

1st Questionnaire to the exemption request for 2016-3

Exemption for “cadmium in video cameras designed for use in environments exposed to ionising radiation”

1. Abbreviations and Definitions

CCD	Charge coupled devices
Cd	Cadmium
CdSe	Cadmium Selenide
CdSeO3	Cadmium Selenite
CMOS	Complementary metal-oxide-semiconductor

2. General background

BiPRO GmbH has been commissioned by the European Commission (EC) to evaluate two applications for granting new exemptions to be included into the Annexes of RoHS Directive 2011/65/EU (RoHS 2).

Mirion Technologies has submitted an exemption request for “cadmium in video cameras designed for use in environments exposed to ionising radiation” that has been subject to a preliminary evaluation. The information you provided within the request has been reviewed by BiPRO which has led to some questions that need clarification. The relevant questions are outlined below.

3. Questions

3.1. General questions related to the exemption request

- According to the application form, chapter 4 (A) 1. a., the exemption relates to an inclusion into Annex III of RoHS 2 Directive. The relevant categories as identified by the applicant are
 - IT and telecommunications equipment (category 3),
 - consumer equipment (category 4),

- monitoring and control instruments including industrial monitoring and control instruments (category 9), and
- other EEE not covered by any of the categories above (category 11).

Regarding the duration, the request mentions the “maximum validity period”. Since according to Article 5(2) of RoHS 2 Directive, exemptions may have different maximum validity periods depending on the relevant category, and since the categories listed here have different maximum validity periods, please specify the requested validity period.

- **Answer:** 5 years for cats 3, 4 and 11, 7 years for cat 9

- As explained above, category 11 reads *other EEE not covered by any of the categories above*. Please explain why category 11 has been identified as appropriate category although other categories are also identified?

- **Answer:** Four categories have been identified due to the uncertainty and differing opinion on which is appropriate for professional video cameras. Video cameras are usually regarded as being consumer products, however the Chalnicon cameras covered by this exemption are designed for exclusively professional use and so depending on interpretation if they are not in category 4, then they would be in category 11. Some market surveillance authorities may regard CCTV as being in category 9, but when the main purpose is real time imaging, then category 4 is usually regarded as being the correct category, but this not clear.

- In the application, it is stated *“This exemption is requested to allow the use of cadmium as a photo-detector in ionising radiation tolerant video camera tubes. These cameras are used in nuclear facilities to remotely observe operations and inspect various parts of a nuclear reactor for fabrication defects.”* However, the proposed wording in chapter 2 does not refer to the camera tubes but to cameras in general: *“Cadmium in video cameras designed for use in environments exposed to ionising radiation with a dose rate in excess of 100Gy/hour and a total dose in excess of 100KGy with a centre resolution greater than 450 TV Lines”*. On the basis of the information provided in your application we assume that the cameras containing the Chalnicon tubes are also used in other application exposed to ionising radiation such as in the space industry.

Are Chalnicon tubes also used cameras for other environments with ionising radiation that have not the exposure rates as indicated in the proposed wording cited above? Are you aware of

manufacturers, of video cameras using Chalnicon tubes? Please also indicate names of Chalnicon tubes manufacturer(s) if possible.

- **Answer:** Mirion's Chalnicon tube cameras are not intended to be used in medical imaging or space applications where the camera is exposed to ionising radiation but at lower levels than for nuclear applications. As far as we know, other manufacturers of chalnicon tube cameras also only supply for nuclear applications. There are several suppliers of Chalnicon video cameras including Mirion (UK), Exavision (France), ECA Group (France) and several others. However, none of these suppliers are manufacturers of Chalnicon tubes. We are aware of only two manufacturers of Chalnicon tubes one of which is located in Russia: Electron www.electron.spb.ru¹. Perkin Elmer and stopped manufacture of Chalnicon tubes several years ago. The other manufacturer is Hamamatsu who manufactures Chalnicon tubes exclusively for Mirion.

- Please confirm if the following wording is sufficient to cover the use of cadmium selenide and cadmium selenite as a photo-detector in ionising radiation tolerant video camera tubes of the type Chalnicon, for which the request has been submitted. Alternatively, please propose an alternative wording if possible accompanied by a justification.

Cadmium selenide (CdSe) and Cadmium selenite (CdSeO3) in Chalnicon video camera tubes exposed to ionising radiation with a dose rate in excess of 100Gy/hour and a total dose in excess of 100KGy with a centre resolution greater than 450 TV Lines

- **Answer:** This wording is sufficient

- No information included in the application has been highlighted as proprietary information. Please confirm that all information provided is meant to be published.

- **Answer:** Yes, apart from sales data which has been supplied as a separate document which is confidential (answer to Q4 below)

¹ http://www.electron.spb.ru/data_eng/VIDICON%20LI501-1MK.pdf

3.2. Questions related to the technical description of the exemption request

- In chapter 4 (A) 4. the content of the substance in homogenous material (% of weight) is estimated to be “58.7% (Cd in CdSe)”. Please confirm that in your understanding CdSe layer is a homogenous material in the sense of Article 3(20) of the RoHS 2 Directive, i.e. “one material of uniform composition throughout or a material, consisting of a combination of materials, that cannot be disjointed or separated into different materials by mechanical actions such as unscrewing, cutting, crushing, grinding and abrasive processes”. Should the CdSe layer not be considered homogenous material in the sense of the Directive, please estimate the applicable amount provided for the substance in homogenous material.
 - **Answer:** The CdSe layer thickness is 0.5 to 2 microns in thickness. This would be regarded as a homogeneous material if it can be removed from the substrate by a mechanical method. Abrasive materials with grit size of 0.25 to 1 micron are commercially available and so could be used to separate the CdSe from the substrate by abrasion and therefore this layers is consistent with the RoHS Directive’s definition of homogeneous materials.
- Also within chapter 4. (A) 6. of the application form you state related to the question of name of material/component “Cadmium used as cadmium selenide based semiconductor detectors. A thin layer of cadmium selenite (CdSeO3) is also used” which goes beyond the description of chapters 4 (A) 4. and 4 (A) 5. Please confirm which Cd compounds are applied on the camera tubes as layer and consider all Cd compounds for the calculation of Cd entering the EU market.
 - **Answer:** This is correct. The exemption needs to be for cadmium in CdSe and in CdSeO3

- Could you please provide a description and an illustration of the video tube (photo or drawing) in order to show where the CdSe is applied?

- **Answer:**

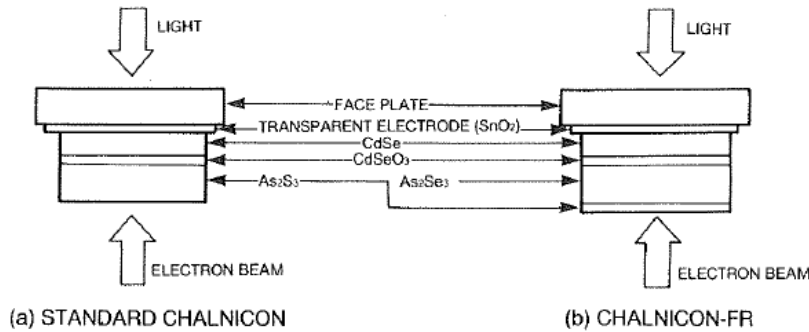


Figure 1: Schematic Representation of the Target Structure

- From information provided in chapter 4 (A) 5. it can be deduced that the data provided are assumptions based on data available from another “illustrative” camera tube of the type “Radiant-Resistant Vidicon LI501-1MK”. Can you confirm that, and if possible provide evidence that the information on the Vidicon camera tube provided is comparable to the Chalnicon tubes in terms of CdSe and (if applicable) CdSeO3 content?

- **Answer:** Mirion do not manufacture Chalnicon tubes and this information could not be obtained from tube suppliers. Therefore the only available method for estimating the quantity of cadmium was the one included in the exemption request. As the mode of function of the CdSe layer will be the same in all tube designs (all rely on the same thickness range), it seems likely that there will only be small variation in the amounts of cadmium in other tube models.

3.1. Questions related to possible preparation for reuse or recycling of waste from EEE

- In chapter 5.1., the statement is made that “the equipment is likely to become radioactive in use, so has to be treated as radioactive hazardous waste.” Do you have any evidence confirming this assumption?

- **Answer:** The materials used to construct cameras when exposed to intense ionising radiation (neutrons, electrons, α , β or γ) can become radioactive. This is referred to as induced radioactivity, first discovered by Pierre and Marie Curie. For example, high energy gamma rays

can cause photodisintegration of atomic nuclei where a proton or neutron is ejected. The resultant isotope may be radioactive. See:

- https://en.wikipedia.org/wiki/Induced_radioactivity
- <http://www.nrc.gov/reading-rm/basic-ref/glossary/induced-radioactivity.html>
- <http://www.ncbi.nlm.nih.gov/pubmed/9571615>
- <http://www.aesj.or.jp/publication/pnst001/data/525.pdf>

There is also the fact that the cameras can become contaminated with radioactive dust during use that can't be removed.

3.2. Questions related to justification for exemption

- Chapter 6 explains that *“the main requirement of the video camera is resistance to very high exposure levels of ionising radiation that occurs in nuclear environments which includes α , β and γ radiation”* and that *“the only commercially available camera tube with sufficient radiation tolerance is the Chalnicon tube, all other types are either no longer produced (and would have been inferior) or are not sufficiently radiation tolerant for nuclear applications.”*

Please detail the required resistance to exposure levels of ionising radiation of the camera tube must be in order to fulfil the necessary characteristics. Please state the minimum requirements for instantaneous and accumulated dose for each type of radiation (α , β and γ radiation).

- **Answer:**

	Minimum required instantaneous dose rate (Gy / h)	Minimum required cumulative dose (Gy)
α radiation	unknown	unknown
β radiation	unknown	unknown
γ radiation	100	1M
Neutron	unknown	unknown

The main concern for nuclear facilities is the gamma radiation because it is very penetrating. While we know α , β and neutron radiation is present the levels are relatively low compared to γ radiation and there is no defined minimum requirement from our experience.

It was stated that other camera types such as “vidicon” are “less light sensitive”, implying further requirements than just radiation tolerance. Are there other minimum relevant requirements the cameras need to fulfil for each use.

- **Answer:** Image quality should be as clear as possible although there is no quantitative specification. The image sensor needs to have as high a sensitivity to light as possible to reduce lighting requirements without compromising the instantaneous dose rate performance. Data which shows the superior image quality of Chalnicon is provided in the table on page 5 of Mirion’s exemption request.

How high are the resistance to exposure levels of ionising radiation of camera tubes that are used in cameras for other applications/environments with comparably high exposure to ionising radiation, such as space or medicine?

- **Answer:** A datasheet from ECA Group gives comparative radiation resistance values for different types of its cameras that may be used in other industry sectors.

Camera type	Instantaneous maximum dose rate	Maximum accumulated dose
Chalnicon	10^4 Gy / h	10^6 Gy
Radiation hardened CMOS	10^3 Gy / h	10^5 Gy
Radiation hardened CCD	1 - 2 Gy / h	2×10^2 Gy

In the same chapter, it is stated that all other types of Vidicon camera tubes available do not meet the necessary resistance to ionising radiation. Are there any test results or evidences (peer reviewed studies, independent research) for this statement?

- **Answer:** It is stated in the exemption request chapter 6 that of the Vidicon tubes that are still available and do not contain cadmium, only Plumbicon is available and this is not radiation tolerant or RoHS II compliant as it contains lead. Peer reviewed studies could not be located.

3.3. Questions related to the development of substitutes

- Regarding chapter 7, please list current activities for the development of possible alternatives you are aware of.
 - **Answer:** Chalnicon and other semiconductor video camera tube technologies were developed many years ago. Current video camera research focuses mainly on silicon semiconductors which are not resistant to radiation. At present there are no known detector materials available that have not already been evaluated that could conceivably be investigated.
- Are design changes possible in order to replace the restricted substance?
 - **Answer:** No. Cameras must have a detector material that is exposed to the zone which is to be imaged and cadmium selenide is the only material with sufficiently resistant to radiation and with acceptable image quality. Design change is not feasible.
- Within chapter 8. (B) 3., it is stated *“Other types of Vidicon camera tubes either do not give the required performance or are much less resistant to radiation and so will be less reliable due to their lower resistance to ionising radiation as explained in answer to Q6. Shorter lifetimes are not acceptable as plant operators need to view their facilities remotely as operators will be severely harmed if exposed to these environments.”* Please precise how much shorter the lifetime of other video camera tubes would be compared to the Chalnicon tube? Is it possible to back the statements with any more evidence?
- **Answer:** Currently the only other vidicon tube available is the Plumbicon, which is not RoHS II compliant because of the lead content. The Plumbicon was tested by Mirion back in the 1980’s at the request of a customer and found not to be radiation tolerant (so would have an very short lifetime in a nuclear facility). The relevant report was the property of the customer who is no longer trading and Mirion doesn’t have a copy.

3.4. Questions related to REACH compliance

- Within chapter 8. (B) 3., the assessment of REACH compliance states that the provisions on registration of REACH are not applicable for CdSe and CdSeO₃. May we ask to elaborate further on why the registration provisions are not applicable?
 - **Answer:** Substances manufactured in the EU or imported into the EU in quantities of more than 1 tonne per year need to be registered. Whether CdSe or CdSeO₃ need to be registered by Mirion or its suppliers has no relevance to this exemption request. A search of the ECHA registration database shows that neither CdSe nor CdSeO₃ have been registered, presumably because only small quantities are used in the EU.

Please note that answers to these questions are to be published as part of the available information relevant for the stakeholder consultation to be carried out as part of the evaluation of this request. If your answers contain confidential information, please provide a version that can be published along with a confidential version, in which proprietary information is clearly highlighted.