Exemption Request Form

Date of submission: 5/11/2022

1. Name and contact details

1) Name and contact details of applicant:

Company: AMETEK MOCON, Inc.
Tel.: 763-493-7286

Name: Kourtney Smith
E-Mail: kourtney.a.smith@ametek.com

Function: New Products Development Engineering Manager
Address: 7500 Mendelssohn Ave N., Brooklyn Park, MN 55428 USA

2) Name and contact details of responsible person for this application (if different from above):

Company: _____
Tel.: _____

Name: _____
E-Mail: _____

Function: _____
Address: _____

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2. Reason for application:

Please indicate where relevant:

☒ Request for new exemption in: Cadmium in Hersch cells for oxygen sensors used in industrial monitoring and control instruments, where sensitivity below 100ppm is required

☐ Request for amendment of existing exemption in

☐ Request for extension of existing exemption in

☐ Request for deletion of existing exemption in:

☐ Provision of information referring to an existing specific exemption in:

☐ Annex III ☐ Annex IV

No. of exemption in Annex III or IV where applicable:

Proposed or existing wording:

Duration where applicable:

7 years (per Directive 2011|65|EU Article 5.2)

☐ Other: _____

3. Summary of the exemption request / revocation request

An exemption is requested for cadmium in Hersch cells for high-sensitivity oxygen sensors capable of measuring oxygen concentration below 100ppm. Using a Hersch Cell, the range of oxygen detection is from 80ppt to 70ppm.

With reference to Article 5.1.(a), this exemption is made for the following reason:

> *— their elimination or substitution via design changes or materials and components which do not require any of the materials or substances listed in Annex II is scientifically or technically impracticable,*

An Annex IV n. 43 application exemption presently exists for cadmium in anodes of oxygen sensors the extension of this exemption was rejected because the request to extend it was within the 18 month expiration requirement.

While lead is less toxic than cadmium, lead anodes are unable to provide the levels of sensitivity (measurements of tens or hundreds of parts per trillion) and stability required by certain industries. Therefore, the request is made for cadmium in equipment designed for sensitivity ranges where lead is unsuitable.

Of the industries requiring high-sensitivity oxygen measurement, the following industries provide examples where human health or the environment would be placed at risk if the technology were to become unavailable:

- Manufacture of certain pharmaceutical products which are sensitive to extremely low levels of oxygen
- Integrity of food packaging design
- Lifespan of solar panels, which require a high oxygen barrier to ensure component integrity

The above examples were chosen to identify socioeconomic costs. There are other industries requiring highly sensitive oxygen measurements but, there is no other use known for the Hersch cell outside of analytical equipment.

The net environmental benefit to refusing this exemption request would be minimal, amounting to the removal of at most, 3.101 kg of cadmium from the European waste stream per year.

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4. Technical description of the exemption request / revocation request

(A) Description of the concerned application:

1. To which EEE is the exemption request/information relevant?

   Name of applications or products:

   Cadmium is present in the anodes of Hersch cells, which are used in specialized, high sensitivity oxygen sensors where parts per trillion (ppt) measurements are required.

a. List of relevant categories: (mark more than one where applicable)

☐ 1 ☐ 7

☐ 2 ☐ 8

☐ 3 ☒ 9
☐ 4 ☐ 10
☐ 5 ☐ 11
☐ 6

b. Please specify if application is in use in other categories to which the exemption request does not refer: None

c. Please specify for equipment of category 8 and 9:
The requested exemption will be applied in
☒ monitoring and control instruments in industry
☐ in-vitro diagnostics
☐ other medical devices or other monitoring and control instruments than those in industry

2. Which of the six substances is in use in the application/product?
(Indicate more than one where applicable)
☐ Pb ☒ Cd ☐ Hg ☐ Cr-VI ☐ PBB ☐ PBDE

3. Function of the substance:
Cadmium anodes are used in oxygen sensors for specific applications when a high degree of sensitivity and long-term instrument stability is required. Given the absolute nature of the sensor, it is the only possible instrument where no calibration is necessary.

There are several properties that are important in the Hersch cell:
- Must follow Faraday's Law
- Flat discharge curve (accuracy)
- Sensor life (charge)
- Inherent method of maintaining electrolyte heath over years
- Absolute method of measurement (Coulometric)
- Temperature independent
- Oxygen efficiency measurement > 95%
- Sensor response (fast)
- Size and format similar to current sensor
- Specific to Oxygen (Limited cross sensitivity)

4. Content of substance in homogeneous material (%weight):

5. Amount of substance entering the EU market annually through application for which the exemption is requested: average of 3.101 kg / year
   Please supply information and calculations to support stated figure.

6. Name of material/component: Hersch Cell

7. Environmental Assessment: _____
   LCA: ☐ Yes
   ☐ No

   The average mass of cadmium sent to the EU over the last three years was 3.101 kg / year. However, since 1991 we have had a recycling program where we instruct our customers to send back the sensors when they are replaced or the instruments are thrown out. On average we see about 67% of our sensors which contain the cadmium come back to the US for proper recycling. So, the net result of added cadmium to the EU averaged 2.07 kg/year.

   It is important to note this is the maximum amount of cadmium added per year. This is because many of these instruments may still be in use or in inventory and not in use. The customer may have also properly recycled the sensor somewhere else. Therefore, this is worst case scenario.

(B) In which material and/or component is the RoHS-regulated substance used, for which you request the exemption or its revocation? What is the function of this material or component?

A Hersch cell operates by introducing a sample gas to an electrolytic solution; in this case it is potassium hydroxide (KOH).

How the Coulox Sensor Works

The Coulox oxygen sensor is a fuel cell that performs in accordance with Faraday's Law. When exposed to oxygen, the Coulox generates an electrical current that is proportional to the amount of oxygen entering the sensor.

Overview

The Coulox sensor has a carbon cathode and a cadmium anode. The cathodic and anodic reactions respectively:

$\frac{1}{2}O_2 + H_2O + 2e \rightarrow 2OH^-$
$Cd + 2OH^- - 2e \rightarrow Cd(OH)_2$

The electrons create an electrical current, which can be used to calculate the amount of oxygen entering the Coulox sensor.

How Much Current is Produced?

As noted, each oxygen molecule entering the Coulox results in four free electrons creating an electrical current. One mole of oxygen (22.4 litres at 0 ºC and 760 mmHg) would produce four Faradays of current. With one

Faraday = 96,500 Ampere-seconds, each mole of oxygen will produce 4 x 96,500 = 3.86 x 10^5 Ampere-seconds.

In more practical terms:
One cc of oxygen in 24 hours = 0.000199 Amperes of current. This means that the sensor has a sensitivity as little as 100 picoamps and a repeatability of 500 picoamps.
To illustrate that; if you were to take the entire population of the world and multiply it by 40, so 312 billion people, and asked the sensor to find any one specific person it would pick them out!

This creates a current which is used to coulometrically determine the absolute amount of oxygen in solution with the electrolyte.

Lead is commonly used as an anode in this application. However, cadmium has specific properties which are necessary for high-sensitivity applications.

Therefore, an application to extend the exemption for cadmium in anodes of Hersch cells for high-sensitivity oxygen sensors is requested.

(C) What are the particular characteristics and functions of the RoHS-regulated substance that require its use in this material or component?

The two major reasons why certain industries are unable to substitute cadmium Hersch cell oxygen sensors:

- The Hersch cadmium Cell is “Coulometric” and follows Faraday’s Law at ppt levels. This removes the need to calibrate at these extreme low levels.

  This is critical because the lowest level of NIST calibration gas is 1 Mole% oxygen (10,000 ppm). The best “Certified” gas is about 10 ppm (± 20%) which is still 10,000 times away from where the application requires accurate measurements. Competing technologies (exempt lead in particular) require calibration at the testing range of interest, for which there are no standards below 10 ppm.

- The solubility of cadmium in KOH (electrolyte) is very low, therefore does not migrate (like other metals) to the sensing electrode, precipitate or block the sensing electrode sights. This gives the Hersch cadmium cell extraordinary long stable sensitivity life, on the order of years. Other metals do not have the life, sensitivity, or stability

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5. Information on Possible preparation for reuse or recycling of waste from EEE and on provisions for appropriate treatment of waste

1) Please indicate if a closed loop system exist for EEE waste of application exists and provide information of its characteristics (method of collection to ensure closed loop, method of treatment, etc.)

Yes. Since 1991, the applicant has maintained a program where end-of-life sensors are returned to the applicant’s facility in the United States for recycling.

Every sensor which is shipped with cadmium has a label marked: "RETURN EXPENDED SENSOR TO MOCON FOR DISPOSITION" somewhere on it. This is a global label which present on every sensor installed or shipped. When AMETEK MOCON receives back the cadmium, it is picked up by Stericycle, a local recycling company. The cadmium is designated recycle and reuse. This means that it is reused in other things and not sent to a landfill.

2) Please indicate where relevant:

☐ Article is collected and sent without dismantling for recycling

☐ Article is collected and completely refurbished for reuse

☐ Article is collected and dismantled:

- ☐ The following parts are refurbished for use as spare parts: _____
- ☒ The following parts are subsequently recycled: Cadmium plaque

☐ Article cannot be recycled and is therefore:

- ☐ Sent for energy return
- ☐ Landfilled

3) Please provide information concerning the amount (weight) of RoHS substance present in EEE waste accumulates per annum:

☐ In articles which are refurbished	_____
☒ In articles which are recycled	Approximately ≥ 1.031 kg/year
☒ In articles which are sent for energy return	≤ 2.07 kg/year
☐ In articles which are landfilled	_____

Note: It is possible that some of these articles have been recycled by EU-based WEEE service providers without the knowledge of the applicant. Therefore, a net value of ≤ 2.07 kg/year represents an upper limit. In addition, some of these instruments may still be in use or in inventory at the customers' facilities.

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6. Analysis of possible alternative substances

(A) Please provide information if possible alternative applications or alternatives for use of RoHS substances in application exist. Please elaborate analysis on a life-cycle basis, including where available information about independent research, peer-review studies development activities undertaken

An application exemption exists in annex IV:

1b. Lead anodes in electrochemical oxygen sensors

(B) Please provide information and data to establish reliability of possible substitutes of application and of RoHS materials in application

The applicant currently manufactures several oxygen sensors, not all of which rely on cadmium. However, the sensors using other anode materials (lead) are suitable only for other applications that do not require the high sensitivity of the cadmium Hersch cell application.

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7. Proposed actions to develop possible substitutes

(A) Please provide information if actions have been taken to develop further possible alternatives for the application or alternatives for RoHS substances in the application.

Since the original exemption we have tested 2 different galvanic cell combinations, and 2 different fuel cell designs. Both fell short of efficiency and sensitivity. The applicant is actively investigating 6-12 other materials. So far, none have been found to be an equivalent replacement for the Cadmium. This has been a considerable effort of time and resources due to the degree of difficulty of these designs.

The length of a sensor development project can be 1 year or 10 years or never. The last electrochemical sensor development took 6-7 years. The last improvement (not the same as development) made in the Cd Coulox sensor took 3 years (only one component changed). The length of development depends on how many components or materials or geometries have to be changed to accommodate the new anode.

It is very possible we will never be able to find a successful option.

(B) Please elaborate what stages are necessary for establishment of possible substitute and respective timeframe needed for completion of such stages.

At this time, it cannot be confidently stated that an alternative material exists. None is currently known. Section 8.(B).3 of this document references an analysis performed for the European Commission in which the consultant explores various metals which can potentially be used as anodes in oxygen sensors. The conclusion is that lead and cadmium comprise the only two viable metals for scientific reasons. Please refer to 8.(B).3 for more detail.

As is shown elsewhere in this request, lead is unsuitable for ppt measurements.

8. Justification according to Article 5(1)(a):

(A) Links to REACH: (substance + substitute)

1) Do any of the following provisions apply to the application described under (A) and (C)?

☐ Authorisation

☐ SVHC
☒ Candidate list
☐ Proposal inclusion Annex XIV
☐ Annex XIV

☐ Restriction

☐ Annex XVII
☐ Registry of intentions

☐ Registration

2) Provide REACH-relevant information received through the supply chain.
Name of document: ______

(B) Elimination/substitution:

1. Can the substance named under 4.(A)1 be eliminated?

☐ Yes. Consequences? ______

☒ No. Justification: See 8(b).2

2. Can the substance named under 4.(A)1 be substituted?

☐ Yes.

☐ Design changes:
☐ Other materials:
☐ Other substance:

☒ No.

Justification:

Alternative substances exist and are commonly used in oxygen sensors. However, for specialized applications where stable sensitivity on the order of parts per trillion is required, there are no available substitutes.

The basic type of oxygen sensor used is a Hersch Cell. By using cadmium, the instrument is able to measure oxygen transmission down to 0.0005 cc/m^2 x day which equals 170 ppt (parts per trillion) and a sensitivity of 0.0001 cc/m^2 x day (equal to 34 ppt).

Another advantage is the long-term stability of the sensor sensitivity (years); over which the > 95% efficiency to oxygen detection does not change. It should be noted that 70 ppm is the highest level of oxygen measurable and still be linear.

It is believed that the technology has another 100 to 1000 times more sensitivity for future development. This level of sensitivity has been requested by some users of the technology.

It should be noted that the sensor measurement is a direct absolute (Coulometric) measurement of oxygen and follows Faraday's Law. Second, the cadmium is very specific to oxygen and has very few interfering gases. Third is the sensitivity the cadmium has to oxygen without degrading over long periods of time (years).

There are several major reasons why certain industries are unable to substitute Hersch cell oxygen sensors:

- The Hersch cadmium cell is "Coulometric" and follows Faraday's Law even at ppt levels. This means calibration is not required at these extreme low levels.
- This is critical because the lowest level of NIST calibration gas is 1 Mole% oxygen (10,000 ppm). The best "Certified" gas is about 10 ppm (± 20%) which is still 10,000 times away from where the user needs to measure accurately. All competing technologies require calibration at the testing range of interest, which there are no standards below 10 ppm.
- The solubility of cadmium in KOH (electrolyte) is very low, therefore does not migrate (like other metals) to the sensing electrode, precipitate or block the sensing electrode sights. This gives the Hersch cadmium cell extraordinary long stable sensitivity life (years). Other metals do not have the life, sensitivity or stability.
- It is recognised by ASTM (D-3985, F-1307, F-1927), ISO (15105-2), JIS (K 7126-2), DIN (53380-3), GB/T (GB/T 19789, GB/T 31354), and other standards worldwide.

3. Give details on the reliability of substitutes (technical data + information):

   Available technologies for oxygen sensors are described by Dr. Paul Goodman in section 10.1.3 of "*Reliability and Failure Analysis: Review of Directive 2002/95/EC (RoHS) Categories 8 and 9 – Final Report*[1]"

[1] Retrieved from http://ec.europa.eu/environment/waste/pdf/era_study_final_report.pdf 2013-01-30

In the context of lead as an anode material in electrochemical oxygen sensors, Dr. Goodman investigates several possible materials.

He evaluates several possible Pb substitutes and concludes that:

- Zn is unsuitable due to its high corrosion rate. This provides an unpredictable reference current and therefore precludes its use in anything but rudimentary measurements.
- Sn, Al, and In self-passivate, which prevents reaction from continuing after a short period.
- Ni, Cu, Fe are unsuitable due to the necessity of adding an external power supply.
- Au, Pt, Ag are unsuitable due to electrode potential issues.

Cadmium is dismissed by Dr. Goodman as it is more toxic than lead.

However, for measurement of oxygen concentrations on the order of hundreds or tens of ppt, lead does not provide adequate sensitivity (ppt) or the "Coulometric" (absolute) accuracy and characteristics.

Sensor technologies discussed in ERA Report 21006-0383 "Alternative types of sensors" are comparator type sensors which do not have the sensitivity, accuracy or the Coulometric characteristics the Hersch Cell has.

To accurately measure oxygen (gas) permeation through packaging barrier material below 0.001 cc/m^2·day (0.36 ppb v/v) with an upper range of 200 cc/m^2·day (72 ppm v/v). The Food, Pharmaceutical, Solar and OLED industries also need the permeation measurements to be NIST traceable. This method needs to be robust, economical and good response (minutes to T99).

Calibration methods

Almost all oxygen sensing technologies are indirect comparator types of measurements vs absolute, therefore requires calibration. Additionally, today's Safety and Quality control require NIST traceable calibrations. Then a NIST traceable reference gas or material is needed.

- Need a 1 ppb v/v NIST traceable gas
- 2 Mole% (20,000 ppm) oxygen gas in nitrogen is the lowest NIST Standard Reference Material (SRM) available
- Mixing gases increase errors to greater than 100%+

- This all assumes no additional ambient oxygen leaking into the calibration system or the nitrogen mixing gas is free of oxygen. At these trace levels all things leak
- Use a NIST SRM film with a known oxygen transmission rate. NIST discontinued their permeation reference film program (70 cc/m^2·day)

All other sensor technologies require that a membrane be present to keep the electrolyte from leaving the sensor. When the membrane is present the sensors no longer directly measure all of the oxygen. This requires that the sensor be calibrated.

To accurately calibrate the sensors a NIST traceable gas must be used. As of October 8, 2014, the lowest NIST Standard Reference Material which is available for purchase from NIST is 2 Mole % (20,000ppm). There are a few gas manufacturers who can make a lower value, but it must go through NIST's NIST Traceable Reference Material (NTRM). The manufacturer must make at least ten tanks which follow a NIST Traceable process. The data is sent to NIST and verified. The lowest NIST has seen done with this process is 10,000ppm +/- 1% relative with the most common level made being 210,000ppm. There are some manufacturers who claim they can make a NIST traceable gas down to 10ppm but when AMETEK MOCON contacted NIST they stated they have never seen a gas that low. Therefore, these claims of 10ppm are suspect. Even if it was possible to dilute the 10,000ppm gas below this concentration the +/- 1% relative uncertainty would be multiplied down to the level of measurement.

Clearly, if there is no calibration gas (or film) near 1 ppb, some other accurate (absolute) low level (ppb) oxygen measurement is required.

Coulometric Concept

References: "*Measurement, Instrumentation and Sensors Handbook*" (CRC Press 1999) and "*Instrumental Methods of Analysis, Sixth Edition*" (Wadsworth Pub. Co. 1981) both define Coulometric the same, which is:

> *"Coulometric methods of analysis measure the quantity of electricity, that is, the number of coulombs, required to carry out a chemical reaction. Reactions may be carried out directly either by oxidation or reduction at the proper electrode (primary coulometric analysis). The fundamental requirement of coulometric analysis is that only one overall reaction must occur, and that the electrode reaction used for the determination proceed with "100% current efficiency", that is, the reaction corresponds to Faraday's law."*

In other words, if all of the oxygen molecules in a gas stream could be reduced at the anode, the measurement (100% current efficiency) would represent the absolute number of oxygen molecules by using Faraday's law (Coulombs). Avogadro's number allows conversion of Coulombs to volume of gas. Thus, no calibration would be required at trace levels. A method to accomplish repeatable answers with the Hersch cell was written into both ASTM D-3985 and ISO15105-2, which are attached after the appendix.

100% Efficiency is Problematic

Several electrochemical oxygen technologies are fundamentally Coulometric, but when reduced to practice (sensor) they all have oxygen barriers or restrictions to the electrodes, therefore only measuring a fraction (< 0.001%) of the total oxygen present. Inherently, this means they are far less sensitive to oxygen, and they are not measuring all the analyte (O2), which is a critical Coulometric requirement. If a sensor does not collect and measure all the analyte, then it needs to be calibrated because the sensor is only measuring some unknown fraction of the total oxygen.

Life of the sensor is the primary reason why electrochemical sensors have oxygen barriers or restrictions to the electrodes. The three primary reasons for these oxygen restrictors/barriers are:

- Reduce electrolyte depletion (loss of water). Most electrochemical sensors use an aqueous electrolyte. Once the water is gone the electrolyte doesn't conduct ions and the sensor no longer works. Without the water barrier the sensor would dry out in about 2-3 weeks.
    - A selective barrier that blocks water permeation but allows oxygen through is far from perfect. Teflon (one of the best) has a water/oxygen ratio of 1:2000 which still reduces the amount of the original oxygen reaching the electrodes by 1000-10,000X.
    - The water barrier extended the life of the sensor to 1 or 2 years but lost significant sensitivity (best about 100 ppm). Many applications don't need more sensitivity.
- Using an analyte barrier would significantly reduce the amount of anode (Cd, Pb, Zn, etc.) required to get a 1-2 year life for a sensor. This is a plus if an application doesn't need better sensitivity.
- Less anode material and electrolyte also reduces the size of the sensor significantly. Again, this is a plus if an application doesn't need better sensitivity.

The point of the above discussion is to illustrate a barrier or restrictor can't be placed between the oxygen molecules in a gas stream and the electrodes if the goal is to measure all the oxygen molecules. Several oxygen sensor manufactures advertise Coulometric properties but fail to tell people that calibration is still required, to some people's dissatisfaction.

Cadmium

Cadmium is the current anode used in today's oxygen Coulox sensor. It has a long history of accepted performance and ruggedness. Multiple sources in the required plaque format improve availability. The voltage discharge level is the flattest of the electrochemical sensors which gives the Coulox its accuracy and consistent measurements throughout its life. Cadmium doesn't meet the RoHS directives.

Lead

Lead could substitute for Cadmium as an anode, and it is available in plaque form. Its voltage discharge level is almost as flat as Cadmium but has a significant and sooner drop at end of discharge. Lead doesn't meet the RoHS directives.

It should be emphasized that **if** other RoHS restricted substances were used the most likely candidate would have a ratio nearly 1:1 to the current Cd use. This is because the path length needed to achieve 100% reduction would still need to be maintained.

If we need the same volume for lead the weight would increase about 30% over Cd. However, the specific energy of Cd is about 1.7 times greater than Pb. More work is required to know exactly how much Pb is needed to replace Cd.

Zinc

Zinc anodes would give a similar output as Cadmium; however, has a non-linear voltage discharge curve. In effect, this gives the appearances that the accuracy is significantly changing throughout the sensor's life. Zinc can be found in many formats, but plaque is more difficult to find. Some testing with Zinc/air batteries in a starved condition (as a sensor) says the concept may work. However, at low oxygen levels the sensors generate hydrogen and in a sealed condition this causes the sensor to burst.

Lithium

Lithium anodes would give similar output as Cadmium; however, it has a non-linear voltage discharge curve, about half as much as Zinc. In effect, this gives the appearances that the accuracy is significantly changing throughout the sensor's life. Like Zinc, Lithium can be found in many formats, but plaque is more difficult to find. Most important, Lithium and water is explosive, therefore aqueous electrolytes are not allowed. This leaves organic electrolytes and the evaporation of their solvents. As of now we don't know how to replenish these solvents.

Exotic Materials

AMETEK MOCON has contacts with other sensor manufactures and has discussed other anode material. One of the bigger problems is finding a metal/alloy that uses gases oxygen as a fuel and meets RoHS directives.

There are other technologies which have been researched but they too have their own limitations. In fact, AMETEK MOCON uses several of these other technologies in other less sensitive instruments. They include Pb, $ZrO2$ and Optical Fluorescence. These technologies all measure oxygen as low as single ppm levels and all require frequent calibration with certified gases.

Other technologies have been researched but have been met with their own limitations. These include Tunable Laser Diodes, Pb, $ZrO2$, other electrochemical sensors and Optical Fluorescence. They all have to be calibrated because there is no direct measurement of oxygen taking place.

4. Describe environmental assessment of substance from 4.(A)1 and possible substitutes with regard to
    1) Environmental impacts: See below
    2) Health impacts: See below
    3) Consumer safety impacts: See below

There are several users of high-sensitivity oxygen sensors requiring ppt measurements. Applications affecting human health and the environment include:

- The pharmaceutical industry uses Hersch cell sensors to ensure certain medications are protected from oxygen. This is required to maintain strength, and therefore public safety. The high instrument sensitivity is required to manufacture some medicines which are very sensitive to even trace amounts oxygen.
- Freshness and Safety in food packaging design, which requires ppt sensitivity, is the largest application of Hersch cell sensor technology. This affects consumer safety and potentially human health.
- The solar panel industry relies on ppt oxygen sensors instruments to measure their high oxygen barriers. Oxygen barriers are required to prolong the lifetime

of the panels. Long-lasting Solar Panels are necessary to generate "green" energy, which results in benefits for the environment.

- Similarly, the OLED industry requires oxygen barriers to create OLED screens. Only very sensitive instruments using Hersch cells are capable of measuring at the levels they require.

⇨ Do impacts of substitution outweigh benefits thereof?

Substitution of Hersch cells with lead-based instruments would result in (among other impacted industries):

- Specific medicines being unable to be reliably manufactured
- Loss of integrity in food packaging design
- Decreased lifespan of solar panels

For the net gain of eliminating 3.101 kg of cadmium annually from the European market.

Please provide third-party verified assessment on this: _____

(C) Availability of substitutes:

a) Describe supply sources for substitutes: _____

b) Have you encountered problems with the availability? Describe: _____

c) Do you consider the price of the substitute to be a problem for the availability?

☐ Yes ☐ No

d) What conditions need to be fulfilled to ensure the availability? _____

(D) Socio-economic impact of substitution:

⇨ What kind of economic effects do you consider related to substitution?

☐ Increase in direct production costs

☐ Increase in fixed costs

☐ Increase in overhead

☒ Possible social impacts within the EU

☒ Possible social impacts external to the EU

☐ Other: _____

⇨ Provide sufficient evidence (third-party verified) to support your statement: _____

9. Other relevant information

Please provide additional relevant information to further establish the necessity of your request:

10. Information that should be regarded as proprietary

Please state clearly whether any of the above information should be regarded to as proprietary information. If so, please provide verifiable justification:

Confidential information consists of:

- Exact metallurgy of the anode (this information is a trade secret)
- Sales figures used to quantify amount of substance placed on market (sales figures would benefit competitors, are unnecessary for scientific analysis of the merits of this request, and could be used to reverse engineer the anode metallurgy given the mass of cadmium placed on the market)