resistors are often used. Reed relays located near sources of strong magnetic interference such as steel plates, transformers, etc. can experience changes in operational characteristics and false operation is likely. The wetted mercury reed relay must be mounted in the vertical position for proper operation.

Mercury wetted reed relays can be replaced by dry reed magnetic relays for most applications with the exception of applications that require no contact bounce, long operational life, or low contact resistance.

Manufacturers

The following are manufacturers of mercury wetted reed relays:

Manufacturer Name	Product	Phone Number & Website
American Relays, Inc.	Numerous DIP, SIP, and encapsulated, models	562-944-0447 www.americanrelays.com
Celduc Relais (France) Laube Technology – US Representative	F81A, F72C2 Series	Laube Technology: 805-388-1050 www.celduc-relais.com
Computer Components, Inc.	Numerous models	800-864-2815 www.relays-unlimited.com

Manufacturer Name	Product	Phone Number & Website
Crydom Magnetics (UK)	DIP Series	Crydom USA 619-210-1600 www.crydom.co.uk
Meder Electronic, Inc.	MRE and MT Series	800-870-5385 www.meder.com
SRC Devices	MSS Series, HGWM Series	858-292-8770 www.srcdevices.com

4.16.C Mercury Contact Relay

Description

The mercury contact relay establishes contact between electrodes in a sealed capsule as a result of the capsule being tilted by an electro-magnetically actuated armature, either on pickup or dropout. No manufacturers were identified that currently produce this type of mercury relay, and therefore there will be no further coverage of this type of relay in this report.

Alternative 1: Dry Magnetic Reed Relay

Description

A dry magnetic reed relays consists of a pair of low reluctance, ferromagnetic, slender flattened reeds. These reeds are hermetically sealed into a glass tube with a controlled atmosphere in cantilever fashion so that the ends align and overlap with a small air gap. Since the reeds are ferromagnetic, the extreme ends will assume opposite magnetic polarity when brought into the influence of a magnetic field. When the magnetic flux density is sufficient, the attraction force of the opposing magnetic poles overcomes the reed stiffness causing them to flex toward each other and make contact. This operation can be repeated millions of times at extremely high speeds. Energizing the coil sets up a magnetic field that acts in the same manner as the permanent magnet. At the contact area, these relays are usually plated with rhodium, ruthenium, or gold to provide a low contact resistance when they meet.

Dry magnetic reed relays are typically small circuit controls that are used in electronic devices. Reed relays are primarily used in test, calibration, and measurement equipment applications where stable contact resistance over the life of the product is necessary.

Cost

The cost of dry magnetic reed relays are approximately $2 to $15 depending on product or application requirements. For one manufacturer, the cost of mercury wetted relay was the same as a dry magnetic reed relay for a similar device. For another manufacturer, the cost of mercury wetted relay was double the cost for a dry magnetic reed relay for a similar device.

Advantages/Disadvantages

The dry magnetic reed relay has long operational life, fast cycling time, no mercury life cycle impacts to address, and can be mounted in any position for proper operation.

The dry magnetic reed relay experiences similar effects from electromagnetic interference as the mercury wetted reed relay. Exposure to high voltage may cause the contacts to weld together. The dry magnetic reed relay has more contact bounce than mercury wetted reed relays, shorter operational life than mercury wetted reed relays, and has higher contact resistance than the mercury wetted relay.

Manufacturers

The following are manufacturers of dry magnetic reed relays:

Manufacturer Name	Product	Phone Number & Website
American Relays, Inc.	Numerous models	562-944-0447 www.americanrelays.com
Celduc Relais (France) Laube Technology – US Representative	D31 and D41 Series	Laube Technology: 805-388-1050 www.celduc-relais.com

Manufacturer Name	Product	Phone Number & Website
Computer Components, Inc.	Numerous models	800-864-2815 www.relays-unlimited.com
Coto Technology	Numerous models	401-943-2686 www.cotorelay.com
Crydom Magnetics (UK)	S Series	Crydom USA 619-210-1600 www.crydom.co.uk
Magnecraft & Struthers-Dunn	W107 Series	843-393-5778 www.magnecraft.com
Meder Electronic, Inc.	H, LI, HE, MRX, MT and other series	800-870-5385 www.meder.com
NTE Electronics, Inc.	R56 Series	973-748-5089 www.nteinc.com
SRC Devices	Series DSS4 and PRMA	858-292-8770 www.srcdevices.com

Alternative 2: Other Electro-Mechanical Relays

Description

There are several classifications of electro-mechanical relays including mercury displacement, mercury wetted reed, dry reed, and other electro-mechanical relays. This section will focus on the other electro-mechanical relays that include general purpose, definite purpose, heavy duty, and printed circuit board mounted relays. Most electromechanical relays are driven electro-magnetically, by passing a current through a coil and generating a magnetic flux. This flux then causes an armature to move prompting isolated electrical contacts to open or close.

Cost

The cost for other electro-mechanical relays is approximately $1 to $35 depending upon product or application requirements. As the power level requirement goes up, the price for other electro-mechanical relays rises and they become less cost competitive with solid-state relays.

Advantages/Disadvantages

Other electro-mechanical relays are often used as safety devices because of the complete mechanical break in the electrical circuit, whereas solid-state units are subject to leakage current. Other electro-mechanical relays are often selected because of their low initial cost. Electromechanical relays are desirable when electrical interference is likely to be present or when low heat dissipation is required.

Other electro-mechanical relays will typically wear out either mechanically or electrically within several hundreds of thousands of cycles. This is a shorter operational life than for either mercury or solid-state relays. Labor costs and production down time to change a failure are significant when selecting this type of relay for high cycling applications. Other electro-mechanical relays also have a slow cycle time. Therefore, the control of equipment is poor for many sensitive applications. The controlled equipment may be damaged and heater life can be shortened due to thermal shock.

Manufacturers

The following are manufacturers of other electro-mechanical relays:

Manufacturer Name	Product	Phone Number & Website
Chromalox	CONT Series	800-443-2640 www.chromolox.com
Computer Components, Inc.	Numerous models	800-864-2815 www.relays-unlimited.com
Magnecraft & Struthers-Dunn	W199 Series	843-393-5778 www.magnecraft.com
Meder Electronic, Inc.	TC Series	800-870-5385 www.meder.com
NTE Electronics, Inc.	R10 Series	973-748-5089 www.nteinc.com

Manufacturer Name	Product	Phone Number & Website
Omron Electronics	MJN and MGN Series	847-882-2288 www.omron.com
SRC Devices	LM Series	858-292-8770 www.srcdevices.com
Teledyne	Numerous models	800-284-7007 www.teledynerelays.com

Alternative 3: Solid State Relay

Description

A solid-state relay is a semiconductor, electronic switching device that operates a load circuit without the use of physical mechanical contacts. The solid-state relay contains an input circuit, an opto-coupler chip, and an output circuit designed to switch either an alternating current or direct current voltage. Solid state relays control power by switching on and off at the zero cross point.

Cost

The cost of a solid-state relay is approximately $1 to $150 depending on product or application requirements.

Advantages/Disadvantages

Solid state relays provide the following advantages: very long operational life, immunity to electromagnetic interference, lower power consumption, high operating speeds, bounce-free operation, low level control signals, small package size, and multi function integration. The printed circuit board mounted solid-state relay has a tremendous size advantage over the electromagnetic relay, resulting in critical printed circuit board space savings. The solid-state relay is also more immune to physical shock, vibration, and damage. Solid-state relay operational testing by one manufacturer resulted in a mean time between failure (MTBF) of thirty-three years. Compared to the dry reed relay, the solid-state relay has no contact bounce, and longer operational life.

Solid-state relays experience voltage drops across the device resulting in heat generation. The more current put through the device, the greater the quantity of heat that needs to be dissipated. Overheating protection is usually provided by heat sinks or cooling fans. Solid-state relays require proper fusing for short circuit protection. Solid-state relays also may require protection from transient voltage spikes. This is usually provided by metal oxide varistors. Solid-state relays only turn circuits on or off, resulting in controlled equipment receiving either full current or no current. Some solid-state relay manufacturers use infrared light emitting diodes (LEDs) made of gallium/aluminum/arsenic to control the optically coupled input. The solid-state relay experiences current leakages, and the contact resistance is typically higher than mercury wetted relays.

Manufacturers

The following are manufacturers of solid-state relays:

Manufacturer Name	Product	Phone Number & Website
ABB SSAC	Numerous models	315-638-1300 www.ssac.com
Carlo Gavazzi (Switzerland) U.S. Rep - Allied	RN and RS1A Series	Allied: 800-433-5700 www.carlogavazzi.com
Celduc Relais (France) Laube Technology – US Representative	SC Series	Laube Technology: 805-388-1050 www.celduc-relais.com
Chromalox	7750 Series	800-443-2640 www.chromolox.com
Clare	CPC, LCA Series	978-524-6700 www.clare.com
Computer Components, Inc.	Numerous models	800-864-2815 www.relays-unlimited.com

Manufacturer Name	Product	Phone Number & Website
Continental Industries Inc.	SV, RS, and RV Series	703-669-1306 www.ciicontrols.com
Crouzet Corporation	84132 and 84130 Series	972-471-2555 www.crouzet.com
Crydom Magnetics (UK)	H12 Series	Crydom USA 619-210-1600 www.crydom.co.uk
International Rectifier	PV Series	310-322-3331 www.irf.com
NTE Electronics, Inc.	RS1 and RS3 Series	973-748-5089 www.nteinc.com
Solid State Optronics, Inc.	Numerous models	888-377-4776 www.ssousa.com
Teledyne	C3P24D25 Model	800-284-7007 www.teledynerelays.com
Tyco Electronics	SSRD, SSRQ, and SSRT Series	800-468-2023 www.relay.tycoelectronics.com
Vishay	LH Series	402-563-6866 www.vishay.com
Watlow Electronic Manufacturing Company	SSR Series	507-454-5300 www.watlow.com

Alternative 4: Silicon Controlled Rectifiers

Description

The silicon controlled rectifier functions as a switch that can rapidly turn power on or off in a variety of applications. The silicon controlled rectifier is made up of four layers of semiconductor material. Silicon controlled rectifiers can deliver electrical power to controlled equipment in several ways:

- Phase-angle-fired controls – Provides smooth, variable application of power to heaters.
- Zero-voltage switching controls – Proportionally turns on and off each full cycle of the power line.
- On/off controls – Function similar to electro-mechanical or mercury relays, but has much faster cycle times.

Cost

The cost of a silicon controlled rectifier is approximately $30 to $150 depending on product or application requirements. The cost of silicon controlled rectifiers is higher than electro-mechanical relays at low power, but becomes more comparable with electromechanical relays at mid to high power levels.

Advantages/Disadvantages

The silicon controlled rectifier is an extremely fast switch that can be cycled in milliseconds. Silicon controlled rectifiers offer the following advantages: improved response time, closer process control, extended life of controlled equipment, reduced maintenance costs, silent operation, and reduced peak power consumption. The level of process control that can be achieved with a silicon controlled rectifiers is unattainable with any other relay type. Silicon controlled rectifiers are excellent for addressing high inrush current, soft start, step up, ramp up, or other applications where variable power is required and satisfied by using phase angle functionality.

The silicon controlled rectifier needs to be physically disconnected before servicing controlled equipment, and has heat dissipation requirements. The silicon controlled rectifier costs more than other relays for low current applications.

Manufacturers

The following are manufacturers of silicon controlled rectifiers:

Manufacturer Name	Product	Phone Number & Website
Avatar Instruments	A1P, A3P, B, C1P, D, CZ, and R Series	610-543-5155 www.avatarinstruments.com
Carlo Gavazzi (Switzerland) U.S. Rep - Allied	RM1A and RE Series	Allied: 800-433-5700 www.carlogavazzi.com
Chromalox	4001 SCR Series	800-443-2640 www.chromolox.com
Tyco Electronics	SSR Series	800-468-2023 www.relay.tycoelectronics.com
Watlow Electronic Manufacturing Company	DIN-A-MITE Series	507-454-5300 www.watlow.com

Alternative 5: Hybrid (Electro-mechanical and Solid-State)

Description

Hybrid relays combine electromechanical and solid-state technologies, offering the advantages of both without the disadvantages associated with either individually. The switching of a hybrid relay is controlled by a microprocessor. When switched on, the circuit is closed by the solid-state element and the load energized, while absorbing transient peaks. The solid-state element is then short-circuited a few milliseconds later by an electromechanical relay contact, which maintains the load. The reverse cycle operates when the control signal disappears and the circuit is de-energized. The hybrid power relay is designed to cycle power on and off for a variety of applications including heating, ventilation, air conditioning and lighting.

Cost

The cost of a hybrid relay is approximately $40 to $140 depending on product or application requirements. One manufacturer prices its hybrid relay slightly less than its mercury displacement relay with comparable functionality.

Advantages/Disadvantages

By combining solid state and electromechanical relay technology, the hybrid relay eliminates the internal heating effect caused by current flow through electronic power components. This eliminates the need for integrated heat sinks and consequently reduces the physical size of the relay. The hybrid relay provides a long operation life, often greater than five million cycles. The hybrid relay has a virtually silent operation, enabling the relay to be mounted in noise sensitive areas.

A wide range of hybrid relays is not currently available to meet all design parameters. However, the hybrid relay is a good alternative for retrofitting mercury relays when the hybrid relay can cover the necessary design parameters.

Manufacturers

The following are manufacturers of hybrid relays:

Manufacturer Name	Product	Phone Number & Website
Carlo Gavazzi (Switzerland) U.S. Rep - Allied	RZ Series	Allied: 800-433-5700 www.carlogavazzi.com
Crouzet Corporation	84138 Series	972-471-2555 www.crouzet.com
Watlow Electronic Manufacturing Company	E-Safe Relay	507-454-5300 www.watlow.com

Summary

There are numerous non-mercury alternative technologies currently in use for relay products and applications. The non-mercury alternatives have been designed for use in various applications, including demanding process control applications in industries such as food, glass, plastics, semiconductors, chemical, and petroleum. It appears that these non-mercury alternatives are cost competitive and can meet the functional requirements for most, but not all new relay products and applications. In addition, these non-mercury alternatives may not meet the

requirements for retrofitting existing relay products and applications in some circumstances.

4.17 Flame Sensor

Mercury Flame Sensor

Description
Flame sensors are used as a safety device in gas appliances. The flames sensor will stop the flow of gas if there is no heat being produced by an open flame meaning the pilot light is out, or the product is malfunctioning. The mercury within the bulb of the sensor vaporizes and expands when the pilot light is on causing the gas valve to open.

Cost
The difference in cost of flame sensors as a component is difficult to find. One cost comparison made was between gas ranges that contain a mercury flame sensor and those that have an electronic ignition system. The prices were comparable ranging from $300 up to $1000. A low-end quality name gas range with an electronic ignition and a gas range with a mercury flame sensor were both around $300. The leading manufacturer of mobile home products also offers an electronic ignition system in its ranges and hot water heaters. No cost difference was noted in any product literature, and almost every model manufactured was offered either as electronic ignition flame detection or a mercury flame sensor.

Advantages/Disadvantages
The mercury flame sensor provides the safety of controlling the flow of gas when no flame is lit. This prevents natural gas from leaking out and creating a serious situation. A majority of the manufacturers identified offered an electronic ignition flame detection unit that does not use mercury in its sensor.

Manufacturers
The following are manufacturers of mercury flame sensors:

Manufacturer Name	Product	Phone Number & Website
Andy Baumen Associates, Ltd.	Mercury Flame Sensor	1-800-387-817 www.andybaumenltd.com
Channel Products Inc.	Mercury Flame Sensor	440-423-0113
White-Rodgers	Mercury Flame Sensor	314-577-1300 www.white-rodgers.com
Fenwal	Mercury Flame Sensor	508-881-2000 www.fenwalcontrols.com
Derlite Limited	Mercury Flame Sensor	44-1208-72565 www.derlite.com
Harper-Wyman Co.	Mercury Flame Sensor	630-870-3300 www.harper-wyman.com
Invensys Appliance Controls	Mercury Flame Sensor	804-756-6524 www.invensys.com
Major International	Mercury Flame Sensor	847-593-0796 www.majorinternational.com
Sit La Precisa S.p.A.	Mercury Flame Sensor	+39-049-8293111 www.sitgroup.it

Alternative 1: Electronic Ignition System

Description
Using an electronic ignition system in gas appliances eliminates the need for a standing pilot light. The electronic ignition sparks when the gas is turned on to ensure rapid lighting of gas and to prevent gas discharge before sparking.

Cost

In general, the difference in cost between a range with an electronic ignition and the cost of a range with a mercury flame sensor is negligible. However, one manufacturer indicated that the price of their electronic ignition range was 10% - 20% higher than the price of their pilot model range containing a mercury flame sensor. A low end quality name gas range with an electronic ignition starts at $300 and can run up to $1000. A majority of the manufacturers identified offered an electronic ignition flame detection unit that does not use mercury in its sensor.

The leading manufacturer of mobile home products also offers an electronic ignition system in its ranges and hot water heaters. No cost difference was noted in any product literature, and almost every model manufactured was offered either as electronic ignition flame detection or a mercury flame sensor.

Advantages/Disadvantages

One key concern when using an electronic ignition gas product is the fact that electricity must be present in order to light the appliance. In remote areas where electricity is not offered safety becomes a concern. The electronic ignition flame detection products can still be lit without electricity, but offer no safety to control the gas flow. The mercury flame sensors do not require electricity to function, but ensure the detection of a flame and the control of gas flow. The electronic ignition system ranges do not contain any mercury containing devices or sensors, and are a good alternative.

Manufacturers

The following are manufacturers of electronic ignition systems:

Manufacturer Name	Product	Phone Number & Website
Andy Baumen Associates, Ltd.	Electronic Flame Sensor	1-800-387-817 www.andybaumenltd.com
Ventronics, Inc.	Electronic Flame Sensor	908-272-9262 www.ventronicsinc.com
Trivar Inc.	Electronic Flame Sensor	905-671-1744 www.trivar.com
Steelman Industries, Inc.	Electronic Flame Sensor	903-984-3061 www.steelman.com
Capable Controls	Electronic Flame Sensor	630-860-6514
Derlite Limited	Electronic Flame Sensor	44-1208-72565 www.derlite.com
Harper-Wyman Co.	Electronic Flame Sensor	630-870-3300 www.harper-wyman.com
Invensys Appliance Controls	Electronic Flame Sensor	804-756-6524 www.invensys.com
Johnson Controls	Electronic Flame Sensor	414-524-1200 www.johnsoncontrols.com
Major International	Electronic Flame Sensor	847-593-0796 www.majorinternational.com
Sit La Precisa S.p.A.	Electronic Flame Sensor	+39-049-8293111 www.sitgroup.it

Summary

The electric ignition system is a cost effective and functional replacement for the mercury flame sensor. Electronic ignition systems are currently in use for many applications. In remote areas where electricity is intermittent or unavailable, the electronic ignition system is not a safe alternative to the mercury flame sensor. Even when electricity is available, the mercury flame sensor cannot always be easily retrofitted with an electronic ignition system for existing applications because the flame sensor is often highly integrated within a product.

5.0 Conclusions and Recommendations

5.1 Conclusions

Researching alternatives to the priority mercury added products showed that many of these mercury-containing products can be replaced with non-mercury products of equal or greater functionality at comparable costs.

For most priority products examined in this study, at least one manufacturer of the non-mercury alternative was identified where the cost differences between mercury and non-mercury technologies were minimal. The research findings suggest that many non-mercury alternatives are available to address the full range of functions required by consumer products.

Examples of some product specific mercury replacement programs were discussed in the findings section of this report. In addition, there are mercury replacement programs that address multiple mercury containing products. For example, the Mercury Pollution Prevention Initiative involves three Indiana steel mills that are inventorying mercury containing products, identifying non-mercury alternatives, and replacing the mercury products with non-mercury alternatives. Products included in this effort are barometers, manometers, hydrometers, pyrometers, thermometers, thermostats, pressure switches, tilt switches, float switches, and relays. The inventory effort identified approximately one thousand pounds of mercury in equipment and devices at these three steel mills. The three mills have committed to a reduction of 330 pounds of mercury in equipment by the end of 2000, a reduction of 660 pounds by the end of 2004, and a reduction of 900 pounds by the end of 2008. (Delta Institute, 2001)

Legislation to address mercury containing products has been in existence since the early 1990s. In 1993, Sweden banned or phased-out the manufacture, import, or sale of thermometers, barometers, manometers, tilt switches, float switches, pressure switches, thermostats, relays, and other types of measuring instruments. Some exemptions remain for spare parts of existing products and applications. Other European countries have banned or restricted the import, sale, and/or use of various mercury containing products. (UNEP, 2002)

In the United States, there is legislation at the state level to address the sale of various mercury containing products. For example, Rhode Island and Connecticut have recently adopted into law mercury product phase-out legislation based on the NEWMOA Mercury Model Legislation.

Sphygmomanometers
Alternatives to mercury sphygmomanometers are available from a number of manufacturers. The basic function and purchase price of the aneroid (dial) sphygmomanometer appear to be comparable to that of the mercury sphygmomanometer. A relatively new class of electronic blood pressure monitors is also now available. This type of device, with an entry level price of approximately $700 (roughly five times the cost of the least expensive mercury gauge), is promoted as being more forgiving of operator technique and providing more comprehensive information about blood pressure.

Esophageal (Bougie) Tubes
Tungsten gel-filled bougies are readily available from medical device manufacturers and appear to be quite acceptable to practitioners.

Gastrointestinal Tubes
The research suggests that gastrointestinal tubes are not widely used and tubes seem to be consistently sold empty of mercury. Thus, a facility electing to use these tubes would supply its own mercury for weighting. One manufacturer advised using sterile water for weighting, although it may result in a longer time for the medical procedure.

Manometers
Mercury manometers can be replaced by digital or vacuum gauge manometers. Both alternatives are available and cost competitive. The digital manometer is very accurate, and routine

calibration of the digital manometer will ensure its accuracy.

Basal thermometers
Non-mercury basal thermometers are readily available and it appears that digital and liquid-in-glass alternatives would be functional and acceptable to consumers. The digital basal thermometers offer features that the mercury thermometers lack: easy-to-read digital display, beep upon achieving maximum temperature, and memory functionality. One supplier offers a liquid-in-glass thermometer that is similar in appearance and function to a mercury basal thermometer. Although non-mercury basal thermometers are slightly more expensive than the mercury counterpart (by a few dollars), this is an infrequent purchase and is in the same price range as some single-use fertility related products (e.g. over-the-counter pregnancy test kits).

Thermometers (other non-fever)
Many viable alternatives exist to the mercury thermometer for multiple applications. The alternatives to mercury thermometers are widely available in the United States, have been in use and are considered to be comparable in accuracy to mercury thermometers. The overall cost to switch from mercury to non-mercury is minimal.

Barometers
Aneroid barometers can be manufactured with or without mercury. Some digital barometers can perform other tasks, and therefore cost more. The digital barometer can be very inexpensive if it is only needed to perform the task of measuring atmospheric pressure. The aneroid and digital barometers appear to be cost competitive alternatives to the mercury barometer.

Hygrometers/Psychrometers
Both the hygrometer and psychrometer are used to measure the relative humidity. They both can be replaced with a spirit-filled thermometer instead of a mercury thermometer and provide the same functionality at similar costs.

Hydrometers
The hydrometer has many different applications; its primary use is in the beer and wine making industry. The use of a spirit filled hydrometer is preferable because it is reliable and cost competitive with the mercury hydrometer.

Flow Meters
During this study, no manufacturers of mercury flow meters were identified. The reliability of the digital flow meters and other non-mercury flow meters are of high caliber, and are in use in numerous application.

Pyrometers
During this study, no manufacturers of mercury pyrometers were identified. The alternatives to a mercury pyrometer (used mainly in foundries to measure the temperature of extremely hot materials) include the digital pyrometer and the optical pyrometer. The optical pyrometer is manufactured for large industrial type foundries. The digital pyrometer seems to be a much more economical choice than the optical pyrometer for smaller foundries.

Thermostats
Rugged industrial thermostats are made to withstand extreme environmental conditions and are used in lieu of electronic thermostats where there is a risk of explosion. The manufacturers of digital thermostats indicated that they are not designed for rugged industrial use, but can be used in low-level industrial applications. In some circumstances the mercury thermostat may be replaced with a digital thermostat. However, for extreme environmental conditions, the manufacturer should be contacted to help determine the appropriate technology.

Flame Sensors
The mercury containing flame sensor is used in many applications as a safety device to prevent the flow of gas when a pilot lamp is not lit. An alternative to the mercury flame sensor is the electronic ignition system. The electronic ignition system can be used in similar applications as the mercury flame sensor and is available for most products. The mercury flame

sensor is often used in remote areas where electricity is not always available. Without electricity the electronic ignition system cannot automatically light the pilot or range. The pilot or range can however be lit by hand, but this poses a safety issue.

Switches and Relays

There were many common findings and conclusions during this research for float switches, pressure switches, temperature switches, tilt switches, mercury wetted reed relays, and mercury displacement relays. The following is a summary of these similarities:

- These components are used in a wide range of products and applications.
- Numerous design parameters need to be considered prior to final component selection.
- Several different non-mercury alternative technologies were identified to replace each of the mercury switches and relays.
- Several manufacturers were identified for most non-mercury alternative technologies.
- Manufacturers of mercury containing products often provide non-mercury alternatives.
- Manufacturers often provide more than one non-mercury alternative technology.
- The non-mercury technologies identified provide a variety of options for each major design parameter.
- Non-mercury alternatives were identified to meet the needs from low cost, simple applications to higher cost, more demanding applications.
- Although, it is difficult to precisely compare pricing for the various switch and relay technologies because there are many design features and options available for each component, it appears that mercury and non-mercury switches/relays with similar functionality for many applications are comparable in price.
- At least one manufacturer was identified that produced both the mercury and non-mercury relay/switch with comparable functionality at comparable costs.

The key differences identified between the mercury switches and relays are as follows:

Switches: No design parameters for new switch products/applications were identified where the mercury containing component could not be replaced by a non-mercury alternative for a comparable cost.

Relays: The majority of design parameters for new relay products/applications could be met by a non-mercury alternative for a comparable cost. However, in some cases the design parameters could not be met by a non-mercury alternative. For example, a mercury wetted reed relay application that requires long life, no contact bounce, and low contact resistance cannot be satisfied by any single non-mercury alternative.

Non-mercury alternatives appear to be available in the United States marketplace to meet the various design parameters that specify float, tilt, pressure, and temperature switches in new products and applications. Non-mercury alternatives appear to be available in the United States marketplace to meet most, but not all, design parameters specifying the use of mercury wetted reed and mercury displacement relays in new products and applications.

Although there are readily available non-mercury alternatives for new products and applications, complications can appear when retrofitting existing mercury switches or relays in

existing products and applications. The relay or switch component of an existing product or application can wear out and require replacement before the end of service life for the product or application. In some instances, the mercury switch or relay is embedded in an existing application in such a way that currently available non-mercury alternatives cannot be retrofitted into the existing product or application. The following two scenarios illustrate this situation:

Retrofit Scenario 1: Mercury Tilt Switch
The Michigan based Clean Car Campaign initiated its "Switch the Switch" program in 2001 to replace mercury tilt switches with non-mercury tilt switches in automobiles across the nation. This program used the metallic ball tilt switch to replace mercury tilt switches found in hood lights and trunk lights. For many vehicle models, this is a simple, drop-in exchange that takes about ten minutes.

Tilt switches are also used in antilock braking systems (ABS) for certain trucks and sport utility vehicles. However, the ABS system usually consists of two to three mercury tilt switches that are physically embedded in a plastic box that is integrated with the braking mechanism. Because of this complex design, there is not a simple drop-in non-mercury tilt switch commercially available for retrofitting the ABS tilt switch system.

Retrofit Scenario 2: Mercury Displacement Relay
An industrial application utilizes a control panel populated with twenty mercury displacement relays to control on-site equipment that requires high current. This equipment also requires fast cycling for proper control. One of the mercury displacement relays fails, and there is now a need to replace this failed mercury relay in the existing control panel. A review of the non-mercury alternatives reveals that a new mercury displacement relay may be the only cost effective option because of the following:

1) Solid-state relays and silicon controlled rectifiers have power dissipation issues that need to be addressed. These relays cannot be easily retrofitted to existing control panels because they may not fit in the available footprint, or there may not be enough ventilation to cool the device. In this case, a significant control panel retrofit expense would be required to accommodate the solid-state relay or silicon controlled rectifier.
2) A non-mercury electro-mechanical relay may not be sufficient to meet the demands of this fast cycle application.
3) A dry reed relay may not be sufficient to meet the high current demands of this existing application.
4) The market for hybrid relays appears to not be mature enough to cover the other design parameters for this particular existing application.

As the two examples above illustrate, the retrofitting of mercury switches and relays in existing products or applications can present challenges. The cost of the relay or switch component is often a small fraction of the total cost of the product or application. In situations where a non-mercury alternative cannot be used for retrofit purposes, it would be unreasonable and cost prohibitive to require the consumer to replace the entire product or retrofit the application.

Relays and switches are used in hundreds of existing products and applications. Each product or application would need to be examined on a case-by-case basis to determine if retrofitting with a non-mercury alternative is cost competitive. Therefore, it is not possible to specify situations in which retrofitting of existing products or applications is cost competitive without conducting further study of individual products and/or applications. However, there are certain common factors that could negatively affect the cost competitiveness of retrofitting

with non-mercury alternatives. These factors include:

- Factor 1: Numerous switches and/or relays are combined to perform a particular function
- Factor 2: The switch or relay is integrated with other components of the product or application
- Factor 3: There are heat dissipation issues presented by using the non-mercury alternative
- Factor 4: The physical size limitations or other design parameters of the product/application cannot be met by the non-mercury alternative
- Factor 5: A custom-designed rather than off-the-shelf switch or relay is used to meet unique operating requirements

Float switches are used in bilge pumps and provide an illustrative example of retrofit considerations for existing equipment. There are two types of bilge pumps:

1. Non-automatic operation: The bilge pump does not contain a float switch and the bilge pump is often controlled by manual methods. However, non-automatic bilge pumps can often be converted to automatic mode by connecting an external float switch.
2. Automatic operation: The bilge pump is controlled by a timer, a water detection technology, a combination of timer and water detection technology, or a float switch. If a float switch is used, it can either be integrated into the bilge pump housing or can be connected to the bilge pump and mounted externally to the pump.

The float switch used in bilge pumps can be either a mercury or non-mercury model. According to a recent study of mercury float switches in bilge pumps, "Most switches are easily accessible for easy replacement of old switches, which have a shorter life span than bilge pumps. An old switch can usually be replaced by any mercury or non-mercury variety that fits the amperage requirements of the pump." (Pollution Probe, 2000).

LCSP contacted two float switch/bilge pump manufacturers to determine if their float switches could be used to retrofit bilge pumps with external float switches. Both manufacturers indicated that their float switch could be used to retrofit their own bilge pumps, as well as other manufacturer's bilge pumps. One of these manufacturers did not recommend using their float switch to retrofit another manufacturer's bilge pump because their float switches were not specifically tested on other manufacturer's bilge pumps. However, this manufacturer does provide non-mercury bilge pump models.

LCSP also contacted a float switch manufacturer that provides both mercury and non-mercury float switches for use with bilge pumps and other applications. The manufacturer estimated that 98% of their float switches sold were non-mercury models, and the remaining 2% were mercury models.

There may be a small number of instances where the mercury float switch in a bilge pump cannot be replaced by a non-mercury float switch. Factor 2 could occur when a mercury float switch is integrated into the bilge pump housing for automatic operation. Factor 4 could occur for bilge pumps with high amperage requirements. For example, the Atwood 4201 non-mercury float switch is marketed as being able to convert any bilge pump to fully automatic operation that draws less than 12 amps at 12 volts direct current. No situations were identified where Factors 1, 3, or 5 would occur for bilge pump retrofit situations.

5.2 Recommendations

The product research conducted for this report suggests that there are cost competitive, viable non-mercury alternatives for a large majority of the priority mercury containing products. In most cases, the purchase price of an alternative is comparable to the mercury device and if the downstream costs are considered, non-mercury alternatives can be considerably more cost effective. Additional information to assist with

the transition to non-mercury alternative products is provided in Appendix 3.

Non-mercury alternatives have been researched and recommended for the following products: sphygmomanometers, esophageal dilators, manometers, barometers, non-fever thermometers, hygrometers, psychrometers, hydrometers, flow meters, and pyrometers. The two products where alternative replacements cannot be recommended for all applications are gastrointestinal tubes and industrial thermostats. More research is needed to understand gastrointestinal tubes applications and the viability of mercury replacement.

It appears that digital thermostats cannot withstand the harsh environmental conditions demanded by certain industrial settings, and mercury thermostats are currently the only industrial type thermostats available that can perform effectively.

There are cost competitive, viable non-mercury alternatives available and recommended for the following components of new products and applications: flame sensors, float switches, tilt switches, temperature switches, and pressure switches. The majority of design parameters for new relay products/applications could be met by a non-mercury alternative for a comparable cost. However, in some cases the design parameters could not be met by a non-mercury alternative. Also, the use of electronic ignition systems is not recommended to replace mercury flame sensors in remote areas where electricity is unavailable.

Non-mercury alternatives were identified and recommended to meet the needs of retrofitting existing relay/switch products or applications. However, there are certain retrofit circumstances in which the cost implications preclude the use of the non-mercury alternatives.

6.0 Sources

Barr Engineering Company, "Substance Flow Analysis of Mercury in Products" Prepared for the Minnesota Pollution Control Agency, August 15, 2001.

California DHS, A Guide to Mercury Assessment and Elimination in Health Care Facilities.

California Poison Control System, University of California (2000-2002). "Mercury and its Many Forms". Available at: http://www.calpoison.org/public/mercury.html (August, 2002).

Canzanello, Vincent J., MD; P.L. Jensen, RN; GL Schwartz, MD, "Are Aneroid Sphygmomanometers Accurate in Hospital and Clinic Settings?", *Arch Intern Med*. 2001;161:729:731.

Clean Car Campaign, Driving Forward – Switch the Switch, Volume 3, March 2002.

Delta Institute, Inland Ispat Indiana Harbor Works, Bethlehem Steel Burns Harbor Division, United States Steel Gary Works, and Lake Michigan Forum, "A Guide to Mercury Reduction in Industrial and Commercial Settings", July, 2001. Available at: http://delta-institute.org/Steel-Hg-report-0627011.pdf (September, 2002).

Gordon, John A., Venture Development Corporation, An Executive White Paper On: The World Electromechanical and Solid State Relay Industry, Fifth Edition, Volume I – North America.

Gordon, John A., Venture Development Corporation, An Executive White Paper On: 2001/2002 Global Relay Market Intelligence Service, April 2002.

Hoerr, Donald, Solid-State Pressure Switches – Technology for Today's Fluid Power Applications, IICA Journal.

ICL Calibration Laboratories, www.iclslabs.com.

Inform, Inc., Purchasing for Pollution Prevention Project (2002). "Mercury-Containing Products and Alternatives in the Health Care Setting". Available at: http://www.informinc.org/fsmerchealth.pdf (August, 2002).

Kansas Department of Health and Environment, "Mercury Information Page". Available at: http://www.kdhe.state.ks.us/mercury/ (August, 2002).

Knoop, Alan R., Fundamentals of Relay Circuit Design, Reinhold Publishing, New York.

Maine Department of Environmental Protection, "Mercury in Maine: A Status Report", February 2002.

Minnesota Pollution Control Agency, Managing Mercury Switches: Hazardous Waste Fact sheet #4.26 October 1998.

Minnesota Office of Environmental Assistance Mercury applications in major appliances and heating/cooling systems, April 1998.

Minnesota Office of Environmental Assistance, Mercury in Households and Commercial products and applications, John Gilkeson, November 1997.

Minnesota Pollution Control Agency, "Mercury". Available at: http://hubble.pca.state.mn.us/air/mercury.html (August, 2002).

National Association of Relay Manufacturers, Engineers Relay Handbook 2nd and 5th Edition, Hayden Book Company, New York.

New York Academy of Sciences, "Pollution Prevention and Management Strategies for

Mercury in the New York/New Jersey Harbor", May 14, 2002.

Northeast Waste Management Officials' Association, "Mercury-Added Product Notification Form".

Northeast Waste Management Officials' Association, "Total Mercury in All Mercury-Added Products".

Northeast Waste Management Officials' Association, "Reported Mercury Spills in the Northeast States", October 2001.

Offner, Arnold, How do Relays Work, Motion Control, July/August 1999.

Pollution Probe, A Study of the use of Mercury Switches in Bilge Pumps of Pleasure Boats in Ontario, March 2000.

Powell, William B. and Pheifer, David, "The Electrolytic Tilt Sensor", Sensors, May 2000.

Pulse Metric, Inc., "Non-Invasive Blood Pressure Measurement and Pressure Waveform Analysis", (1996).

Purdue University, Department of Agricultural and Biological Engineering. "What Devices Contain Mercury?" Available at: http://pasture.ecn.purdue.edu/~epados/mercbuild/src/devicepage.htm (August, 2002).

Sedivy, David, Electronic Controls Spawn Integration, Appliance Manufacturer.

State of California Department of Health Services, "A Guide to Mercury Assessment and Elimination in HealthCare Facilities", September 2000. Available at: http://www.dhs.cahwnet.gov/ps/ddwem/environmental/med_waste/guide_to_mercury_assessment_v1.00.pdf (August, 2002).

State of Maine Statutes, Title 38, Chapter 16-B, Mercury-added Products and Services.

Tellus Institute, "Healthy Hospitals: Environmental Improvements Through Better Environmental Accounting", July 2000.

Timbrell, J.A., "Introduction to Toxicology", Second Edition, 1995, Taylor & Francis; pp. 118-121.

United Nations Environment Programme (UNEP), (July, 2002). "Global Mercury Assessment". Available at: http://www.chem.unep.ch/mercury/WG-meeting1-revised-report-download.htm (October, 2002).

United States Environmental Protection Agency, Mercury Study Report to Congress, December 1997.

United States Environmental Protection Agency and Environment Canada, "Background Information on Mercury Sources and Regulations; Appendix C. Regulations on Products that Contain Mercury". Available at: http://www.epa.gov/grtlakes/bnsdocs/mercsrce/9409merc.pdf (August, 2002).

United States Geological Survey, "Mercury in the Environment", Fact Sheet 146-00 (October 2000)

United States Geological Survey, 2002 Mineral Commodity Summary – Mercury.

University of Michigan Pollution Prevention Program, "Mercury-Filled Esophageal Devices". Available at: http://www.p2000.umich.edu/mercury_reduction/mr1.htm (August, 2002).

Von Rein, K. and Hylander L.D., Experiences from Phasing out the Use of Mercury in Sweden, Regional Environmental Change, 2000, 1:126-134.

Williams, Raymond R., Sensors Magazine, April 1997, "An Introduction to Solid State Pressure Switches".

Winkler, Robert, and Wells Erik A., "The UVM Mercury Thermometer Swap. January, 1999. Available at: http://esf.uvm.edu/chemsource/thermoswap/ (October, 2002)

Wisconsin Department of Natural Resources, Draft Wisconsin Mercury Source Book.

Wisconsin Department of Natural Resources, Success Stories & Partnerships, August, 2002. Available at: http://www.dnr.state.wi.us/org/caer/cea/projects/pollution/reports/1999/report2_p6.htm (October 2002)

Yeats, Mike, Derriford Hospital, Plymouth, UK, "The Maintenance of an Aneroid Sphygmomanometer", *Update in Anesthesia*, Issue 3 (1993) Article 8, World Federation of Societies of Anaesthesiologists. Available at: http://www.nda.ox.ac.uk/wfsa/html/u03/u03_018.htm (August, 2002).

Appendix 1: Medical Device Reports for Spilled Mercury

The United States Food and Drug Administration (FDA) regulates the use of medical devices in the United States. In 1990, the Medical Device Reporting (MDR) system was implemented as a mechanism for the Food and Drug Administration to receive significant medical device adverse events from manufacturers, importers and user facilities, so they can be detected and corrected quickly. The following MDRs demonstrated the potential for health or environmental problems with mercury in healthcare. In addition to remediation associated with the mercury release (both environmental and health related), each MDR requires investigation and documentation at the reporting facility, the manufacturer, and the FDA.

Date FDA Received Report	Reference & Description
05/09/2002	Baumanometer Stand-by Blood Pressure Machine "A blood pressure unit blew, **causing 2.5 ounces of mercury to vaporize**."
10/23/2000	Baumanometer "Glass tube containing mercury on Baumanometer cracked causing **mercury to spill** in facility."
01/05/2000	Rusch Maloney Esophageal Bougie "It is reported that the tip of the bougie broke off during use. Distal end was not retrieved at the time of the event. Upon removal of the device, it was noted that **mercury was leaking** from the broken end of the tube."
10/12/1999	Pilling-Weck Maloney Esophageal Dilator 24 Fr. "During procedure, a bougie dilator for esophagus was transected inside the stomach, **allowing mercury from the dilator to escape.**.. The bougie that was used for the procedure had been expired."
07/14/1999	Rusch Cantor Tube "It is alleged that a Cantor tube was inserted and **mercury instilled**. A subsequent x-ray indicated the **presence of mercury in the stomach**."

Appendix 2: Cost of Mercury Spills

Cost Estimate for Clean-up	Reference & Description
Small spill - $1000 Large spill - $tens of thousands	http://www.melg.org/mcea/rcbmcrmt.htm "Mercury Contamination Risk Control", Middle Cities Risk Management Trust, Okemos, MI " A typical thermometer contains ½ to 3 grams (.018 to .11 ounces) of mercury. A typical household mercury fever thermometer contains approximately 1 gram of mercury. A typical barometer contains 1 pound (454 grams) of mercury and poses a significant spill risk. The cost of cleaning up a spill will vary by the size of the spill and the degree of exposure to property and people. Small spill clean-ups usually cost around $1,000 and large spills can go into the tens of thousands of dollars."
3 oral fever thermometers - $5000 Not uncommon … to exceed $25,000	http://cc.ysu.edu/eohs/bulletins/MERCURY.htm "The Hazards of the Element Called Mercury," Youngstown State University "Unfortunately, it does not take a large amount of mercury to produce a problem. In one specific instance, three oral fever thermometers were broken. The mercury fell onto the floor in an office that was approximately ten square feet in size. Following the accident, the mercury vapors present in the air of that room were about three times that permitted by OSHA. Consequently, the room had to be decontaminated, all carpeting had to be discarded at a total cost of about $5000. This was a very small mercury spill. It is not uncommon for cleanup costs of mercury spills to exceed $25,000."
Reported costs went up to $130,000	c) http://www.des.state.nh.us/nhppp/hospital_survey.htm New Hampshire Mercury Reduction Project: Hospital Baseline Survey 1999 Preliminary survey results, New Hampshire Department of Environmental Services "Spills and Breakages - Seven hospitals indicated some kind of mercury spill or equipment breakage and release during 1998. The actual number of spills may be higher, as small spills and breakages may not always be reported. Most hospitals did not have any idea of the cost of clean-up, but reported costs went up to $130,000!!"
~$5,000 for 1 broken sphygmomanometer One hospital spent $10,054 to clean up a spilled sphygmomanometer	http://dnr.metrokc.gov/swd/bizprog/waste_pre/MIRTsem8.htm Medical Industry Waste Prevention Round Table Reducing Mercury in Hospitals and Biomedical Facilities (A MIRT Seminar, May 23, 2001), King County, Seattle, WA " Economic Considerations · Clean up costs – It often costs ~$5,000 for 1 broken sphygmomanometer - you could buy 30 or 40 non-mercury ones for that cost. One local hospital recently spent $10,054 dollars to clean up a spilled sphygmomanometer. · Regulatory Costs - 30-ppt pretreatment level in some places (fines) · Hazardous Waste training costs · Joint Commission on Accreditation of Health Care Organizations (JCAHO) compliance - JAHCO is starting to ask questions"
$570,000 to clean up after sink trap work Environmental service (alone) for any spill costs $1000-1500	http://dnr.metrokc.gov/swd/bizprog/waste_pre/MIRTsem8.htm "Question: How did you get voluntary switch-out of Hg? Answer: VA People remember the Hg spills and are willing to work to avoid going through it again. UW always calls in Foss Env. for any spills. Just for Foss's services costs $1000-$1500. Someone at Bowling Green University changed their sink traps, piled them up and carried them across campus. Mercury was spread everywhere. Cost $570,000 to clean up."
$350,000 to clean up contamination and restore building to original condition	http://204.178.120.25/library/college.htm XL Environmental, Exton, PA “ Spill Spreads Mercury Contamination - A large university in Ohio contracted plumbing work on one of its science labs. While dismantling laboratory piping, the contractor discovered an existing mercury spill that resulted in mercury contamination throughout the building. Costs to clean up the contamination and restore the building to its original condition were $350,000.”

Appendix 3: Transition to Non-mercury Products

There are many challenges to substituting more benign alternatives for mercury containing products and components. Most alternatives are not drop-in substitutions. That is, although an alternative may ultimately achieve the same outcome, such as providing an accurate measure of blood pressure or sensing a flame, there are usually design considerations or different techniques or practices that must be learned and communicated. Even under the best of circumstances progress involves risk and there may be unexpected outcomes, both favorable and undesired.

On the bright side, one manufacturer reported that he continues to learn about the utility of his company's oscillometric blood pressure monitor from doctors using the device. The breadth of blood pressure information offered by the monitor was unexpectedly revealing of a patient's condition, far exceeding the diagnostic utility of the simple systolic and diastolic blood pressures provided by a mercury sphygmomanometer. In another example, a digital manometer used for calibrating sphygmomanometers can result in more accurate calibration than the mercury manometer. Depending on the quality of instruments used, the difference can be as great as having a sphygmomanometer with an accuracy of $\pm$ 3.1mm Hg by using a digital manometer for a reference, versus $\pm$ 6 mm Hg by using a mercury manometer. (Welch Allyn, 2002)

On the negative side, many well designed products and practices will need to be rethought and non-mercury components may not even fit in the footprint of an existing product. There is also a learning curve associated with new designs and components and it is likely that there will be glitches and unintended outcomes as products are changed over. One example is the replacement of a mercury column thermometer in an industrial setting. After a mercury thermometer broke in use and required clean up, a non-mercury alternative was sought. An alcohol thermometer was chosen from a catalog because it was similar in size, shape and temperature range and appeared to be a drop-in substitution. The alcohol thermometer proved to be unsuitable when the alcohol column quickly separated due to the bumping and jarring the thermometer received in the application. When the supplier was consulted, after the fact, a much more appropriate alternative was recommended and it performed capably.

Fortunately there are many resources available for smoothing the transition away from mercury components and products. These include manufacturers' technical support staff, online how-to guides, email lists that share questions and answers, and pollution prevention organizations that can provide guidance. A sampling of useful resources follows. (Many of these resources are related to healthcare, an industry that has been at the forefront of mercury reduction).

Organizations' Websites

Health Care Without Harm (HCWH)
http://www.noharm.org
The mercury section of the HCWH website contains a wealth of information about reducing mercury in healthcare. The Health Care Without Harm coalition is an international campaign to reform the environmental practices of the health care industry. Health Care Without Harm (HCWH) is comprised of more than 300 organizations in 27 countries and includes major health care systems, regulatory bodies, and industry leaders.

Hospitals for a Healthy Environment (H2E)
http://www.h2e-online.org/
The goal of H2E is to educate health care professionals about pollution prevention opportunities in hospitals and healthcare systems. H2E fosters the development and communication of best practices, model plans for waste management, resource directories, case studies, and how-to tools for minimizing the volumes of waste generated and the use of persistent,

bioaccumulative, and toxic chemicals. H2E is a joint project of the American Hospital Association (AHA), the Environmental Protection Agency, Health Care Without Harm and the American Nurses Association. In addition, various state and local resources are active participants in the effort to help hospitals. Two areas of note are the Listserv, an online forum for discussion, and the H2E website's Mercury area.

- H2E Listserv

http://www.h2e-online.org/programs/list.htm
The Hospitals for a Healthy Environment (H2E) Listserv is a communication tool for health care professionals to share information about minimizing the volume and toxicity of health care waste. Healthcare facilities across the country are designing and implementing many projects, including starting recycling programs, eliminating mercury containing devices, and purchasing environmentally preferable products. There are countless opportunities to share questions, answers, and advice through this Listserv.

- H2E Mercury Resources

http://www.h2e-online.org/tools/mercury.htm
The Mercury area of the H2E website includes many resources and links for reducing mercury. One very nice document is the "Mercury Virtual Elimination Plan", found at: http://www.h2e-online.org/tools/merc-over.htm
This is a comprehensive how-to guide to help hospitals assess existing mercury sources, develop action plans for elimination, and set up an environmentally preferable purchasing plan.
non-mercury
Northeast Waste Management Officials' Association (NEWMOA)
http://www.newmoa.org
http://www.newmoa.org/Newmoa/htdocs/prevention/mercury/
The information resources available in the mercury area of the NEWMOA website are designed to help the NEWMOA states achieve their "virtual elimination" goal for mercury by focusing in particular on efforts to reduce or eliminate mercury from the waste stream.

Sustainable Hospitals Project
http://www.sustainablehospitals.org
The Sustainable Hospitals Project (SHP) provides technical support to the healthcare industry for selecting products and work practices that eliminate or reduce occupational and environmental hazards. The SHP website lists alternative products and manufacturer contacts and SHP maintains a technical help line (phone & email) to provide technical support and help hospitals improve their practices.

Journal Article & Reports

Vincent J. Canzanello, MD; Patricia L. Jensen, RN; Gary l Schwartz, MD, "Are Aneroid Sphygmomanometers Accurate in Hospital and Clinic Settings?", Arch Intern Med, 2001; 161:729-731.
This article summarizes an evaluation done at Mayo Clinic in Rochester, Minnesota to assess the accuracy of aneroid sphygmomometers used in their hospitals. Their conclusion was "Aneroid sphygmomanometers provide accurate pressure measurements when a proper maintenance protocol is followed."

Maine Department of Environmental Protection, (February, 2002). "Mercury in Maine: A Status Report". This report provides an update to the 1997 report on Mercury in Maine and it addresses the Maine mercury reporting requirements enacted in May 2000. Available at: http://www.state.me.us/dep/mercury/hginmereport.htm (September, 2002)

Tellus Institute, (July, 2000). "Healthy Hospitals: Environmental Improvements Through Environmental Accounting". This report examines environmental accounting practices in the health care industry and explores whether environmental accounting is a useful approach for uncovering waste minimization opportunities. The report also considers opportunities for influencing upstream procurement practices and supply chain issues. Available at:

http://www.epa.gov/opptintr/acctg/pubs/hospitalreport.pdf (September, 2002)

United Nations Environment Programme (UNEP), (July, 2002). "Global Mercury Assessment". This report provides a global assessment of mercury and mercury compounds, including options for addressing significant global adverse impacts of mercury. The document examines and summarizes worldwide efforts to control releases and limit use of and exposure to mercury, including: national initiatives, international agreements and instruments, international organizations and programs, and sub-regional and regional initiatives. Sections that most relate to Maine DEP study include:

8. Prevention and control technologies and practices
9. Initiatives for controlling releases and limiting use and exposure

Appendix. Overview of Existing and Future National Actions, Including Legislation, relevant to mercury; by Region.

Available at: http://www.chem.unep.ch/mercury/WG-meeting1-revised-report-download.htm (October, 2002).

Manufacturer's Resources

Welch Allyn, Inc. (January 11, 2000). "Analysis of Different Sphygmomanometer Technologies". This provides a discussion on the different types of blood pressure devices and their merits and shortcomings. Available at: (http://www.welchallyn.com/medical/support/manuals/Tycoswhitepapers.PDF (August, 2002).

Welch Allyn, Inc. (July 10, 2002) "Calibrating Your Sphygmomanometer". This describes considerations for routine calibration of sphygmomanometers and describes how digital reference meters can potentially offer a more accurate calibration than mercury references. Available at: http://www.welchallyn.com/medical/support/manuals/Aneroid%20Calibration%20Memo.pdf (August, 2002)

Online Case Studies & Mercury Videos

Clean Car Campaign, "Switch the Switch", Driving Forward: Volume 3, March 2002. Available at http://cleancarcampaign.org/pdfs/wol_3%20_March_2002.pdf (September 2002).

The Delta Institute, Inland Ispat Indiana Harbor Works, Bethlehem Steel Burns Harbor Division, United States Steel Gary Works, and Lake Michigan Forum, "A Guide to Mercury Reduction in Industrial and Commercial Settings", July, 2001. Available at: http://delta-institute.org/Steel-Hg-report-0627011.pdf (September, 2002).

Sustainable Hospitals Project "Mercury Reduction Case Studies", Available at: http://www.sustainablehospitals.org/HTMLSrc/IP_Merc_CS_Strong.html (September, 2002).

Tellus Institute, (July, 2000). "Healthy Hospitals: Environmental Improvements Through Environmental Accounting". Appendix B in this report includes a mercury reduction case study at Kaiser Permanente.

United States Environmental Protection Agency, "Mercury Pollution Prevention in Michigan Hospitals". Available at: http://www.epa.gov/seahome/mercury/src/prevcase.htm (September, 2002).

University of Michigan, Occupational Safety and Environmental Health, "Mercury-Filled Esophageal Dilators". Available at: http://www.p2000.umich.edu/mercury_reduction/mr1.htm (September, 2002).

University of Vermont, "Mercury Thermometer Swap". (Lab thermometers) Available at: http://esf.uvm.edu/chemsource/thermoswap/ (September, 2002).

Western Lake Superior Sanitary District, (March, 1997) “Addressing Sources of Mercury: Success Stories”. Available at: http://www.wlssd.duluth.mn.us/Blueprint%20for%20mercury/HG12.HTM (September, 2002).

The Michigan Department of Environmental Quality , Bowling Green University, Ohio Environmental Protection Agency and Radar Environmental have produced two video clips which allow viewers to see mercury vapor rising from elemental mercury. Two short online videos show mercury vapor at room temperature rising from a petri dish of mercury and from mercury spilled from a broken fever thermometer onto a carpet. Available at: http://www.ecosuperior.com/pages/mercuryvapour.html (September, 2002).

Appendix 4: Maine DEP Letter to Manufacturers of Mercury-added Products

The information request below was sent to manufacturers who filed information on mercury-added products with the Interstate Mercury Education and Reduction Clearinghouse (IMERC). As explained in section 2.0 of this report, IMERC was formed under the auspices of the Northeast Waste Management Officials' Association to, among other things, coordinate implementation of state laws that prohibit sale of mercury-added products unless the manufacturer has disclosed the amount and purpose of the mercury. Maine, New Hampshire, Connecticut and Rhode Island have such laws.

May 1, 2002

Dear [*manufacturer*]:

Enclosed please find a copy of *An Act to Phase Out the Availability of Mercury-added Products* as recently enacted by the Maine Legislature.

The law contains two sections. Section 1 prohibits the sale or distribution of a mercury-added thermostat in Maine for most residential and commercial applications after January 1, 2006. It also provides an exemption process from the prohibition where specified demonstrations can be made.

Section 2 of the bill requires the Department to review information on mercury-added products and, based on that review, prepare a comprehensive strategy to reduce their mercury content. The strategy is due to the Legislature by next January, and presumably will be considered by the Legislature as it contemplates additional legislation regarding mercury-added products.

One of our main sources of information that will be utilized in this effort is the data you and other manufacturers already provided under the mercury product notification law enacted last year. As you will recall, that law-38 MRSA §1661-A-prohibits the sale of mercury-added products in Maine after January 1, 2002 unless the manufacturer has notified the Department as to the amount and purpose of the mercury.

Preparation of the strategy the Legislature seeks will also require additional information, such as the availability of non-mercury alternatives, and on manufacturers' plans (if any) to phase out the use of mercury. This is why I write to you now - to provide you with the opportunity to provide specific information on your product(s) that can be considered by the Department in the development of its strategy. The additional information you provide will be considered in conjunction with research performed by a consultant the Department intends to retain shortly.

At this time, we are focusing our inquiry on mercury-added products (other than lamps and dental amalgam) that contain more than 100 milligrams of mercury or, for formulated products like cosmetics and cleansers; that have a mercury concentration exceeding 50 ppm. If you make such a product or products, we invite you to submit the following information:

- Your plan, if any, for reducing or phasing out the use of mercury, including relevant

timetables for such reductions or elimination,

- Information bearing on the availability, feasibility and affordability of non-mercury alternatives to the product;
- The public health, environmental or other societal benefits (if any) of continuing to use mercury in the product; and
- Any other information you believe relevant to the development of the Department's strategy.

The timetable for completing this strategy is driven by the Legislature's January 1, 2003 deadline. To meet this deadline, we need to receive your information by June 30, 2002 so that it can be adequately considered by the Department and its consultant before preparation of a draft document. The draft document should be available in early fall, and I will provide one at your request.

Thank you for your help, and please feel free to call me at (207) 287-8556 or email me at Enid.Mitnik@state.me.us if you have questions.

Sincerely,

Enid Mitnik

Appendix 5: Aneroid Sphygmomanometers

Aneroid sphygmomanometers are comparable to mercury sphygmomanometers in cost, technique and performance. However, some medical professionals hesitate to adopt aneroid blood pressure devices because of conflicting statements they have heard about aneroid gauge performance. This appendix addresses common perceptions about aneroid sphygmomanometers.

What are the concerns about aneroid sphygmomanometers?

Obtaining accurate blood pressure measurement is a foremost concern in the selection of sphygmomanometers. Once calibrated, there is no expected difference in performance between aneroid and mercury sphygmomanometers manufactured by reputable companies. All sphygmomanometers need routine calibration checks and regular preventive maintenance. The procedures are different for mercury and aneroid sphygmomanometers, but are otherwise equivalent in frequency, complexity and the amount of attention required. In practice, aneroid and mercury sphygmomanometers require different calibration techniques but otherwise proportionate amounts of attention.

Some medical professionals have concerns that aneroid sphygmomanometers are easily damaged during use, resulting in inaccuracy due to the device being dropped or bumped and knocked out of calibration. This is perceived to be less of a concern for mercury sphygmomanometers due to the mercury column's rigid mounting requirements. Because the mercury column must be perfectly vertical in its mounting and the mounting perpendicular to the floor for accuracy, most mercury devices are either wall mounted or mounted on robust mobile stands. Concerns about dropping aneroid devices can be alleviated by purchasing aneroid sphygmomanometers as either wall-mounted units or mounted on mobile stands, comparable to the mercury sphygmomanometers, rather than selecting portable aneroid devices. One manufacturer has also responded to 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. (Welch Allyn)

Comparative Characteristics of Sphygmomanometers

Sphygmomanometers are introduced to the marketplace only after thorough testing and evaluation. Sphygmomanometers sold in the United States are regulated and must be approved by the Food and Drug Administration (FDA). The FDA approval process requires companies to show that new sphygmomanometers are substantially equivalent to models already on the market and to demonstrate accuracy through a clinical validation study. The FDA recognizes ANSI/AAMI SP-9 (a voluntary standard) as a performance standard and both aneroid and mercury sphygmomanometers meet this standard. This Standard covers functionality, accuracy and safety, including requirements and suggested tests to verify compliance.

Many United States hospitals have eliminated mercury sphygmomanometers. Indeed, several hospitals in Maine are among those that eliminated the mercury devices, including: Eastern Maine Medical Center in Bangor, Maine General Health in Augusta, Mercy Hospital in Portland, Mid Coast Hospital in Brunswick, St. Andrew's Hospital in Boothbay Harbor, and Southern Maine Medical Center in Biddeford. Four of these hospitals interviewed in a recent survey reported that the alternatives perform satisfactorily. There are many more hospitals that have not completely eliminated mercury sphygmomanometers but have phase out programs underway. (EPA, HCWH)

Both mercury and aneroid sphygmomanometers require routine maintenance. Key issues for mercury gauges include: verify (and adjust if

necessary) the zero level of mercury, replace air filter, verify that column is perpendicular in its unit and vertical to the ground, check for oxidation of mercury (making column appear dirty and difficult to read) and clean tube if necessary. Key issues for maintenance of aneroid gauges include: check needle for smooth rotation, and test accuracy at several intervals against a reference meter.

In addition to managing the maintenance and calibration of the sphygmomanometers themselves, hospitals that use mercury gauges must also maintain the capability to safely handle mercury and respond to a mercury spill. Mercury spill capability includes personnel trained to respond to a spill on a 24-hour, 7 day per week basis, a mercury spill kit, hazardous waste resources for decontaminating a spill area and removing the mercury, and the financial resources for the spill response and liability associated with mercury exposure.

Increasingly hospital Group Purchasing Organizations (GPOs) are voluntarily supporting pollution prevention efforts. Premier, a healthcare alliance collectively owned by more than 200 independent hospitals and healthcare systems in the United States (representing more than 1,500 hospitals and healthcare sites) recently announced it will no longer allow products containing mercury to be offered through any group contract, unless no viable alternative exists. This means that mercury sphygmomanometers will no longer be offered. Consorta, Inc, (a cooperative health care resource management and GPO, whose shareholders are Catholic-sponsored, faith-based or non-profit health systems) also has an effort underway to obtain shareholder approval to take mercury containing medical devices off their contracts.

Conclusions from National Medical Associations on Sphygmomanometers

American Heart Association: "The aneroid manometer is also widely used and can provide accurate measurements if properly calibrated". (Perloff et al)
American Heart Association: "… because of the risk of the toxic effects of mercury spills, mercury manometers must be handled carefully and their use has been discouraged in some areas of high traffic where accidental spills are more prone to occur." (Perloff et al)
American Medical Association: "When in proper functioning condition, both mercury and aneroid sphygmomanometers are acceptable instruments for blood pressure measurement." (Bailey and Bauer)
American Medical Association: "Lest clinicians be lulled into a false sense of security about the accuracy of the mercury column manometer, frequent examination of the instrument is necessary to eliminate it as a source of blood pressure measurement error." (Bailey and Bauer)
Working Meeting on Blood Pressure Measurement: "There is no reason to fear replacing mercury manometers with manual aneroid devices. The issue is ensuring validation, calibration, and regular maintenance." (Summary Report: National High Blood Pressure Education Program, "Equipment Calibration" discussion by Dr. Bruce Morgenstern, April 19, 2002)

References and Supplemental Information

Richard H. Bailey and John H. Bauer, "A review of common errors in the indirect measurement of blood pressure sphygmomanometry", *Archives of Internal Medicine*, December 27, 1993
This document reviews three sources of error in indirect measurement of blood pressure (observer bias, equipment, and lack of measurement standardization) and the effect of these errors on accuracy. It also reviews techniques for proper for blood pressure measurement.

EPA Region 1 Mercury Challenge Program
http://www.epa.gov/region01/assistance/neeat/mercury/Directory2000.pdf (accessed 1/13/03)
http://www.epa.gov/region1/pr/2001/apr/010428.html (accessed 1/13/03)

These references highlight mercury reduction activities in the New England region under the EPA's Region 1 Mercury Challenge program. About a year ago, the Mercury Challenge program was merged with EPA nationwide efforts under the Hospitals for a Healthy Environment Program (H2E).

"Guidance for Industry: Non-Automated Sphygmomanometer (Blood Pressure Cuff) Guidance Version 1", November 19, 1998
http://www.fda.gov/cdrh/ode/blprcuff.pdf (accessed 1/13/03)
This is the FDA requirement for manufacturers to obtain approval to introduce new sphygmomanometers.

Health Care Without Harm (HCWH), "A New Era: The Elimination of Mercury Sphygmomanometers"
http://www.h2e-online.org/pubs/news/sphygmo.pdf (accessed 1/13/03)
This publication discusses elimination of mercury sphygmomanometers in hospitals. It includes a table of hospitals that had eliminated mercury sphygmomanometers as of January 2002.

Dorothee Perloff, Grim, Carlene; Flack, John; Frohlich, Edward D.; Hill, Martha; McDonald, Mary; Morgenstern, Bruce, "Special Report: Human Blood Pressure Determination by Sphygmomanometry" [AHA Medical/Scientific Statement]
American Heart Association, Volume 88(5), November 1993, pp 2460-2470
http://www.americanheart.org/presenter.jhtml?identifier=3000894 (accessed 1/13/03)
This is the American Heart Association's recommendation for indirect measurement of blood pressure. It is a useful resource that includes potential errors in measuring blood pressure and ways to correct or avoid them.

"The Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure", National Institutes of Health, National Heart, Lung, and Blood Institute, NIH Publication No. 98-4080, November 1997
http://www.nhlbi.nih.gov/guidelines/hypertension/jnc6.pdf (accessed 1/13/03)
This document provides guidance for primary care clinicians.

Summary Report: National High Blood Pressure Education Program (NHBPEP)/National Heart, lung, and Blood Institute (NHLBI) and American Heart Association (AHA) Working Meeting on Blood Pressure Measurement. National Institutes of Health, April 19, 2002
http://www.nhlbi.nih.gov/health/prof/heart/hbp/bpmeasu.htm (accessed 1/13/03)
This working group meeting examined the science supporting current blood pressure measurement policies and sought to identify additional research needed to develop policies to improve blood pressure measurement.

Welch Allyn DuraShock Sphygmomanometer
http://rcs.welchallyn.org/productpg.nsf/intro/durashock?opendocument (accessed 1/14/03)
This web reference is a link to product information on a gear free aneroid sphygmomanometer that is more shock resistant than traditional aneroid sphygmomanometers. (There is no implied endorsement of the product).