Exemption Request Form – Exemptions #8(b) & #8(b)-I

1. Name and contact details

1) Name and contact details of applicant:

1) Company: Sensata Technologies Holland BV	Tel.: +31-(0)74-3578154
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Name: Mark Kohorst Director - Environment, Health & Safety	E-Mail: Mar_Kohorst@nema.org Address: Suite 900 1300 N. 17th Street Rosslyn, VA 22209 United States

On behalf of the Company/Business organisations/Business associations listed below participants in the **RoHS Umbrella Industry Project ("the Umbrella Project")**:

We will be inserting in this table endorsing Associations: (i) names, (ii) EU Transparency Register IDs (where applicable) and (iii) Logos.	Name Marquardt & logo	Name Sensata & logo	

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2. Reason for application:

Please indicate where relevant:

☐ Request for new exemption in:

☒ 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: #8(b) & #8(b)-I

Proposed or existing wording:

Existing wording including amendments to reflect the following adaptations to scientific and technical progress:

- 8(b) Cadmium and its compounds in electrical contacts
- 8(b)-I Cadmium and its compounds in electrical contacts used in:
  - circuit breakers **rated at;**
    - **10 A and more at 250 V AC and more, or**
    - **15 A and more at 125 V AC and more,**
  - thermal sensing controls **rated at**
    - **10 A and more at 250 V AC and more, or**
    - **15 A and more at 125 V AC and more,**
  - thermal motor protectors (excluding hermetic thermal motor protectors)
  - AC switches rated at:
    - **10** A and more at 250 V AC and more, or —
    - **15** A and more at 125 V AC and more,
  - DC switches rated at **25** A and more at 18 V DC and more, and
  - Switches **rated at 300V and more** for use at voltage supply frequency ≥ 200 Hz.

Duration where applicable:
We apply for renewal of these exemptions for the categories marked in section 4 further below for the respective maximum validity periods foreseen in the RoHS2 Directive, as amended. For these categories, the validity of these exemptions may be required beyond those timeframes. With regard to Category 11, we request that this application is not processed earlier than the applicable latest application date foreseen in RoHS2, as amended (i.e. 18 months before the respective maximum validity periods foreseen in RoHS2).

☐ Other:

3. Summary of the exemption request / revocation request

Cadmium is used in switching[1] electrical contact systems in the form of silver cadmium oxide (AgCdO), which is one of many categories of metal alloys commercially available for use in switching electrical contacts. Electrical arcs occurring at the opening and closing of the contacts alter the surface layer of the contacts during cycling, which affects the contact system properties and consequently its performance. Surface damage resulting from arcing can lead to contact failure, compromising the reliability of the equipment and creating potential safety hazards for humans, animals and property. As explained further within this dossier, AgCdO remains far superior to most alternatives at "quenching" electrical arcs - switching off electrical current quickly and cleanly and avoiding contact welding and premature failure.

Where suitable cadmium-free alternatives have been found to provide required cycle reliability and product performance/safety, the contact system is converted to a cadmium-free alternative (the following examples are provided by Marquardt and Sensata Technologies in 4(A)5 last paragraph). The suitability of alternative materials is affected by a range of factors such as, but not limited to, voltage, current range, size, opening and closing speed, contact force, frequency and required number of operating cycles and other complex conditions in the application; such as continuously changing electromagnetic fields in electric motors.

This multiplicity of factors leads to a substantial amount of "trial-and-error" by manufacturers, their customers and suppliers during product development. It also makes it highly impractical to specify, with any precision, the conditions under which alternative formulations offered by material suppliers are suitable for specific applications. Differing formulations within each major category of metal alloys result in literally hundreds of possible choices.

In addition to switching electrical contacts, cadmium is also being used in fixed[2] electrical contacts under special conditions for category 8 and 9 applications. Use of cadmium in fixed contacts is needed in highly sensitive applications, such as oxygen and capnography sensors. These applications require very low "drift" during continuous operating periods spanning many years, along with the ability to withstand electro-migration whilst providing suitable conductivity and adhesion properties.

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[1]In this document, a distinction is made between switching and fixed electrical contacts. Switching contacts consist of a contact pair that can be physically closed or opened with the main function to make or break an electrical current.

[2]A fixed contact is where two conductive parts are joined together as part of an assembly and are intended to stay securely connected during operation.

In line with the current state of the business to replace cadmium in electrical contacts by reliable and safe alternatives, we apply for an extension of the exemption for the maximum validity period, based on a partly narrowed scope as proposed by this application.

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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:

The below listed applications/products are currently known to the workgroup applying for extension of this exemption:

- Electrical contacts (fixed) used in sensors for detection of low oxygen levels at elevated temperatures;
- Electrical contacts (fixed) used in capnography sensors that are used to measure carbon dioxide in inhaled and exhaled air of patients who are undergoing surgery, are being ventilated to assist their breathing or to diagnose medical conditions;
- Electrical contacts (switching) used in switches above certain current and voltage ratings and/or frequency of supply voltage;
- Electrical contacts (switching) used in control devices for improving safety of various applications, such as:
    - Circuit breakers;
    - Thermal sensing controls;
    - Thermal motor protectors.
- Electrical contacts used in monitoring and control devices that include safety-related products (*e.g.* overload relays, transfer switches, bypass contactors, fire pump controllers); power switching products (*e.g.* motor starters, contactors, pilot devices); as well as replacement contacts for these applications.

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

☒ 1
☒ 2
☒ 3
☒ 4
☒ 5
☒ 6
☒ 7
☒ 8
☒ 9
☒ 10
☒ 11

b. Please specify if application is in use in other categories to which the exemption request does not refer:
With regard to Category 11, we request that this application is not processed earlier than the applicable latest application date foreseen in RoHS2, as amended (i.e. 18 months before the respective maximum validity periods foreseen in RoHS2).

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 in the form of the silver cadmium oxide alloy (AgCdO) is used in electrical switching (switching: open and close) contacts in various products and end-applications.
The technical function of cadmium in switching contacts is to resist the arc energy that is created when the contacts open and “bounce” when closing, as well as helping to prevent contact weld.
Given the high temperatures generated under arcing conditions, the cadmium oxide helps to:

- minimize heat concentrations as higher thermal conductivity allows heat to go through the contact layer faster, thereby reducing the temperature rise;
- resist welding of contacts, so that the function of opening and closing occurs reliably;

- minimize contact surface erosion[3];
- prevent contacts “sticking” (partial/momentary welding or hooking by rough surface).

During one breaking operation of electrical contacts, arc erosion results from the combination of:

- material removal due to vaporization of the contact material;
- material removal because of the ejection of contact material particles; and
- redepositing of vaporized or ejected contact material.

The amount of layer change and material erosion (failure mode) induced by the electrical arc at each contact opening and closing defines the product performance, reliability and product safety (failure effect). Surface damages by arcing lead ultimately to contact failure such as, but not limited to, contact welding and contact destruction. When this occurs the switching device can no longer fulfil its designed functions at the required conditions, resulting in impaired safety function or dangerous failures.

During cycling, the size and distribution of cadmium oxide clusters become smaller, more homogeneously and finely dispersed. This results in good contact stability and anti-welding properties, due to:

- high viscosity (preventing contact material from splash erosion);
- high thermal conductivity (fast heat distribution and reduced temperature elevation);
- high electrical conductivity/low contact resistance over long periods (good electrical features and limited heating up of the contact) which is particularly important to long life products such as MRI’s which have product lifetimes up to 25 years.

Cadmium in contacts for category 8 applications forms a fixed electrical contact between other electrical components. The use of cadmium in formable contacts such as inks or pastes allow unique properties to be achieved. Properties include very low drift and high reliability over multiple years while the device is continuously used, along with the ability to operate at high temperatures as well as good adhesion and resistance to electro-migration.

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

[3] Reference to: F. Pons, “Electrical contact material arc erosion: experiments and modeling towards the design of an AgCdO substitute”, PhD Thesis, May 2010, Georgia Institute of Technology, https://smartech.gatech.edu/bitstream/handle/1853/33816/pons_frederic_201005_phd.pdf

Contacts in electrical switching devices typically contain 10-25% cadmium in the homogeneous material of the contact face layer. This is the contact face only; the contact itself will typically be copper or copper alloy.
Fixed electrical contacts contain typically 0.1-2% cadmium in the homogeneous material of the paste/ink.

5. Amount of substance entering the EU market annually through application for which the exemption is requested:

   Using reference year 2010, the International Cadmium Association estimated total industrial "consumption" of cadmium in the EU to be 641 tonnes annually, the vast majority of which is in rechargeable batteries. Cadmium in "electrical contact alloys" is cited as one of many "Minor Uses" of cadmium that together constitute less than 1% of total usage of cadmium in the EU[4].

   This data suggests that electrical contacts – along with other 'minor uses' – accounted in 2010 for a portion of approximately 6 tonnes of cadmium consumed annually in product manufacturing. Yet this total includes many products/applications that are outside of the scope of the RoHS directive such as power distribution in large-scale fixed installations, transport, etc.
   Furthermore, manufacturers of products within the scope of RoHS have sought to redesign products in the intervening period to reduce reliance on cadmium-based contacts. Consequently, the amount of cadmium currently required for products affected by this exemption is undoubtedly smaller than it was in 2010 and likely totals far less than one tonne per year.
   In this respect, for example, Sensata Technologies reports a reduction of 810kg during the 2010-2020 period from 950kg to 140kg (where the remainder resides in high capacity contacts and thermal motor protectors). A similar trend is demonstrated by Marquardt reducing from 6.9kg in 2010 to 2.9kg in 2020. Plans for 2022 indicate a further reduction to <90kg for Sensata Technologies and approximately 0.9kg for Marquardt. The latter represents that 99.9% of the Marquardt switch portfolio is Cadmium free. It is important to mention that these data represent worldwide numbers including Europe. It is therefore obvious that for Marquardt and Sensata Technologies clearly smaller amounts will end up in Europe. However, due to the global production and distribution structure of end products, these numbers can't easily be deduced.

6. Name of material/component:

[4]Information provided in e-mail of Director International Cadmium Association to the WG chair on November 4, 2019

Cadmium is being used in the form of AgCdO in electrical contacts. Cadmium is used in the contact faces, which are fused to the copper (or other conductive metal) movable contact holders and stationary contact supports.
Cadmium is being used in the form of a thick film paste or ink in fixed electrical contacts of category 8 & 9 applications such as oxygen or capnography sensors.

7. Environmental Assessment:
   LCA: ☐ Yes
   ☒ No

(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?

The RoHS-regulated substance is cadmium, which is used in electrical switching contacts found in a range of electromechanical devices. The function of cadmium – in compound or alloyed form – is to carry current intermittently through contact surfaces. The basic properties required for these materials are high electrical and thermal conductivity, high melting point, good oxidation resistance and good resistance against contact welding.

High melting point is required to avoid any accidental overheating because of fusion of the contact points whereas high thermal conductivity helps to dissipate heat effectively.

In order to keep the contacts clean and free of insulating oxides, it is essential that the material possesses good oxidation resistance.

Many applications of the electrical contacts require high reliability and long lifetimes: therefore, component design and material choice are critical to maintain the required function. Some of the variables that determine the component design and materials choice include:

- Switching current and voltage;
- Number of switch cycles required;
- Inductive effects;
- Inrush and breaking current[5];
- Space available for the contact and for cooling the contactor;
- Available "open" gap between contacts for reliable arc suppression;

[5] Explained on page 1 of http://www.te.com/commerce/DocumentDelivery/DDEController?Action=srchrtrv&DocNm=13C3236_AppNote&DocType=CS&DocLang=EN

- Frequency of switching;
- Heating effect of the surface material;
- Type of voltage supply (AC or DC); and
- Contactor design, e.g. how this affects “bounce” when contacts close.

For Category 8 devices cadmium-based electrical contacts are used in a variety of applications, which require the full scope of the 8b exemption. Many types of medical device use high power circuits that require relays and contactors, both of which have switching contacts to switch power on and off. One such example is as relays in automated external defibrillators (AED) which require stand-off voltage while the relay is open, and high current pulse conduction while closed. Cadmium-based relays ensure that the contact resistance remains low (<50 mOhm). Without this function the self-tests undertaken by the AED daily, weekly, and monthly might fail, posing a risk of product failure at a critical time for a person experiencing a heart attack.

Another example is the use of a cadmium-based circuit breaker mounted on the rotating unit of the Computerised Tomography (CT) system. The circuit breaker operates under high speeds (0.35 sec/rot) and high centrifugal force (about 30G) so the size and weight of the circuit breaker is critical in order to obtain high centrifugal force resistance characteristics. Failures of the circuit breaker would lead to concerns over electrical safety and reliability.

Cadmium based electrical contacts are also used in power switching of electric motors, specifically as thermal protectors and line-break switches. Electric motors are used in many types of X-ray system including CT, MRI, PET and SPECT[6]. These types of devices require high levels of reliability over a long lifetime, which can be more than 20 years.

For example, in the medical imaging (RoHS Category 8) sector, cadmium-based electrical contacts are used as a power switch in X-ray tubes, which are characterized by high voltages and high current, as well as to power MRI wherein electromagnets may consume 800 amps.‘

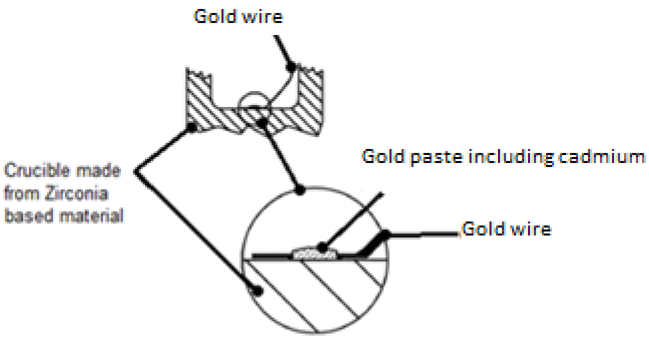
Two specific examples of how cadmium-based compounds function in fixed electrical contacts are as follows.

Cadmium and its compounds in oxygen sensors

Oxygen sensors use electrical contacts by coating conductive electrodes and ‘tacking’ gold wire electrodes to oxygen sensors which in turn is connected to

[6] CT = Computed Tomography, MRI = Magnetic Resonance Imaging, PET = Positron Emission Tomography and SPECT = single-photon emission computerised tomography

additional electrical sensing and signal processing circuits; as illustrated by the following diagram.



The passage of O_2 ions becomes possible at high operating temperatures as at the operating temperature of the transducer - the zircona - becomes conducting. This therefore produces a voltage across the electrodes, the magnitude of which is a logarithmic function of the ratio of the O_2 partial pressures of the sample and reference gas.

Cadmium and its compounds in capnography sensors

Capnography sensors are used in a patient's breathing circuitry, usually located close to the patient's mouth or nose and therefore must be small and light-weight and not generate excessive heat. A capnography sensor has a source of infrared energy and an infrared detector. Infrared energy from the source is absorbed as it passes through carbon dioxide in the air to measure its concentration. RoHS exemption 8b is utilised for the electrical contacts that supply electricity to the heater resistors that generates infrared light.

The electrical contact used in this application is made by printing a special thick film ink to create a contact that connects the heater to the power supply. The ink utilises a gold/platinum alloy as the electrical conductor, a glass binder and cadmium oxide. The ink is printed on a fragile surface where good adhesion is essential, therefore precluding the use of metallic wires. The ink is fired at high temperature to melt the glass to form a matrix. Then a thick-film resistor is printed onto the gold/platinum alloy contacts and then heated to create a resistor which is electrically heated to emit infrared radiation.

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

As noted earlier, electrical arc erosion plays a crucial role in the reliability and life-span of switching devices, affecting functionality or preventing fails that can lead to safety issues. Depending on the contact material's behaviour in response to an electrical arc, surface damage can induce severe changes in contact material properties that will adversely impact the device's functionality. Consequently, electrical arc effects and consequences on the contact material surface are highly important.

Welding of contacts presents a safety concern because the actuating part cannot open the circuit. Cadmium effectively prevents tack welding, both under severe operating conditions and when the product nears end-of-life.

The following characteristics have made cadmium an essential element for contact materials:

- Provides superior performance over longer time periods, which for medical devices and other applications may exceed 20 years;
- Quenches arcs – resists contact welding;
- Produces higher conductivity – *i.e.* smaller size of contacts;
- Leads to less contact erosion – demanded by critical and safety applications;
- Easily manufactured compared to alternatives – *i.e.,* methods for manufacturing alternatives to cadmium vary significantly among suppliers, and these methods influence such properties as arc erosion, contact resistance, and tendency to weld in service. (ASTM B844). Extensive testing is therefore necessary for each supplier as compared to AgCdO.

More generally, a wide variety of industrial products and components would fail more often, resulting in more frequent replacement and increased volume of product disposed into the waste stream. Failure of safety-related products (e.g., overload relays, circuit breakers, power tool switches like angle grinder switches, transfer switches, thermal sensing controls, thermal motor protectors, bypass contactors, fire pump controllers, etc.), is particularly concerning due to potential loss of life and property.

The amendment of exemption 8(b)-I takes into consideration the progress made over the past years whilst still allowing for use in specific, critical applications (related to certain ratings for current, voltage and/or voltage frequencies) where additional time is needed.

In addition, replacement contacts built with alternative contact materials would be larger in some applications, requiring larger contactors that may not fit in the space of the original contactor. This in turn creates a need for redesign or replacement of the entire end-product. Where possible, activities are already being undertaken to redesign products using alternatives to cadmium-based connectors. However, the qualification of the products requires assessment time, as discussed in Section 7 (b), and may also result in increased volume of product disposed into the waste stream.

For electrical contacts used in oxygen sensors, cadmium offers the following properties:

- Very low sensor measurement drift required, when the device is used continuously for multiple years; and
- Safe operation under high continuous operating temperature (>500°C).

For capnography sensors, cadmium and its compounds fulfills the following requirements:

- Must be reliable for at least ten years in use;
- Must not cause electro-migration;
- Withstand being dropped – 1.5m onto a hard surface;
- Conductivity 60-100 mΩ/square; and
- Adhesion >50N (initial pull, 90° pull, 2.0 x 2.0 mm pads).

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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.)

Electrical contacts are typically components in other end-use applications. It is not possible to make any statements as to the existence and specifics of closed loop systems for waste collection of electrical and electronic equipment incorporating electric motors benefiting from the current exemption.

Equipment and components containing the substance are in many cases collected and recycled under the existing provisions of the WEEE recast Directive 2012/19/EU.

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: _____
☒ Article cannot be recycled and is therefore:
    ☒ Sent for energy return
    ☐ Landfilled

As the range of products in which cadmium contacts are being used is quite broad it is difficult to determine with accuracy if parts are actually being refurbished; however, in general this will be not the case. Because electrical contacts are found almost entirely in products and systems used in commercial, industrial and institutional applications, it is extremely unlikely that they ultimately will end up in the solid waste stream, but more probably will be handled through facility waste management programs and/or “reverse distribution” arrangements with suppliers.

In addition, to the extent cadmium-based electrical contacts are integrated into equipment and product categories in scope of the WEEE Directive, they are therefore subject to proper collection and waste treatment requirements.

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 ______
☒ In articles which are sent for energy return ______
☐ In articles which are landfilled ______

We have no information available on the amount of the substance in articles being recycled. However, due to the nature of the applications, as the contacts wear out, the amount of cadmium present in the contact/support assembly is greatly reduced. It is the heat coming from electrical arcs which vaporizes the contact material.

6. Analysis of possible alternative substances

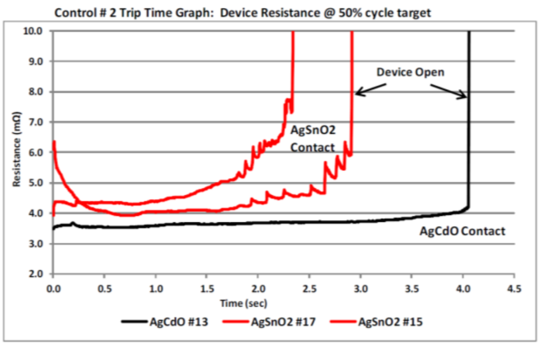
(A) Please provide information if possible alternative applications or alternatives for use of RoHS substances in application exist. Please elaborate analysis on a life-cycle basis, including where available information about independent research, peer-review studies development activities undertaken

Since the RoHS directive was adopted, electric contact and switch manufacturers have researched substitute materials. This work showed that although cadmium performed well in a wide range of applications, each substitute that was evaluated had differing characteristics and no single drop-in replacement exists.
Although there are many different contact materials on the market, each type is used only for certain uses and current ratings.

Potential alternatives may be found in fine silver, silver nickel alloys, AgZnO, or $AgSnO_2$, which potentially offers superior corrosion resistance and better anti-welding properties.

In general, the 10, 12 and 15wt% cadmium oxide grades are replaced with 8, 10 and 12wt% tin oxide. To improve the electrical characteristics of the $AgSnO_2$, a range of additional oxides (dopants) can be added such as tungsten oxide, molybdenum oxide or bismuth oxide. These additives improve the arc-quenching characteristics and prevent the formation of high resistance oxide layers on the surface of the contacts. There are many variants and their selection is dependent on the type of switching application of the electrical contact. As there is no standard composition, $AgSnO_2$ alternatives are more challenging to manufacture[7].

However, while $AgSnO_2$-based contact materials offer certain advantages, they have important deficiencies in comparison with AgCdO, also demonstrated in the below typical trip time graph of a thermal sensing control at 50% of its targeted lifetime.



These include higher contact erosion, contact resistance and bulk resistance as well as greater temperature rise. Overall, AgCdO contacts last longer and have properties that make them ideal for safety-related applications where device failure must be minimized. Products made with substitute contacts may be more susceptible to failure in the dangerous welded-closed state more often than are AgCdO contacts.

Information submitted to request renewal of this exemption in 2015 indicates that choice of contact material is application-specific. Where substitution activities have indicated an alternative is suitable, the transition to alternatives by industry has either already happened or is well underway. However, each application has its own technical requirements. Life-testing "in-situ" is often a requirement to ascertain if the alternative is suitable. As a single protector solution with AgCdO contacts today serves many different applications that see many different electrical and environmental conditions, with different life expectancies; the need for testing with alternate contacts is extensive. Many products have undergone testing of alternatives where substitute materials have so far proven unsuitable.

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[7] Reference, see Wiki https://www.electrical-contacts-wiki.com/index.php?title=Silver_Based_Materials#Silver-Metal_Oxide_Materials_Ag.2FCdO.2C_Ag.2FSnO2.2C_Ag.2FZnO

For example: AED manufacturers have tested alternatives to cadmium, including AgNi, $AgSnO_2$ and Gold Nickel in their products to determine their suitability. Due to the alternatives having contact resistance which builds up over time the product fails the self-test function of the AED. Without the self-test function, the AED, which needs to meet stringent requirements of reliability due to the products function, could cause failures during the product life.

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

Scientific research as well as testing by several manufacturers shows that alternative substances are more prone to electrical arc erosion and tack welding, which will result in more product failures that potentially impact product safety.

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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.

There have been considerable resources invested in the search for cadmium-free silver metal oxide materials. Worldwide, research by manufacturers such as AMI/Doduco, Brainin, Checon, Chugai, Danco, Deringer-Ney, Loxwood, Metalor, Naeco, Umicore; academic institutions such as Carnegie-Mellon University, University of Virginia, the University of Technology - Vienna, University of Wales, Osaka University, University of Braunschweig, University of Southampton; manufacturers such as General Electric, Westinghouse, Siemens, Square-D, and Eaton Electrical; and private research firms such as the Electric Power Research Institute and the Battelle Institute, have conducted research into new contact materials. The number of material formulations, product applications and test conditions is undoubtedly large. This work is often of a proprietary nature, with manufacturers reluctant or unwilling to expose the results of their efforts to competitors.

However, findings from test efforts can be seen in the proceedings of the IEEE Holm Conference on Electrical Contacts (53 editions), the Technical University of Lodz International Conference on Switching Arc Performance (10 editions), the RSIA International Relay and Switch Technology Conference (54 editions), and others.

It is recognised that the number of published articles in recent years has decreased. The underlying technical properties which cadmium based electrical

contacts is uniquely able to offer is well understood and therefore might be a cause for reduced scientific experimentation. One general finding from this research is that cadmium-free contact materials may be suitable for use in products that tend to have short life expectancies and are disposed rather than repaired at end-of-life – examples would include household appliances, toys/leisure/sports equipment, and automatic dispensers.
Cadmium-based contacts must remain available, however, for use in permanently-installed electrical power control equipment and safety- and health-related products, where maintaining public safety is the overriding objective.

Amending wording, scoping down the 8(b)-I exempt is reflecting the state of the business of phasing out the cadmium in electrical contacts – specifically related to Marquardt and Sensata Technologies business – supported by members of the workgroup and endorsed by Company / Business organizations / Business associations as listed in the application.

In the medical device sector, capnography sensors utilising cadmium have investigated the following potential substitutes:

- Alternative thick film inks
- Alternative infrared sources

Inks – The capnography manufacturer has evaluated an alternative thick-film ink that is both cadmium-free and lead-free. Tests showed that on firing the resistive ink, it caused it to interact with the contact ink so that electromigration occurred. During electromigration, thin metallic filaments grow from one conductor to nearby conductors under the influence of an electric field and when two contacts are connected by a filament, this causes a short circuit failure which significantly shortens the product's lifetime. The manufacturers is now testing other alternative inks.

Lamps - Some capnography manufacturers uses lamps as the infrared source. These have several disadvantages of resistive emitters, as shown in the table below.

Issue	Lamp	Resistive emitters
Incandescent lamps are much larger that resistive sources	Incandescent lamp is typically a few mm long and a few mm thick. It usually operate in continuous wave mode and thus requires the use of a chopper and an electric motor and control circuit further increasing the size	Our emitter is 0.5 x 0.5mm sitting on a substrate of 6.25 x 1mm in length and width and 0.125mm thick.
Energy consumption	800 – 1000mW on 100% of time	400mW on 35% of time
Lifetime	Incandescent lamps typically last only two years. Motors and bearings can wear out. The chopper is a moving part in the sensor that will negativley impacts its robustness.	At least 10 years
Durability	If product is dropped in the course of its lifetime product failure is common	Increased durability with ability to withstand shocks

Larger size is an issue for patients where the capnography should ideally be as small as possible so that they do not interfere with hospital staff's access to the patient. Light weight is also very important to prevent the ventilator pulling off the patient. Energy consumption is an issue as hot surfaces are potentially a safety hazard.

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

For 8(b)-I applications, ongoing initiatives, for example at Marquardt and Sensata Technologies, has reduced the use of cadmium by approximately 95% compared to 15 years ago, only leaving the use in critical applications. Ongoing initiatives are planned at these companies to phase out of cadmium by an additional 50kg in 2022. For the remaining critical parts, the exemption as proposed is needed for the maximum validity period to ensure safe transition to viable alternatives.

For Capnography sensors, the next step is to obtain and test alternative cadmium-free inks. Inks that are also lead-free will be tested first but if these are unsuitable, then cadmium-free inks that contain lead will be assessed. If a suitable ink is found in the future, then after testing is complete and the material proven to be suitable, a further two years is required for qualification testing in capnography sensors and to obtain global medical device approvals.

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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:

Based on the current status of Annexes XIV and XVII of the REACH Regulation, the requested exemptions would not weaken the environmental and health protection afforded by the REACH Regulation. The requested exemptions are therefore justified as other criteria of Art. 5(1)(a) apply

(B) Elimination/substitution:

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

☐ Yes. Consequences? _____

☒ No. Justification: See section 4(C)

The technical function of cadmium in switching contacts is to dissipate the arc energy that is created when the contacts open (or bounce upon closure). Given the high temperatures generated under these arc conditions, the cadmium oxide helps to minimize heat concentrations, minimize contact surface erosion, and prevent contact sticking. It is the cadmium oxide additive which prevents the contacts from welding to each other, as well as minimizes any arc damage to allow a significant number of open/close cycles.

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

   ☐ Yes.

   ☐ Design changes:

   ☐ Other materials:

   ☐ Other substance:

   ☒ No.

   Justification: See sections 4(C) and 7(A)

   Potential substitutions may be possible in applications where failure and limited lifetime do not lead to life or health-safety risks. Additional time is needed to qualify technical alternatives to cadmium oxide for critical applications subject to safety standards and sector specific requirements, such as notified body approval for medical devices, circuit breakers, thermal motor protectors, thermal sensing controls and switches. In addition, dynamic electromagnetic fields in application of thermal motor protectors have a huge potential impact on life of the contact requiring additional time for redesign by contact suppliers, thermal motor protector manufacturers and electric motor manufacturers.

3. Describe environmental assessment of substance from 4.(A)1 and possible substitutes with regard to

   1) Environmental impacts:
   Current alternative material alloys have the potential to fail more often, resulting in increased volume of products disposed into the waste stream. Renewal of the exemption will only result in very limited release of cadmium into the waste stream.

   2) Health impacts:
   Information found at the ECHA website: Carcinogenic (Article 57a); Equivalent level of concern having probable serious effects to human health (Article 57 f). It should be noted that cadmium in contact material is normally contained within a mechanical housing, which offers minimal or

zero risk of exposure when used as intended during the working life of the device.

3) Consumer safety impacts:
Current alternative materials will cause the safety of the equipment to be compromised, which especially in safety-critical applications (for instance circuit breakers, thermal sensing controls, thermal motor protectors and power tools) can lead to injuries or fatalities.

⇨ Do impacts of substitution outweigh benefits thereof?
Please provide third-party verified assessment on this: _____

(C) Availability of substitutes:

a) Describe supply sources for substitutes:
Silver Nickel, Silver Tin Oxide and Silver Zinc Oxide are under continuous evaluation for switching devices however currently they do not provide a technical alternative for cadmium in all cases.

b) Have you encountered problems with the availability? Describe:
While suppliers exist for alternative, Cd-free contact materials, there are many potential formulations and selection is closely tied to the type of switching application of the electrical contact. As discussed above, viable substitutes for use in permanently-installed electrical power control equipment and safety-or health-related products are not yet available.

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?
Testing, Customer approval and complete release versus the required standards as determined by the industry sector.

(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

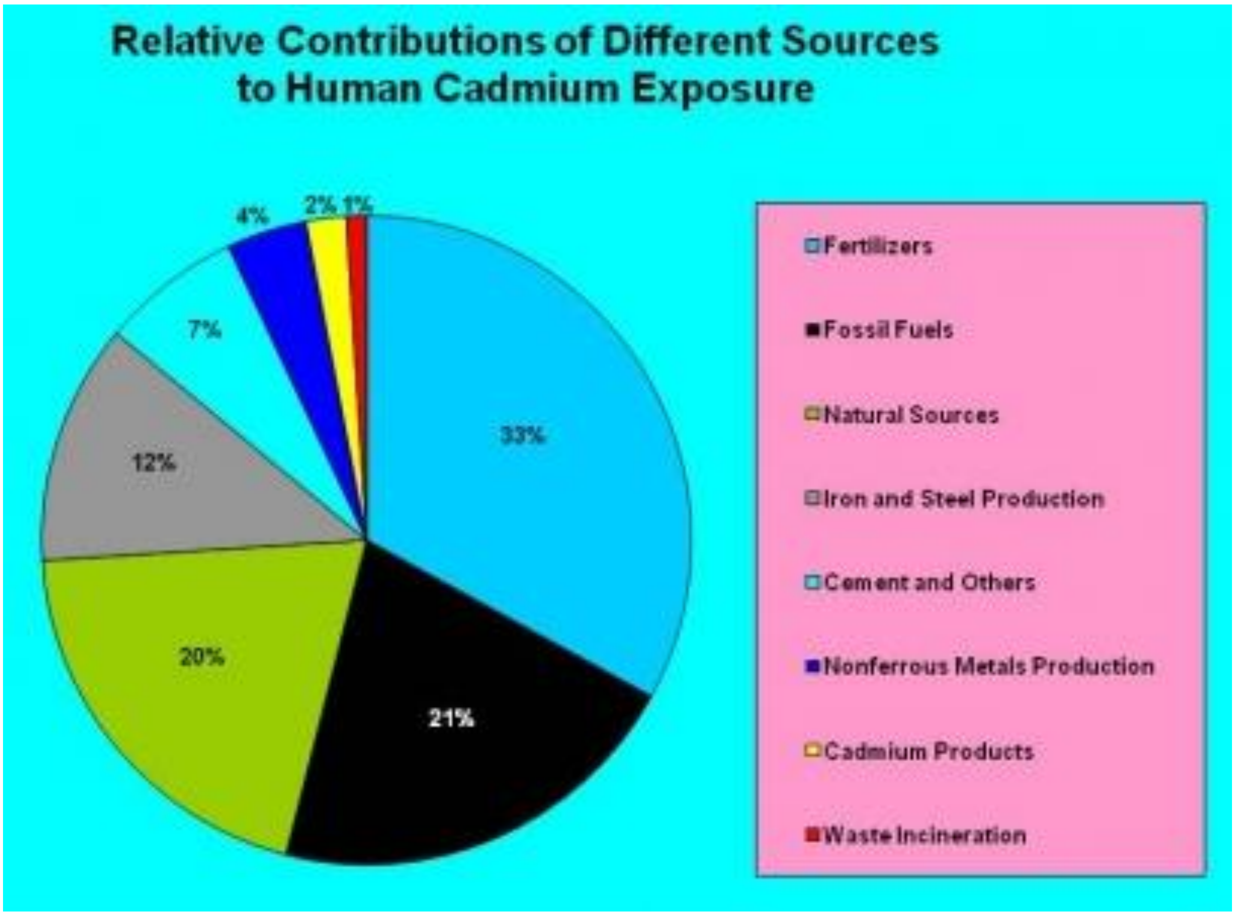
☐ Other: _____

⇨ 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:

Most cadmium emissions and human cadmium exposure for the general population results from cadmium contained as a minor impurity in high-volume products such as fossil fuels, fertilizers, iron and steel production and cement production. Natural sources are also a significant contributor to total cadmium emissions and human cadmium exposure. The production of cadmium, cadmium compounds and cadmium products, their use, and final disposal represent only a small fraction of total cadmium emissions and human cadmium exposure. These results are illustrated in the figure below and show that the production, use and disposal of products to which cadmium has deliberately been added account for less than 2% of the total sources of cadmium emissions and human cadmium exposure. [8]



[8] Source: ICdA at https://www.cadmium.org/introduction

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: