19NRM03 – SI-Hg

Metrology for traceable protocols for elemental and oxidized mercury concentrations

WP1: Development and Validation of a SI-traceable certification protocol for elemental mercury gas generators used in the field

Task 1.1 Development of a traceable certification protocol for elemental mercury gas generators.

The aim of this task is to develop a traceable certification protocol for elemental mercury gas generators used in the field traceable to SI.

Activity A1.1.1 – PSA, with input from VSL and Lumex will compile a list of performance characteristics (e.g., repeatability, reproducibility, accuracy, linearity, drift, bias and robustness) and uncertainty sources of 3 commercially available gas generators used in the field with different working principles (e.g., Bell Jars, gas generators)

Introduction

Accurate determinations of total gaseous mercury (TGM) in ambient air and emission sources are of prime importance to establish and understand the local, regional and global impacts of mercury. This information is essential to underpin global efforts to control and reduce the concentration of Hg in the environment, meet the obligations of legislation and to protect human health.

Analytical measurement systems that are employed to measure the concentrations of TGM are currently calibrated using several manual and automated approaches. In this task we provide an overview of the commercially available elemental Hg calibration systems that are used for ambient air and emission source measurements. The principle of each calibration approach will be explained with reference to the parameters which can influence the calibration uncertainty. Product specification documents will be reviewed and where applicable the performance characteristics and features will be presented.

As part of this review the performance characteristics such as repeatability, reproducibility, accuracy, linearity, drift, bias and robustness of the generator should be listed and complied. Unfortunately, these details are not readily available from the vendors of these devices. Data may exist during QA/QC product testing but very few independent studies have been published and, if they are available, they are not comparable. The performance data of the calibration system will also be defined by the measurement technology being used to evaluate and test the generator. In this review we have therefore provided a general description of each type of generator technology and highlighted the parameters which are known to influence the performance characteristics of each type of generator.

Bell Jar Calibration using saturated vapour of elemental Hg

The most common approach to calibrate mercury in ambient air analysers is via the bell jar method. This is achieved by employing a glass calibration vessel, open to the atmosphere via

a capillary tube, with a small amount of elemental mercury at the bottom, such that a mercury-saturated atmosphere is allowed to develop within the vessel. A known volume of mercury-saturated air may then be removed from the vessel through a septum, using a gas-tight syringe, and then used for calibration purposes. The mass of mercury within the volume removed is a function of the temperature of the air inside the calibration vessel, as measured by a thermometer inserted into the vessel. A diagrammatic representation of such a calibration vessel, often known as a 'bell-jar', is shown in Figure 1. Commercially available bell jar apparatus are widely available from the majority of vendors. Appendix A includes product specification documents from various mercury analyser manufacturers.

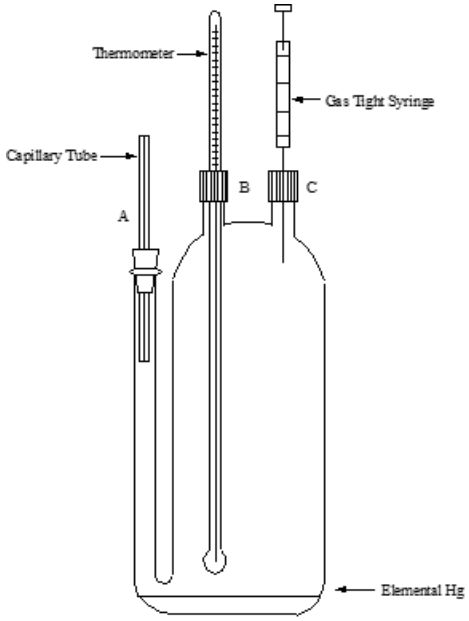

Figure 1 - Diagrammatic representation of a calibration vessel for generating mercury-saturated air, at known temperatures, often known as the 'bell-jar'. The micro-syringe removes mercury saturated air via a septum in the top of the vessel

The accuracy and uncertainty of this approach is dependent on numerous parameters. As this is a manual technique it is also largely influenced by the skill of the analyst and their attention to detail. Other factors include:

1. Mercury versus temperature equilibrium concentration. There are various expressions that can be used to define the concentration of elemental Hg vapour within the bell jar at different temperatures. The majority of mercury analyser vendors supplying this type of calibration equipment have adopted the so called "Dumarey Equation". The origins of this equation are summarised by Dumarey *et al*.[1] The equation is utilised in various ISO, CEN, EPA and ASTM international standards and the majority of technical peer reviewed publications. Other relationships based on the saturated vapour pressure of elemental Hg against temperature in a vacuum have been proposed, such as Huber *et al*.,[2] but not widely adopted as they are between 6 and 8 % higher than the Dumarey equation and are not complaint with international standards methods.

2. The accuracy and precision of the temperature measurement. Whatever expression is adopted the headspace concentration in the bell jar is defined by the temperature of the headspace in the bell jar so the accuracy of the temperature measurement has dramatic impact on uncertainty of the calibration. Some vendors have a temperature-controlled calibration vessel typically set to a few degrees below ambient temperature in the laboratory. A syringe volume correction should be applied when using a bell jar at lower than ambient temperatures[3]. Other vendors have a calibration vessel at room temperature. It is important to ensure that the temperature of the calibration vessel is cooler or at the same temperature as the Hg analyser to avoid condensation of elemental Hg inside the syringe. Temperature gradients within the vessel should be avoided and ideally the syringe needle tip should be at a similar location to the temperature measurement. An SI-traceable temperature measurement device should be used with the most accurate reading and resolution possible as ±0.1 °C can affect the concentration in bell jar by ± 0.83 % at 20 °C.
3. The accuracy and the precision of the syringe and its compatibility to elemental Hg vapour. Different sizes of syringe are typically used to cover a wide calibration range. The majority vendors offer gas tight syringes with and without digital readouts. The uncertainty increases as the low end of the syringe is used. Preconditioning of the internal surfaces of the syringe and needle is normally recommended as materials of construction may adsorb traces of elemental Hg vapour.
4. The amount of Hg in the headspace can be affected by the purity of the elemental Hg. Oxidation of the mercury surface can cause issues reducing the vaporisation of elemental Hg.
5. The bell jar approach is typically only used directly to the Hg analyser and does not include any sampling apparatus upstream. It is typically used for mercury analysers with amalgamation systems. When used on direct measurement systems the integration of the response must be carefully considered as it will depend on the speed of injection and carrier gas flow. During injection of the vapour the Hg is highly concentrated relative to the sample concentration. One could argue that the calibration does not truly represent how the analyser performs when analysing samples with a concentration approximately a million times lower than the calibration gas.
6. Equivalent mass calibration range also has to be considered when using the bell jar approach. For example, at a sample concentration of 1 ng/m³ (1 pg/L) and sampling volume of 10 L, the equivalent mass of mercury is only 10 pg. This would require a nominal syringe injection volume of less than 1 µl at a calibration vessel temperature of 20 °C. Injecting such small volumes is difficult in practice and therefore has a relatively large uncertainty. Cooling the vessel will allow larger syringe injections, however it is worth noting that the majority of ambient air monitoring systems operate close to the blank level and often below the bottom standard of the calibration line where the uncertainty is very high.

When developing a calibration uncertainty model is important to consider all the above parameters. Appendix A includes additional information in the form of product specification sheets for each vendor that can offer this type of calibration equipment.

Dynamic Calibration Systems Using Elemental Hg Permeation Tubes

There are several vendors that offer elemental Hg permeation tube calibration devices. They provide a low-level calibration gas suitable for the calibration of automated mercury analysers for ambient air applications The use permeation tube devices are a commonly used technique for producing gas standards for instrument calibration. Certification by the vendor or supplier is normally performed by establishing the gravimetric loss from the permeation tube over time, at a specified temperature which is accurately and precisely controlled. Suppliers claim that the permeation devices are capable of generating an SI- or NIST-traceable calibration gas that is stable for a long period of time provided that the compound within the permeation tube is still present and the conditions of use are carefully controlled. In the case of the elemental Hg, permeation tubes are commercially available from several vendors but these are typically do not have a certified permeation rate. This is because the gravimetric loss is typically in the low nanogram or picogram/minute range. To certify permeation tubes gravimetrically at these very low mass losses is very difficult and time consuming. Elemental Hg permeation tubes are normally certified in-house by Hg instrument vendors or by research groups by measuring their output against other types of primary calibration techniques. Another complication is that the apparatus supplied for permeation tubes is generically designed to operate with wide assortment of permeation tubes and they may not be suitable for Hg especially at low concentrations because the material of construction

There are several commercially calibration gas generators based on permeation tubes that have been specifically designed for elemental Hg at low ng/m^3 concentration ranges. These are summarised in Appendix A. Figure 2 presents a typical arrangement showing the principle of operation. Although the general operation concept is very simple a highly accurate and precise of temperature and flow control is required to maintain and achieve a stable output of known concentration.

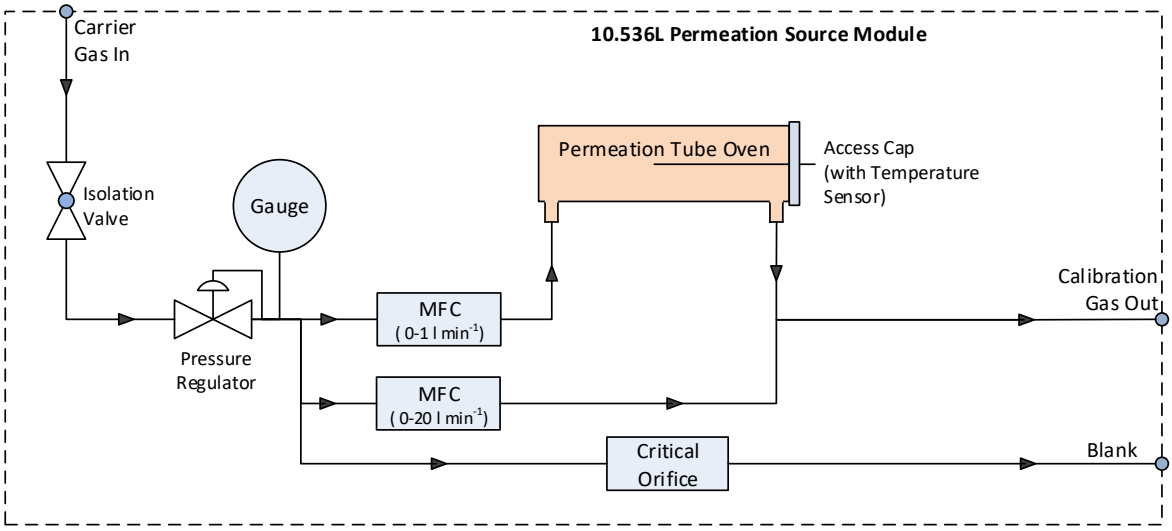

Figure 2 – Dynamic Vapour Generation using a Permeation Tube

The performance of this generator approach is dependent on numerous parameters. These are outlined below:

1. Permeation rates are highly dependent on the temperature and therefore an accurate and precise temperature control and readout is very important. Thermal gradients within the chamber, location of the temperature measurement and control and carrier gas temperatures must be carefully considered. It is normally necessary to have a preheated gas to avoid surface cooling of the permeation tube and to avoid any contact with the internal surfaces of the chamber which could be slightly hotter than the gas flow temperature. Equation 1 shows the dependence of the permeation tube output is reported by the main permeation tube manufacturer (VICI Metronics). This expression however is a generic expression and not necessarily true for elemental Hg. It is therefore necessary to study the effect of permeation rate against temperature to fully understand the uncertainty contribution of temperature. In general terms a temperature accuracy and control of less than ±0.1 °C and this is also dependent on the temperature setpoint. A temperature swing of this amount at a typical perm tube operating temperature of 50 °C is significant.

$$\log PR = \log PR_{cert} + 0.034(T - T_{cert}) \qquad \textit{Equation 1}$$

2. Accuracy of the certified or measured permeation rate. VICI Metronics do not current offer certified permeation rates for mercury permeation tubes. Previously, permeation rates with an uncertainty of 2 % could be obtained but due to the difficulties in customers duplicating the certified permeation rates they now supply uncertified permeation tubes. The use of gravimetry to establish the output of the permeation tube at low ng/min rates is too time consuming and difficult to implement. Certification is now obtained by measuring the concentration output from the generators and back-calculating the permeation rates. The uncertainty of the permeation rate is therefore defined by the combined uncertainty of the generator and the mercury measurement technology employed. In general terms the stability of Hg permeation tubes is very good with vendors reporting less than 2 % permeation rate variation on yearly certifications. Age and deterioration of the permeation tube may affect the permeation rate. Because of the relatively high flowrates required compressed air is often used for the generator. This can cause a gradual surface oxidation of the elemental Hg within the tube. Over long periods of time the Hg may become depleted changing the surface area of the diffusion window.
3. Generators using permeation tubes typically employ two gas flow which have to be accurate and precise. Most commercial generators use certified mass flow controllers which offer very stable, accurate and precise gas flowrates. A lower flow mass flow controller is used for the oven chamber typically around several hundred ml/min and less than 1 L/min. Lower flowrates are utilised to allow the gas flow to reach the chamber temperature. A secondary flow typically in range of 1-20 L/min is normally introduced to dilute the gas into the mercury concentration range of interest. The uncertainty of the gas flow is therefore a contribution from two flow devices. It is the total gas flow which defines the final concentration of the generator. The permeation rate is independent of gas flow and pressure.

4. Generator linearity is defined by the accuracy of the dilution gas and dynamic mixing. As Hg permeation rates are dramatically affected by temperature the chamber gas flow and temperature are normally fixed and different concentration outputs are achieved by adjusting the dilution gas. Field calibration typically uses a single fixed concentration and dilution gas flows are rarely changed. By collecting the calibration gas over different time periods and loading different masses of Hg onto the gold trap it is possible to get a linear calibration graph to cover a wide mass range. This is often deemed to be more accurate method of calibrating the analyser rather than a depending on the linearity of the dilution. The gas flows from the generator are at standardised conditions and if the output of the generator is restricted the absolute concentration may be affected. This should therefore be considered on a case by case basis.
5. To produce well defined and constant concentration from the generator it is essential to keep both the carrier gas flow and the flow of the trace mercury constant. Usually, it is supposed that for a given set of experimental conditions, temperature, material and size of permeation membrane the mercury flow only depends on the partial pressure drop across the membrane and is not affected from the pressure of the carrier gas. This however may not be case for permeation tubes constructed from non-rigid materials such as silicone rubber due to the possible deformation of diffusion walls. These changes are minor due to barometric pressure variation. The user has to consider vent and analyser back pressures.
6. The purity of the carrier gas and dilution gas may affect the output of the generator especially if compressed air is being used. Inline purification must be used to ensure that the zero gas and generator output is not affected by traces of elemental Hg in the carrier gas supply.

Dynamic Calibration Systems Using Elemental Hg saturation

Dynamic calibration gas generators are based on the continuous generation and dilution of saturated mercury vapour. These devices are commercially available and are widely used for automated calibration of online mercury analysers for workroom air and mercury continuous emission monitors (HgCEMs). To generate concentrations in appropriate ranges for these applications, oven temperatures housing the elemental Hg source are typically between 30 and 50 °C thereby producing generator outputs in the µg/m³ range. This is the most common form of commercially available elemental Hg generator.

A low gas flow (e.g., 1-20 ml/min range), controlled by a thermal mass flow-controller passes over a mercury reservoir located in a temperature-controlled oven, picking up a known (calculable) mass-flow of mercury. The mercury mass-flow is then diluted by a gas flow from a second thermal mass flow-controller operating in the 1-20 L/min range. Analyser calibration/verification is achieved by sub-sampling known volumes of the calibration gas stream. To adjust the concentration the reservoir flow or dilution flow is adjusted while the temperature of the reservoir is maintained. A schematic diagram of a dynamic mercury vapour generator is shown in Figure 3.

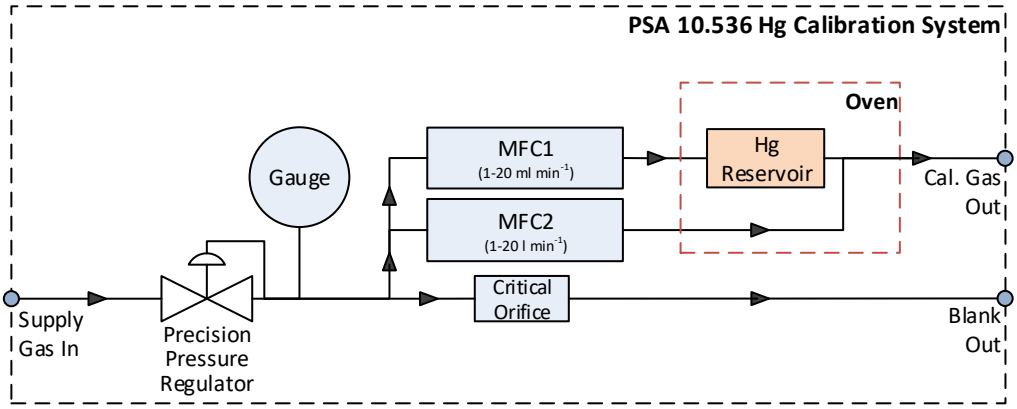

Figure 3 – Dynamic mercury vapour generator

The performance of this type of generator approach is dependent on numerous parameters. These are outlined below:

1. The theoretical output of the generator is dependent of mercury versus temperature equilibrium concentration equation used. The majority of mercury analyser vendors supplying this type of calibration equipment use the “Dumarey Equation”. Other elemental Hg vapour pressure against temperature expressions exist, e.g. Huber *et al.*[2] Some vendors calculate the mean Hg saturated vapour pressure from several expressions. The difference between Dumarey and Huber at 303.15 K (30 °C) is 6.13 % and at 323.15 K (50 °C) the agreement is a little closer at 4.19 %.
2. Accuracy and precision of the temperature measurement. A certified temperature measurement device should be used with the most accurate reading and resolution possible as ±0.1 °C can affect the concentration by ±0.83 % and ±0.71 % at 30 °C and 50 °C respectively. This variance is the combined effect of temperature in relation to Hg saturated vapour pressure and the temperature correction used for establishing the actual flow across the reservoir. As the temperature on the reservoir increases the output of the generator increases because the actual flow and the temperature equilibrium concentration increases.
3. Accuracy and precision of the pressure sensor. The actual flow of gas across the Hg reservoir defines the Hg that is transferred into the gas stream. The standardised flow from the mass flow controller therefore has to be corrected for the reservoir temperature and pressure operating conditions. Most commercial generators therefore include either an automatic correction for these parameters or software correction. The accuracy and precision of the pressure sensor has to be considered when calculating the uncertainty. A certified pressure measurement device should be used with the most accurate reading and resolution possible as ±3 mbar can affect the concentration in of the generator by ±0.32 %. As the pressure on the reservoir increases the output of the generator decreases as the actual flow is reduced.
4. Saturation against flow conditions. Dynamic calibrators based on this approach assume that the reservoir gas stream achieves 100 % saturation and that the Hg in the reservoir is of high purity and has not oxidised. Some commercial generators use

two temperature-controlled zones for the Hg reservoir. The first zone is run at a higher temperature than the second zone to ensure that the stream is fully saturated.

5. The purity of the dilution gas may affect the output of the generator especially if compressed air is being used. Inline purification must be used to ensure that the zero gas and generator output is not affected by traces of elemental Hg in the carrier gas supply.
6. Most commercial dynamic generators use certified mass flow controllers which offer very stable accurate and precise gas flowrates. A lower flow mass flow controller is used for the reservoir chamber typically 1-30 ml/min. The accuracy and precision of the mass flow controllers deteriorates rapidly below 10 % of full scale. A secondary flow typically in range of 1-30 L/min is normally introduced to dilute the gas into the mercury concentration range of interest. The uncertainty of the gas flow is therefore a contribution from two flow devices. The accuracy and precision of the mass flow controllers deteriorates below 10 % of full scale so it is important the setpoint of the flowrate.

For ambient air applications dynamic generators require sub-zero temperatures (e.g., -20 °C) for the mercury source and very low Hg reservoir flowrates (0.2 to 2.0 ml/min) to generate calibration gas in the low ng/m3 concentration range. There use for ambient air measurements is therefore considered to be for research activities only and these generators are not commercially available although prototypes exist.

References

1, Dumarey R., Brown R.J.C., Corns W.T., Brown, A.S., Stockwell P.B., Elemental mercury vapour in air: the origins and validation of the ‘Dumarey equation’ describing the mass concentration at saturation. Accred Qual Assur (2010) 15:409–414 DOI 10.1007/s00769-010-0645-1

2. Huber ML, Laesecke A, Friend DG (2006) Correlation for the vapor pressure of mercury. Ind Eng Chem Res 45:7351

3, Anderson, M.E., Gardfeldf, K., Wangberg, I Stromberg, D., Determination of Henry’s Law constant for Elemental Hg. Chemosphere 73 (2008), 587-592

Appendix A – Commercially Available Hg Calibration Systems: Summary and Example Product Specification Sheets

Supplier	Model	Type	*Output*	*application*	*Sample flow rate*	*Oven temperature*	*Precision*	*Accuracy*	*Carrier gas*	*Pressure*
Thermo Scientific	84i	Permeation source	Default: 5 µg/m³ Range: 2 - 15 µg/m³	Emission monitoring	Default: 600 cc/min Range: 500 - 750 cc/min	10 - 30 °C	0.04 µg/m³ daily	Comparison against vendor prime reference	Air or Nitrogen <20 °C dew point, Oil, Particulate and Hydrocarbon free per ISO 8573.1, <0.01 µg/m3 Hg	supply pressure 40-70 psig, Back pressure 0-4 psig
	Standard 81i	Saturation	1-50 µg/m³, ranges: 5, 10, 20, 30, 40, 50 µg/m³		Accuracy of each mass flow measurement +2% of reading or 1% of full scale, whichever is less - 20 to 100% full scale. Linearity of mass flow measurement 0.5% of full scale. Repeatability of mass flow measurement +2% of reading or 1% of full scale, whichever is less - 20 to 100% full scale. Zero Air Flow Controller 20 slm. Span Gas Flow Controller 5, 50, or 100 sccm. Linearity ±2 % full scale.	6°C	Not specified			
	High level 81iH	Saturation	4-300 µg/m3, ranges: 20, 30, 50, 300 µg/m³			8-18°C	Not specified			
Tekran	3310	Saturation	0.5 - 1900 µg/m³	Emission monitoring	Calibration gas delivery rate: 2 - 30 SLPM, Independent linearization tables for each MFC	Allowable ambient temp: +5 to +40 °C, Hg source control range: +5.00 to +50.00 °C	Accuracy 0.1 µg/m³ or ± 3%, repeatability 0.1 µg/m3 or ± 1 %. Long term stability (1 year) 0.2 µg/m3 or ± 2 %. Ambient temperature variation 0.2 µg/m3 or ± 2%.		Air or Nitrogen <20 °C dew point, Oil, Particulate and Hydrocarbon free per ISO 8573.1, <0.01 µg/m3 Hg	Supply pressure 50 - 120 psig, Back pressure 0 - 10 psig
	2505	Bell-jar	Dependent on syringe size and temperature of vessel	Ambient Air	Not applicable	The unit contains two precision sensors, one to measure the temperature of the isothermal block and one to monitor the temperature within the vapour chamber. Accuracy: ±0.05 °C Resolution: .001 °C Range: -5 - +50 °C	Not Specified - dependent on reproducibility of manual syringe injections	Not specified. Dependent on temperature and syringe volume accuracy	Not applicable	Not applicable
Mercury Instruments	AutoCal UT-3000	Bell-jar	Dependent on syringe size and temperature of vessel	natural gas systems	Not applicable	The temperature sensor within the mercury vessel has an accuracy of 0.01 °C.	Not Specified - dependent on reproducibility of manual syringe injections	Not specified. Dependent on temperature and syringe volume accuracy	Not applicable	Not applicable
	CalSet UT-3000	Bell-jar	Dependent on syringe size and temperature of vessel	Ambient	Not applicable	The temperature sensor within the mercury vessel has an accuracy of 0.01 °C.	Not Specified - dependent on reproducibility of manual syringe injections	Not specified. Dependent on temperature and syringe volume accuracy	Not applicable	Not applicable
	MC-3000		15 ... 500 µg/m³ Hg°	Emission Monitoring	Generated calibration gas flow 1 ... 9 l/min, Carrier gas flow max. 12,5 l/min, Flow controllers mass flow, electronic, 1% precision	Pt-100 with 1 / 10 °C accuracy	Not Specified	Not specified.	Air or Nitrogen <20 °C dew point, Oil, Particulate and Hydrocarbon free per ISO 8573.1, <0.01 µg/m3 Hg	1 ... 2 bar (8 ... 15 psi)
P S Analytical	10.532	Saturation	10, 20, 50, 80, 100 µg/m³	Emission and Workroom air Monitoring. Bench-scale Generator	Output flow rate: 20 L/min	30 - 60°C. Factory setpoint 40°C Resolution ±0.1°C	>2%RSD	Certified concentration within ±5% of the nominal value setpoint.	compressed air, Quality class 3.3.3 to ISO 8573-1, or Nitrogen	Input pressure max 5 bar g Max outlet pressure 6 psig
	10.534	Saturation	100 ng/m³ - 3000 µg/m³		MFC 1 - 0 - 20 ml/min, MFC 2 - 0 - 20 L/min	Ambient, 40-60°C Factory setpoint 40°C Resolution to ±0.1°C	>2%RSD	Measured concentration within 4% of the theoretical value based on the saturated vapour pressure calculations.		
	10.536L	Permeation source	3-60 ng/m³	Ambient Air	MFC 1 - 0 - 1/min, MFC 2 - 0 - 20 L/min	Ambient, 35-60°C	>2%RSD	Certified concentration within ±5% of the nominal value setpoint.		
	10.536	Saturation	100 ng/m³ - 3000 µg/m³	Emission and Workroom air Monitoring. Bench-scale Generator	MFC 1 - 0 - 20 ml/min, MFC 2 - 0 - 20 L/min	Ambient, 35-60°C	>2%RSD	Measured concentration within 4% of the theoretical value based on the saturated vapour pressure calculations.		
	10.536H	Saturation	13 µg/m³ - 13 mg/m³		MFC 1 - 0 - 30 ml/min, MFC 2 - 0 - 20 L/min	Ambient, 35-100°C	>2%RSD	Measured concentration within 4% of the theoretical value based on the saturated vapour pressure calculations.		

	10.555	Bell-jar	Dependent on temperature and syringe volume	Ambient Air	Not Applicable	Thermometer: -1/+51ºC x 0.1 Grads (UKAS certificate)	Not Specified - dependent on reproducibility of manual syringe injections	Not specified. Dependent on temperature and syringe volume accuracy	Not applicable	Not applicable

PSA 10.555 Calibration Kit

Product Specification

The PSA 10.555 Calibration Kit is used for the calibration of the PSA 10.525 Sir Galahad. The System includes a calibration vessel, thermometer (mercury free), and a set of gas tight syringes. Hg vapour is drawn from the vessel and injected into the PSA Sir Galahad system. The user then tells the software the temperature and volume of Hg vapour injected and the software will then calculates the Hg vapour injected based on the vapour pressure of the Hg.

The PSA 10.555 Calibration Kit is comprised of the following items:

Qty	Part No.	Description
1	G523V002	Calibration Vessel (assembled)
2	G525F044	Carbon Filter
2	Z301O007	Union Fitting
1	Z360S524	50µl Syringe
1	Z360S531	250µl Syringe
1	Z360S533	1ml Syringe
1	Z360S535	5ml Syringe
1	Z550T002	Thermometer: -1/+51°C x 0.1 Grads (UKAS certificate)
1 pk	Z36N052	Sideport Needles (3 per pack)
1 pk	Z012S001	Septa: Silicone/PTFE 0.075in. x 12mm (100 per pack)

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Model 2505 Mercury Vapor Primary Calibration Unit

Ver. 090415

- Suitable for field or laboratory use
- Thermoelectric temperature controller no water bath required
- Operates from 12 VDC or line power
- Precision temperature measurement with digital display. Resolution: 0.001 °C
- Built in serial port allows logging of injections, temperatures and other instrument parameters.
- Hamilton® Digital Syringe™ may be used to provide accurate, NIST traceable injection volumes
- Microprocessor automatically calculates amount of mercury injected based on either measured or user entered temperature

The *Tekran*® Model 2505 is a portable mercury vapor injection source for use in applications where a precisely known amount of mercury must be delivered for calibration or quality control evaluation of analytical systems. The unit is based on the well-known principle of Hg vapor pressure as a function of temperature. If the temperature and volume of an injection are known, the amount of mercury delivered can be determined with high accuracy. For this reason, vapor phase injection has become the de facto standard method of system calibration for ultra-trace mercury analytical systems.

When powered externally (either by the line adaptor or a 12 VDC source), chamber cooling is active. An internal battery pack provides sufficient power to run the unit in Low Power mode for up to 12 hours. In this mode, the cooler is deactivated and the system operates as a conventional source. The high accuracy temperature display and all other functions remain available. The vapor pressure of mercury is a sensitive function of temperature, the increase in concentration being in excess of 8% per degree Celsius. The Model 2505 incorporates a second temperature sensor located within the chamber for precise mercury vapor determination.

This unit greatly simplifies the process of calibration via injection. It provides precise control of the reservoir temperature using a thermoelectric cooler. This eliminates condensation within the syringe, resulting in highly reproducible injections. A built in RS-232 serial port provides continuous logging of temperatures, a record of each injection, and a listing of all instrument set points. The Model 2505 is an ideal primary standard for the Tekran Model 2537 Mercury Vapor Analyser or any other application requiring vapor phase calibration.

Note:The 2505 is shipped without Hg to prevent contamination during shipping. The unit must be loaded with Hg by the customer prior to use!

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lab-air-info@tekran.com Tel:+1-416-449-3084 Fax: +1-416-449-9298
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Microprocessor Internal microprocessor with LCD and direct access keypad allows easy activation of all functions. Some of the functions available are:

- Measurement and display of mercury chamber temperature
- Temperature control of the cold block containing the chamber
- Input of injection volume. Volume may be input manually via the keypad or read directly from suitably equipped Hamilton® digital syringes[1] *(On syringes equipped with serial interface only)*
- Automatic calculation of injection amount
- Internal battery charging and power management
- Logging of temperatures, injections and internal parameters to RS-232 serial port

Temperature Sensors The unit contains two precision sensors, one to measure the temperature of the isothermal block and one to monitor the temperature within the vapor chamber.
Accuracy: ±0.05 °C Resolution: .001 °C Range: -5 - +50 °C

Temperature Control Aluminium block insulated and cooled via thermoelectric cooling module. This eliminates problems associated with constant temperature baths, resulting in a rugged, *transportable* unit. For low power applications, the cooler may be turned off. In this case the unit will function as a conventional insulated flask calibration unit. The controller characteristics are as follows:

- Range: 0 – 30 °C (Setpoint must be below ambient)
- Accuracy: ±0.05 °C (Maximum differential from ambient is 15 °C)
- Stability: ±0.01 °C

Mercury Chamber The Teflon® mercury container is entirely enclosed within the isothermal aluminium block. A standard 3/8" (10 mm) Teflon® backed silicone septum is used.

Physical & Electrical Rugged self-contained case, with cover and carrying handle. Suitable for lab or field use.

- Weight: 4.5 kg. (Dimensions: 14 x 10 x 8½ in. {36 x 26 x 22 cm})
- Power: 2.2 Amp Max. (12 VDC)

Syringes Conventional Hamilton 1700 Series gas tight syringes are also available from Tekran. Unit can be used with other suitable syringes.

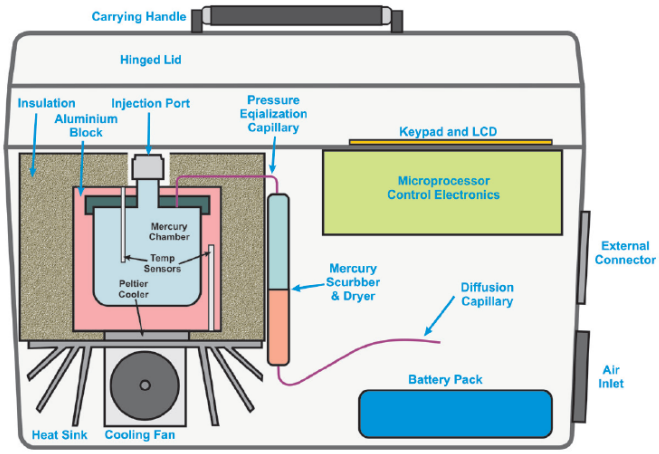
Accessories Included

- Universal Power Supply
- Automotive Adaptor Cable
- 100-240 VAC, 50-60 Hz.
- Septa Replacement Tool
- Replacement Septa (Pkg of 20)

Options

Hamilton® 1700 series gas tight syringes may be ordered as options for the Model 2505. All syringes supplied by Tekran come equipped with special 2¾" long, side port removable needles. Specify the Option order number for syringes required from the table below.

Capacity (µL)	Conventional Syringe	Digital Syringe
10	701	901
25 (Most Popular)	702	902
50	705	905
100	710	910
250	725	925
500	750	950

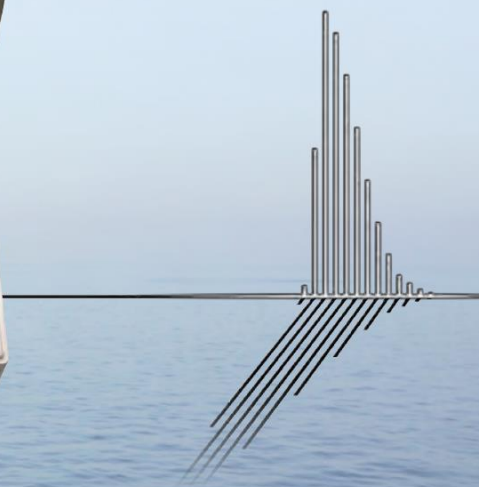


Due to continuing development, all specifications are subject to change.

Mercury Calibration Unit CalSet

AMBIENT

for manually calibrating the UT-3000 Mercury Ultratracer



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Manual Calibration

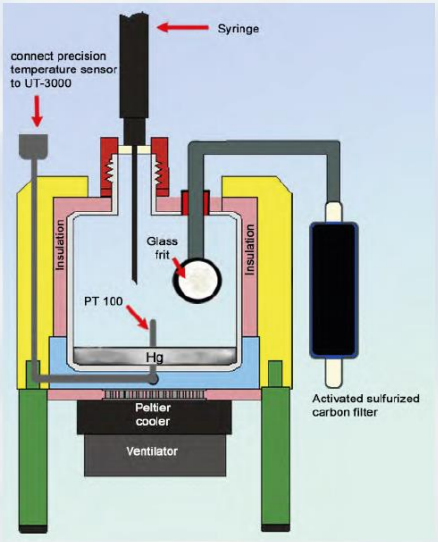
The calibration unit is connected to the UT-3000 Ultratracer. With a special syringe a defined volume of mercury containing gas is drawn from the calibrator and injected into the calibration port of the UT-3000. After entering the volume of the injected gas, the UT-3000 will automatically calculate the mercury mass from the volume injected and the calibration cell temperature.

Operating Principle

The Manual Calibration Unit by ENVEA GmbH consists of a specially designed mercury vessel containing elemental mercury of high purity, surrounded by an aluminium jacket cooled by a thermoelectric cooler.

The temperature of the mercury vessel is exactly measured with a high precision sensor (Pt 100). The electronic temperature sensor has to be connected to the UT-3000 ULTRATRACER using the cable delivered with the system.

The temperature of the calibration gas and the concentration of mercury are displayed on the UT-3000 screen before a calibration is performed.



Technical Specifications CalSet

Purity of contained Hg	99.999999%
Accuracy of T-Sensor	0.01 °C
Power supply	230 VAC / 50 Hz 110 VAC / 60 Hz
Power consumption	30 VA
Dimensions	35 x 20 x 25 cm (W x H x D)
Weight	ca. 4.5 kg

As a leading supplier of high precision analytical equipment,we strive at all times to offer top quality solutions. Our quality management system is certified according to ISO 9001.

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Automatic Calibration Unit AutoCal

CALIBRATORS

for automatic calibration of the Mercury Ultratracer UT-3000

Application

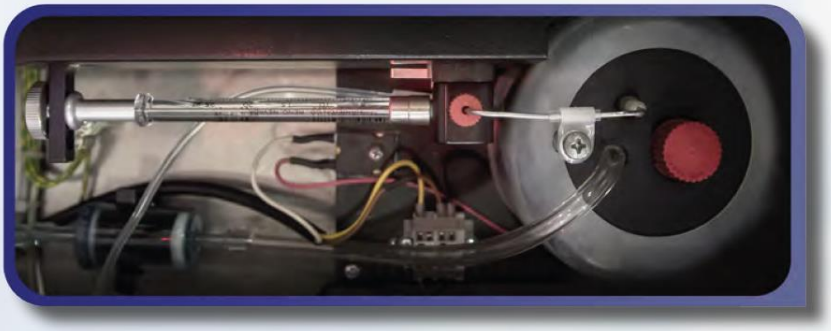
The static Automatic Calibration Unit by ENVEA GmbH is used for calibrating the UT-3000 Mercury Ultratracer in natural gas monitoring systems of low to intermediate mercury concentrations.

Operating Principle

The Mercury Instruments Automatic Calibration Unit consists of a specially designed mercury vessel containing elemental mercury of high purity, surrounded by an aluminium jacket cooled by a thermo-electric cooler. For automatic calibration a motor driven syringe extracts a defined volume of mercury saturated gas and ifeeds it to the UT-3000 Ultratracer.

The UT's microprocessor calculates the mercury concentration from temperature and volume of the calibration gas.

The temperature sensor within the mercury vessel has an accuracy of 0.01 °C.



Technical Specifications MC-3000

Purity of contained Hg	99.999999%
Accuracy of T-Sensor	0.01 °C
Power supply	230 VAC / 50 Hz 110 VAC / 60 Hz
Power consumption	250 VA
Dimensions	45 x 15 x 35 cm (W x H x D)
Weight	approx. 6 kg

ISO 9001

As a leading supplier of high precision analytical equipment, we strive at all times to offer top quality solutions. Our products are manufactured according to the ISO 9001 quality regulations.

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PSA 10.536 Mercury Vapour Generator – RS485

Product Specification

Description

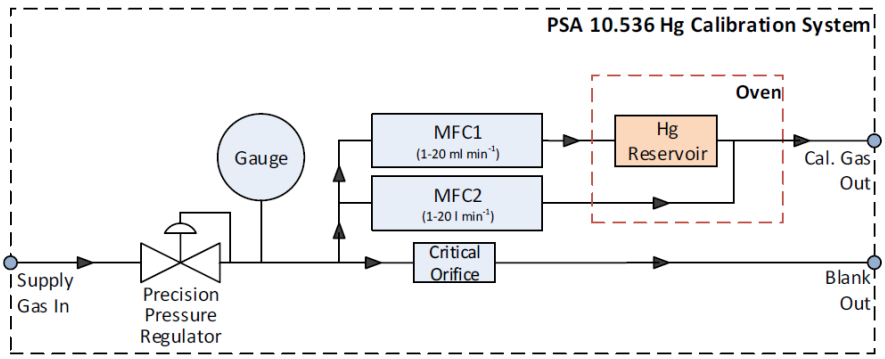
The PSA 10.536 Mercury Vapour Generator is a calibration device for mercury analysers. The system operates by generating a low flow rate of mercury-saturated carrier gas by passing this flow through an encapsulated mercury reservoir at known temperature and diluting the mercury-laden stream into a concentration range of interest with a with a second carrier gas stream. The gas flow rates are controlled by SI traceable precision thermal mass flow controllers (MFCs). The unit also provides a zero gas stream for blank measurements. The system is equipped with MODBUS RTU communications and contact closure alarm outputs to operate with PSA's range of online and offline mercury in gas analyser systems. Control and settings/concentration calculations are supported by PSA OnLine, PSA SGv3 and standalone vapour generator control software.

The calibration gas output has been verified by national measurement institutes including the National Institute of Standards and Technology (NIST), National Physical Laboratory (NPL) and VSL.

The PSA 10.536 Mercury Vapour Generator can provide calibration gas in the 0.6 to 3000 µg Sm^{-3} range and flow rates of up to 20 sL min^{-1}.** Models with higher flow rates and both higher and lower concentration ranges are also available.

** Available flow rate range depends on the concentration required.

Mercury Vapour Generator Schematic



www.psanalytical.com

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Control Specifications

	Range	Measurement Accuracy	Control
Reservoir MFC	1 to 20 sml min^{-1}	± 0.07 to ± 0.12 sml min^{-1}	Modbus RTU
Dilution MFC	1 to 20 sl min^{-1}	± 0.07 to ± 0.12 sl min^{-1}	Modbus RTU
Oven Temperature	Ambient, 35–60 °C	0.05 °C	Modbus RTU

Generator Output

The Modbus control allows the user to easily specify the Hg concentration and the software (PSA OnLine, SGv3 or CavKitCalc) calculates the required flows. Automatic concentration variation to support multi-point calibration is available. Output concentration stabilisation time on changing reservoir flow rates is less than one minute.

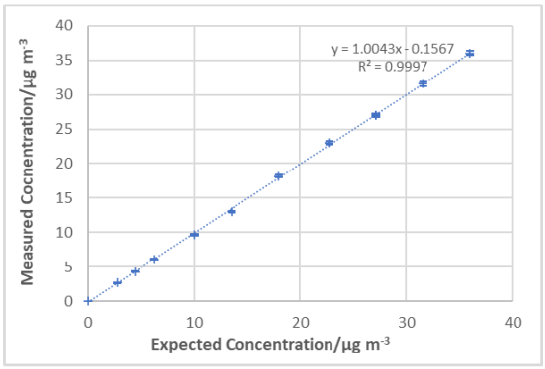
A wide range of output concentrations are provided by varying the MFC and temperature set-points. The unit can be used for numerous applications including calibration of on- and offline mercury analysers, sampling system bias checks, spiking sample streams and for bench studies where precise concentrations of mercury are required.

The estimated relative expanded uncertainty (U_c, k = 2) is 8 % at 10 – 100 µg sm^{-3}.

Calibration gas generator output has been independently verified. Data from NIST using isotope dilution-cold vapour-inductively coupled plasma-mass spectrometry (ID-CV-ICP-MS) is shown below.

Verification of output concentration (NIST ID-CV-ICP-MS)

Reservoir flow /ml min^{-1}	Diluent flow /l min^{-1}	Expected Concentration /µg m^{-3})	Measured Concentration ± Uc /µg m^{-3}	Recovery (%)
1.30	14.00	2.74	2.72 ± 0.03	99.2
2.10	10.40	4.42	4.29 ± 0.04	96.9
2.20	10.00	6.24	6.08 ± 0.06	97.5
3.40	10.00	10.03	9.66 ± 0.09	96.3
4.60	10.00	13.57	13.03 ± 0.12	96.0
6.10	10.00	18.00	18.17 ± 0.17	101.0
7.71	10.00	22.75	23.04 ± 0.22	101.3
9.20	10.00	27.14	26.94 ± 0.26	99.2
10.71	10.00	31.60	31.57 ± 0.30	99.9
12.21	10.00	36.02	36.04 ± 0.34	100.0



General Specifications

Dimensions	30 × 57 × 42 cm (HWD)	
Weight	13 kg	
Carrier gas	Instrument air or nitrogen (as standard)	
Input pressure	2 – 4 bar (gauge)	
Voltage	100 – 240 V AC 50 – 60 Hz	
Power	40 VA	
Input/Output	RS485/Modbus RTU	Flow rates, Temperature
Alarm Outputs	Contact closure	Pressure, Temperature

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thermoscientific

PRODUCT SPECIFICATIONS

Model 81*i* Mercury Calibrators

Standard, high level and low level precision source of mercury for automated calibrations and checks

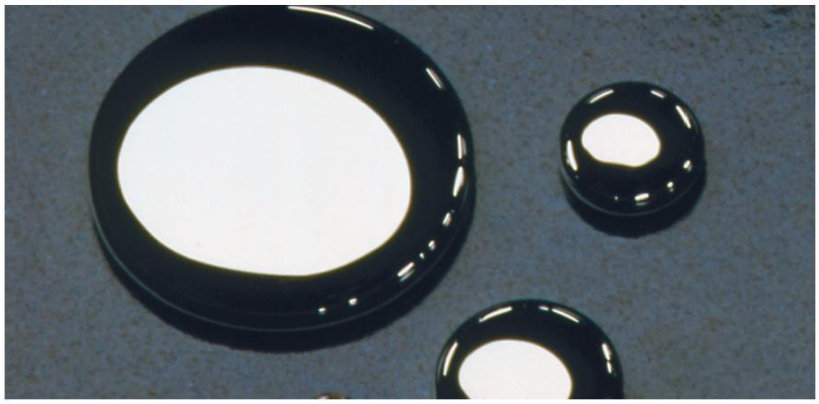
The Thermo Scientific™ Model 81*i* Mercury Calibrator is one of the four major components of the Thermo Scientific™ Mercury Freedom™ System. We also offer high and low mercury ranges with the Thermo Scientific™ High Level Model 81*i*-H and Low Level Model 81*i*-L Mercury Calibrators.

Features

- Choose from three calibrators to meet unique regulatory needs
- NIST-Traceable
- Capable of performing diagnostic calibrations directly to analyzer and probe
- Ideal for periodic linearity testing
- Perform converter efficiency testing in conjunction with the
- Oxidized Mercury Generator

Introduction

The Thermo Scientific Model 81i calibrators utilize a vapor generator that allows standard calibration and calibration through the extraction probe. Available calibration ranges let the user directly calibrate the analyzer at post-dilution concentrations. The calibrators are ideal for daily zero/span checks and routine converter efficiency and linearity testing.



The Mercury Freedom System provides a complete mercury monitoring solution that reports elemental, ionic, and total mercury in exhaust stacks from coal-fired boilers, cement kilns, fossil fuel-burning souces and waste incinerators. The Model 81*i* calibrators are designed to integrate into the Mercury Freedom System to meet the provisions of the U.S. Environmental Protection Agency's (EPA) Utility Mercury and Air Toxics Standards (MATS), as well as the Maximum Achievable Control Technology (MACT) for mercury monitoring.

Thermo Scientific™ 81*i* Mercury Calibrator

The Model 81*i* calibrators also offer benefits of the iSeries platform, which includes flexible communications, ease of service, and a simplified interface. Ethernet connectivity provides effi cient remote access, allowing the user to download important data from the instrument without having to be on site. Captive hardware and slide-apart modules allow easy access for service and periodic maintenance.

Short-cut keys can be easily programmed to allow you to jump directly to frequently accessed functions, menus or screens. The large interface screen can display up to five lines of measurement information while the primary reporting screen remains visible.

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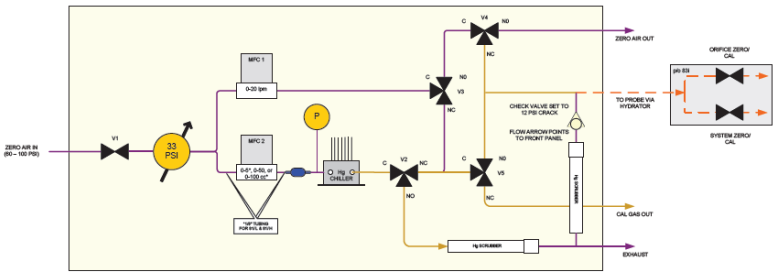
Thermo Scientific Model 81*i* Mercury Calibrators

Model Specific	Standard 81*i*	High Level 81*i*-H	Low Level 81*i*-L
Ranges	5, 10, 20, 30, 40, 50 µg/m³	20, 30, 50, 300 µg/m³	1, 2, 5, 10, 20 µg/m³
Hg Output	1-50 µg/m³	4-300 µg/m³	0.2-20 µg/m³
Hg Source control	6°C	8-18°C	10°C
Gas Dilution			
Accuracy of each mass flow measurement	+2% of reading or 1% of full scale, whichever is less - 20 to 100% full scale		
Linearity of mass flow measurement	0.5% of full scale		
Lower detectable limit	1 ng/m³ (60 second average)		
Repeatability of mass flow measurement	+2% of reading or 1% of full scale, whichever is less - 20 to 100% full scale		
Mass Flow Controller			
Zero air flow controller	20 slm		
Span gas flow controller	5, 50, or 100 sccm		
Linearity	±2 % full scale		
Operating temperature	68°to 86°F (20°to 30°C)		
Power requirements	250 Watts		
Size and weight	16.75" (W) × 8.62" (H) × 23" (D), 49 lbs. 425 mm (W) × 219 mm (H) × 584 mm (D), 21.8 kg		
Outputs	Selectable Voltage, RS232/RS485, TCP/IP, 10 status relays, and power fail Indication. 0-20 or 4-20 mA isolated current output		
Inputs	16 Digital Inputs, 8 0-10vdc analog inputs		

Flow Diagram: Model 81*i* Mercury Calibrator



VALVE STATUS PER GAS MODE

To maintain optimal product performance, you need immediate access to experts worldwide, as well as priority status when your air quality equipment needs repair or replacement. We offer comprehensive, flexible support solutions for all phases of the product life cycle. Through predictable, fixed-cost pricing, our services help protect the return on investment and total cost of ownership of your Thermo Scientific products.

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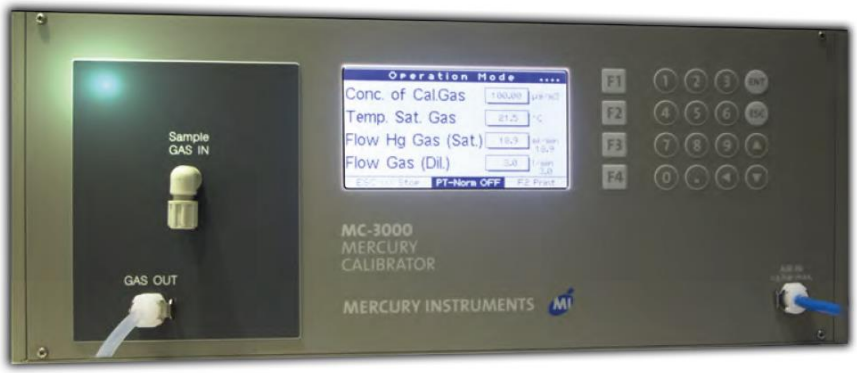
Mercury Calibrator MC-3000

AMBIENT

Generates elemental mercury vapor



- 15 ... 500 µg/m³ Hg° concentration range
- Microprocessor controlled
- Compact sized and portable
- Based on mercury vapor saturation of air
- Vapor pressure calculation according to NIST recommendation

Applications

The MC-3000 is used for generating a continuous stream of mercury vapor loaded gas in order to check or calibrate mercury analyzers. It is also suitable for all applications requiring a flow of preset and constant mercury concentrations.

Principle of operation

A carrier gas stream (air) is first charged with mercury vapor. The mercury loaded gas is then saturated by cooling. Excess mercury is condensing in a special cell thus achieving equilibrium.

After having been saturated with mercury the gas is diluted to get lower mercury concentrations as needed for calibration of instruments. The dilution ratio is continuously controlled by a microprocessor in order to obtain a flow of calibration gas with a constant mercury concentration.

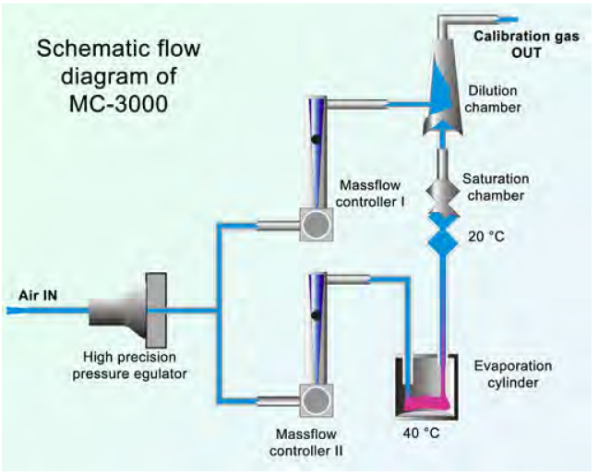
Construction

Keypad and display are mounted on the front panel for easy access. Two carrying handles at the sides of the aluminum case guarantee easy transport.

The mercury containers are firmly mounted inside. There is enough mercury in the MC-3000 to last for the lifetime of the instrument.

Operation

Using the MC-3000 is easy:
The device is placed on a flat surface and connected to instrument air. A portable air compressor with a tank is available as an accessory. The MC-3000 is switched on and the desired calibration gas concentrationis set. The total calibration gas flow can also be set. After allowing the instrument to stabilize for about 30 minutes the MC-3000 delivers a constant flow of calibration gas with exactly the concentration of elemental mercury that has been set before.



Technical Specifications MC-3000

Concentrations created	approx. 15 ... 500 µg / m³ Hg°; others optional
Generated calibration gas flow	1 ... 9 l / min
Carrier gas	air
Carrier gas flow	max. 12,5 l / min
Carrier gas pressure	1 ... 2 bar (8 ... 15 psi)
Particulate filter	built-in, 0.2 µm
Mercury absorption filter	sulphur doted activated carbon
Temperature sensors	Pt-100 with 1 / 10 ° accuracy
Flow controllers	mass flow, electronic, 1% precision
Connectors	for tubing 4 mm i.d. / 6 mm o.d.
Power supply	230 VAC / 50 Hz 110 VAC / 60 Hz
Power consumption	max. 125 VA
Dimensions	45 x 15 x 35 cm (W x H x D)
Weight	approx. 7 kg
Accessories	Air compressor

TEKRAN Instruments Corporation a TSI company

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Model 3310 – Elemental Mercury Calibration Unit

Rev. 041814

The ***Tekran***® **Model 3310 Elemental Mercury Calibrator** allows high level mercury monitoring systems to be accurately calibrated using elemental mercury. It integrates seamlessly with the ***Tekran***® **Series 3300** speciating CEM, however it can also be used as a ***stand-alone*** mercury calibration system. The calibration source allows both multi-point calibrations and standard additions to be automatically initiated. The unit generates concentrations of mercury by using a NIST traceable temperature controlled saturated mercury vapor source. Precision mass flow controllers are used to dilute the output of this source to the desired value. The unit is capable of continuously generating large flow rates of calibration gas at virtually no ongoing cost - unlike expensive mercury calibration gas cylinders.

The **Model 3310** incorporates technology originally developed for the **Model 2505 Manual Calibration Unit.** Unlike other saturated sources, the **Model 3310** contains a host of advanced features that provide superior accuracy and allow unattended, remote operation.

Product Highlights

- Output concentration range: 0.5 - 1900 ug/m^3 *
- Calibration gas delivery rate: 2 - 30 SLPM *
- Mercury source will last for many years
- Allowable ambient temp: +5 to +40 °C
- Hg source control range: +5.00 to +50.00[1] °C
- Independent linearization tables for each MFC

Applications

- Coal fired power plants
- Waste incinerators
- Other industrial sources
- Speciation studies
- Bench scale testing
- Mercury removal process monitoring

* Standard Unit. Other working ranges are available. Not all output flow/concentration combinations are available simultaneously. Contact Tekran for details.

[1] Other temperature ranges available.

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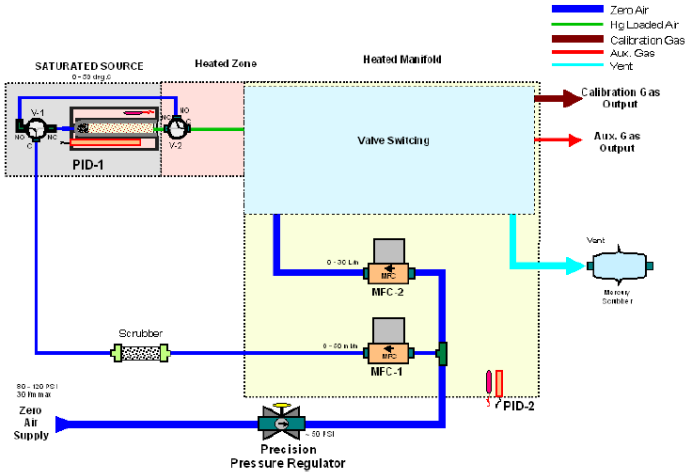
Principles of Operation

A Peltier heater/cooler maintains a precise temperature for the mercury reservoir. A mass flow controller (**MFC-1**) provides a precise and accurate carrier flow through the mercury chamber. The emerging air is saturated with elemental mercury vapor. This saturated flow is diluted with **MFC-2**. Solenoid valves serve to positively isolate the source when mercury is not required and to select between two available outputs. Backpressure regulators provide positive pressure relief in case either output is activated while blocked. The MFC's are heated to minimize thermal drift. Additional heated zones and safety interlocks ensure that the source is activated only when all temperatures are stable.



Product Features

- Two output ports:
  - Main calibration gas output
  - Auxiliary output for special applications
- High Output rate: up to 30 SLPM
- Heated/cooled saturated mercury source
- Ultra-precise source control
  - Repeatability: ±0.02°C
  - Accuracy: ±0.05°C
  - Range: +5.00 - +50.00[1] °C
- Automatic purging of system lines after high value calibrations are complete or if error is detected during operation
- Precision pressure sensor allows constant output concentration despite back pressure variations
- MFC's are temperature controlled to minimize thermal drift
- MFC's are individually calibrated to minimize errors at low flow settings
  - Multi-point calibration tables
  - Linear interpolation between calibration points
- Solenoid valves provide the following functions:
  - Isolation of Hg source until safe to activate
  - Selection between main and auxiliary outputs
  - Venting of source during stabilization period
- Remote control option (***Option 100***)
  - Allows operation with any CEM or control system
  - Six contact closure ***Status*** outputs
  - Six contact closure ***Control*** inputs

Remote Control

All ***Calibrators*** can be used as an integrated part of the ***Series 3300 CEM***. When ***Option 100*** is ordered, the unit can also be used in stand-alone mode (without the CEM). ***Option 100*** provides a set of six rear panel status outputs and six control inputs and a special version of the PC control s/w. In either case, communications with the module is via industry standard RS-485 Modbus-RTU protocol. (A USB to RS-485 converter is supplied with each system.) For stand alone applications, a Windows™ based program provides direct communication & control of the module and provides the calibration unit with a wealth of capabilities.

- Readout and logging of all current temperatures, pressures and flows
- Setting of all temperatures and MFC set points
- Calculation, display and logging of current ***output concentration*** (at any desired reference conditions)
- Initiation of immediate calibration operation
- Initiation of automatic scheduled or "on demand" multi-step calibration sequences
- Periodic temperature sensor and MFC recalibrations

- Control via computer GUI, electrical contact closures or dde link from other PC applications (e.g. ***Excel***)
  - Output log files are available in standard CSV format.
  - Optional: Calibrator PC can act as an ***OPC server*** for use with SCADA systems
  - Optional: Calibrator PC can act as ***Modbus*** or ***Modbus/TCP-IP slave***.

ENVIRONMENTAL MONITORING SYSTEM

Product Specifications

Thermo Scientific Model 84i Mercury Permeation Source

Permeation source designed for the Mercury Freedom System

Thermo Scientific™ Permeation Source is the only permeation oven that fully integrates with the Thermo Scientific™ Mercury Freedom™ system to meet interim protocol QC and U.S. EPA regulatory requirements for Mercury Monitoring.

- Integrates into the Mercury Freedom System with up to two co-located systems
- Automated and manual trigger audits available
- Supports U.S. EPA Utility MATS and Cement MACT regulatory requirment
- Approved method for meeting interim protocol QC requirements

Thermo Scientific Model 84i Mercury Permeation Source

Proven Platform

The Model 84i source complements the Mercury Freedom System by periodically assessing and qualifying the constancy of the mercury concentration output from the Model 81i Mercury Calibrator. The Model 80i Mercury Analyzer is used to control the functions of the Model 84i source, including data capture and DAS interface. An option in the Model 80i software has been added to allow the user to access and manage the Model 84i source.

The Model 84i source can support up to two co-located* Mercury Freedom Systems. The dual built in output ports switch between the co-located system or can alter the flow to (700sccm) to flood the two Model 80i analyzers simultaneously. The Model 84i source is designed to install into the existing system rack or can be used as a standalone bench top mercury source.

Regulatory Support

The Model 84i source uses a process by which a specific and consistent concentration of Mercury is generated from a permeation assembly.

The permeation tube generates a known and reliable concentration of mercury at a constant temperature and flow. The generated mercury concentration, as measured by the 80i analyzer, will be used to confirm the reliability of the 81i calibrator output in accordance with U.S. EPA requirements.

In compliance with the “Interim EPA Traceability Protocol for Qualification and Certification of Elemental Mercury Gas Generators”, periodic quality assessments of Mercury Gas Generators are required following initial certification of an elemental Hg Generator. QC audits performed by the Model 84i source can be triggered automatically through preprogrammed intervals at the desired frequency of the user. A manual QC audit can be triggered as needed to meet specific requirements, in turn acting as a troubleshooting tool or to access additional audit data quickly and

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Thermo Scientific Model 84i Mercury Permeation Source

Product Specifications

Hg Output	Default: 5 µg/m³ Range: 2 - 15 µg/m³
Sample Flow Rate	Default: 600 cc/min Range: 500 - 750 cc/min
Operating Temperature	10–30 °C
Power requirements	105–240 VAC @ 50/60 Hz, ~4 amp service
Physical dimensions	16.75" (W) X 5.25" (H) X 17" (D), 19" rack mountable, 3U
Weight	20 lbs (9 Kg)
Serial Ports	RS-485 with dual connectors (DB-15F)
Precison	0.04 ug/m³ daily
Accuracy	Comparison against vendor prime reference
Carrier Gas	Common input wtih Model 81i analyzer Air or Nitrogen <20 °C dew point Oil, Particulate and Hydrocarbon free per ISO 8573.1 <0.01 µg/m³ Hg
Supply Pressure	40-70 PSIG
Back Pressure	0-4 PSIG

The Thermo Scientific Model 84i Mercury Permeation Source is designed to install into the existing system 19" rack using standard brackets or can be used as a standalone bench top

Ordering Information

The Thermo Scientific Model 84i Mercury Permeation Source is a key component of the Thermo Scientific Mercury Freedom System. The system may require custom configuration based on your application. Please contact your local Thermo Fisher Scientific sales representative and we will work with you to complete an application datasheet that will accurately determine the best configuration for your plant process.

To maintain optimal product performance, you need immediate access to experts worldwide, as well as priority status when your air quality equipment needs repair or replacement. We offer comprehensive, flexible support solutions for all phases of the product life cycle. Through predictable, fixed-cost pricing, our services help protect the return on investment and total cost of ownership of your Thermo Scientific air quality products.

*Co-located refers to two Thermo Scientific Mercury Freedom systems or Model 80i analyzers located in the same shelter.

For more information, visit our website at thermoscientific.com/mercury

This product is manufactured in a plant whose quality management system is ISO 9001 certified.

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PSA 10.536L Mercury Vapour Generator – RS485

Product Specification

The Low Level Mercury Vapour Calibration system is a device used for calibrating mercury analysers, performing system bias and drift checks and spiking gases at known concentrations of mercury. It works on the principle of diluting the known output of a mercury permeation tube. The system uses two mass flow controllers to deliver accurate flow rates. A mercury permeation tube with a known permeation rate is maintained at a constant temperature using an oven arrangement.

A schematic diagram is shown in Figure 2. Essentially a low flow rate is passed through the permeation tube chamber, using a mass flow controller (MFC1) at 0.1-1 l/min. (An Amasil Tube located before MFC1 ensures the gas flow to the permeation tube is free from mercury.) The gas passing through the chamber carries the mercury from the permeation tube out of the chamber into a dilution gas stream (1-20 l min^{-1}) supplied by a second mass flow controller (MFC2) then dilutes the Hg vapour into the concentration range of interest. A zero gas output is also generated by providing a flow of gas through a critical orifice.

Figure 2 Schematic Diagram of Hg Calibration System

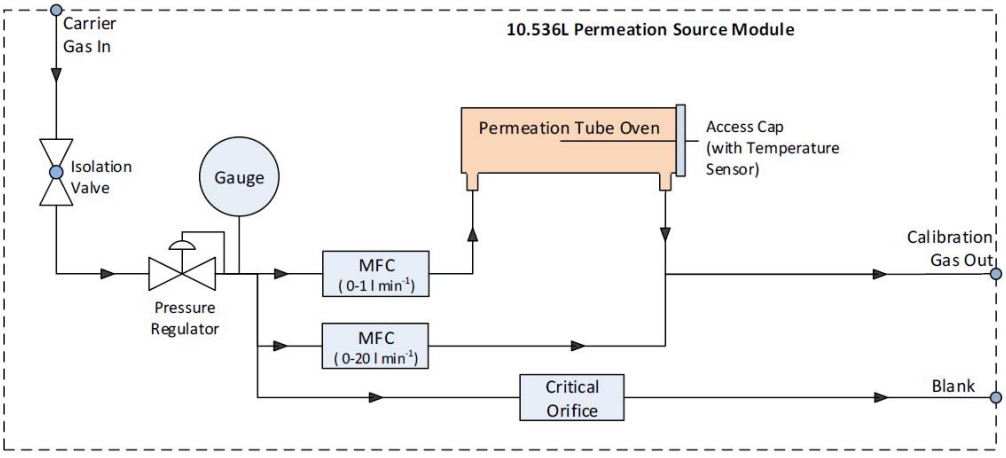

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Table 1

	RANGE	CONTROL
MFC 1	0.1-1 l/min	RS485/MODBUS
MFC 2	1 - 20 l/min	RS485/MODBUS
Oven	Ambient 35-60°C	RS485/MODBUS
Hg Source	Permeation Tube	0.12 ng/min

Figure 4 Typical results for Calibration System

The Mercury Calibration System enables full computer control of the Mass Flow Controllers and reservoir temperature to enable automatic generation of calibration gases at a range of concentrations.

The system is capable of providing a range of Hg concentrations by varying the mass flowcontroller and oven set-points (e.g.3-60ng/m^3). The unit has been used for numerous applications such as online calibrations, sampling system bias checks, spiking sample streams and for bench studies were precise concentrations of mercury are required.

Additional Information

Alarm Outputs	Pressure, Temperature
Dimensions	H 30 x W 57 x D 42 cm
Weight	13 kg

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TEKRAN Instruments Corporation
WHERE MEASUREMENT BEGINS

New Generation - Tekran® Model 3310Xi

The Tekran Model 3310Xi Elemental Mercury Calibrator allows high-level mercury monitoring systems to be accurately calibrated using elemental mercury. It integrates seamlessly with the Tekran Series 3300Xi speciating HgCEM, and can also be used as a stand-alone mercury calibration system. The calibration source allows both multi-point calibrations and standard additions to be initiated automatically. The unit generates precise mercury additions using a NIST-traceable, temperature controlled, saturated mercury vapor source. Precision mass flow controllers are used to dilute the output of this source to the desired value. The unit is capable of continuously generating large flow rates of calibration gas at virtually no ongoing cost - unlike expensive mercury calibration gas cylinders.

The Model 3310Xi incorporates technology originally developed for the Model 2505 Manual Calibration Unit. Unlike other saturated sources, the Model 3310Xi contains a host of advanced features that provide superior accuracy and allow unattended, remote operation.

Product Highlights

- Output concentration range: 0.5 - 1900 ug/m^3 *
- Calibration gas delivery rate: 2 - 30 SLPM*
- Mercury source will last for many years
- Allowable ambient temp: +5 to +40 °C
- Hg source control range: +5.00 to +50.00[1] °C
- Independent linearization tables for each MFC

Applications

- Coal fired power plants
- Waste incinerators
- Other industrial sources
- Speciation studies
- Bench scale testing
- Mercury removal process monitoring

* Standard Unit. Other working ranges are available. Not all output flow/concentration combinations are available simultaneously. Contact Tekran for details.

[1] Other temperature ranges available.