Master’s thesis

Double Master in Industrial Engineering and Nuclear Engineering

Design of a test flight site for calibration of unmanned airborne monitoring systems for radiological events

Annex

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ETSEIB

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Contents

Glossary

Acronyms and abbreviations

AP geometry: "*Anterio-posterior geometry*". The most conservative geometry that considers a radiation field consisting of a parallel beam of particles impinging on the front of the body.

CSN: "*Consejo Nacional de Seguridad".* Its mission is to prepare reports, do inspections and monitor what is related to nuclear and radioactive in Spain.

EDTA: "*Ethylenediaminetetraacetic acid".* It is capable to "sequester" certain metallic isotopes.

ENRESA: Company responsible of collect, treat and store the radioactive waste generated at any point in Spain.

ETSEIB: "*Escola Tècnica Superior d'Enginyeria Industrial de Barcelona".*

Fissile material: Is a material capable of sustaining a nuclear fission chain reaction with neutrons at any energy.

INTE: "*Institut de Tècniques Energètiques.*" Their principal functions are research and technology transfer and are specialized in ionizing radiation, catalysis and development of materials for environmental applications, neutron physics and particle accelerators.

IT: "*Transport Index*". Is a numeric value used to limit the exposition to materials or packages that contain radioactivity.

Parallel geometry: Radiation field consisting of a parallel beam of particles.

RPSCRI: "*Reglamento sobre Protección Sanitaria Contra Radiaciones Ionizantes"*.

SCAR: "*Servei de Coordinació d'Activitats Radioactives*". Its mission is to prepare reports, do inspections and monitor what is related to nuclear and radioactive in Catalunya.

Shallow dose equivalent: Is the external exposure dose equivalent to the skin or an extremity at a tissue depth of 0.007 centimetres (7 mg/cm^2) averaged over an area of 1 square centimetre [Sv].

SPR: "*Servei de Protecció Radiològica*". Its mission is to offer advice on radiation protection in the radioactive facilities of the UPC.

UN number: "*United Nations number".* Is a number of four digits used to identify a specific dangerous materials.

UPC: "*Universitat Politècnica de Catalunya*".

Magnitudes

E**:** Effective dose. Sum of organ and tissue equivalent doses multiplied by appropriate weighting factors [Sv].

Units

[Sv]: Sievert. Is a derived unit of ionizing radiation dose. It is a measure of the health effect of low levels of ionizing radiation on the human body. Basic radiological protection unit.

A. Safety report

A.1. Tasks and doses

The present safety study focuses on the justification of the different tasks to be performed and the doses received over a year, validating the compliance with the limits established by the Regulation on Sanitary Protection Against Ionizing Radiations (in Spanish: Reglamento sobre Protección Sanitaria contra las Radiaciones Ionizantes - RPSCRI) [1].

A.1.1. Use of the radiation source

Hereunder, it is described the tasks to which the source is going to be subjected by estimating the repetitions of each one to subsequently calculate the effective dose over a year.

Two cases will be studied:

- The first one, a realistic estimation of the exposure time for each task.
- The second one, an overestimate in such a way that these times will never be overcome, and thus verify that even in this case the limits are not exceeded.

<u>Source installation in the shielding</u>

Once receiving the source for the first time with its encapsulation, it will be extracted from its original packaging and will be threaded at the base of the shielding. An execution time of about 30 s (**1/120 h**) at **3 cm from the hand and 50 cm from the body** of the professionally exposed worker is estimated and this maneuver is expected to be done only once.

For the critical case, this time is set in 6 minutes (**1/10 h**).

[1] Spain. Real Decreto 783/2001, de 6 de julio, por el que se aprueba el Reglamento sobre Protección Sanitaria Contra Radiaciones Ionizantes. Boletín Oficial del Restado, July 25, 2001, num. 14555, p. 27297-27288, art. 8-13

Transport

A realistic estimation of the transport time is **30 hours** with a distance of **1 m** from the body of the people who travel in the vehicle, which allows to make between 10 and 15 trips per year.

Such trips might be, for example, in a flight site in the vicinity of Tarragona to study the source and take measures assuming 2 h trip (roundtrip) or, in a flight site near Zaragoza for the intercomparisons assuming 6 h trip (round trip).

As a critical case, it is proposed that the travel time will not exceed **250 h**.

Shielding manipulation

This task refers to attach and remove the shielding from the transport package, counting a time of 10 s per action which involves 20 s per flight session. Considering 12 sessions per year, it is estimated that the time required for this task will be 240 s (**1/15 h/year**) with the **hand in contact** with the shielding and the **body at 30 cm** from it.

For the critical case, a time of **1 h/year** is considered.

Utilization

It is considered that the source will be used 12 days per year, and it is expected to be in operation for 6 h each one.

Therefore, the exposure for members of the public and the professionally exposed worker is splited:

- Members of the public attending the flight sessions will last a total of **72 hours** with the source in operation. In the worst case, the shortest distance to which they can access will be **5 m** and, due to geometric issues, the photon beam will never impinge directly on them.
- The professionally exposed worker will be the only one who will be able to approach the source to make the appropriate disc changes for measurements and calibrations. It is estimated a time of 10 s per maneuver (this time includes the time to approach, change the tool and get away) and a total of 10 changes per flight session. The process of opening and closing the shielding at the beginning and end

of the sessions is included in this estimation. The total would be **0.33 h/year** at **3 cm** from the hand and **50 cm** from the body.

For the critical case, **2 h/year** of changes are considered for the professionally exposed worker.

Leakage tests of the encapsulated source

The leakage tests will be carried out by the supervisor once per year. This implies that this person will be around 1 minute (**1/60 h/year**) with the hand in **contact** with the shielding and the body at **30 cm** from it.

In addition, the smear for the test will involve a time of 5 s (**1/720 h/year**) with the hand in contact with the encapsulation (a distance of **5 mm** from the source is proposed) and with the body at **50 cm** from the unshielded source.

For the critical case, a time of 6 minutes (**1/10 h/year**) is proposed for the entire operation and a smear time of 30 seconds (**1/120 h/year**).

Exposure rate tests of the transport package

This task will be carried out when the source arrives for the first time and each time it is taken from the ETSEIB dependencies, wherewith 13 repetitions of 1 min are estimated, being a total of 13 min (**13/60 h/year**) with the hand in contact with the package (**40 cm**) and the body at **1 m** from the source.

For the critical case, a time of **2 h/year** is proposed.

A.1.2. Dose calculation during work operation

With the shielding and the package perfectly defined in the document Thesis, in this section the doses received will be calculated taking into account the time estimations of section A.1.1, both for the realistic and critical case. Doses will be calculated with the MicroShield® .

For whole body doses, the effective doses with the Anterior-Posterior geometry will be used and for doses in hand, the equivalent doses or "Shallow dose" will be considered, using the parallel geometry, which is the most conservative.

The full results of the simulations can be found in Annex C.

Received doses during the source installation in the shielding

This task is the most critical for the professionally exposed worker, together with the changes of attenuators and collimators and leakage tests, since his hand will be practically in contact with the source encapsulation.

Here, one can see in figures A.1 and A.2 the geometries used for the simulations of equivalent and effective dose in hand and in body:

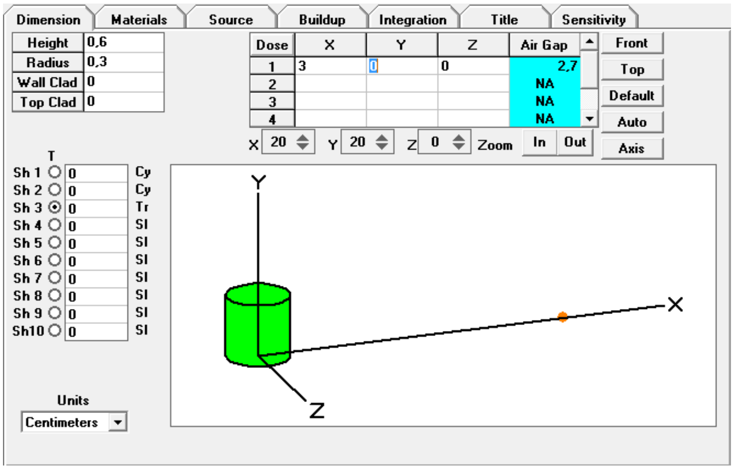


Figure A.1: Simulation geometry for the hand at 3 cm without attenuation.

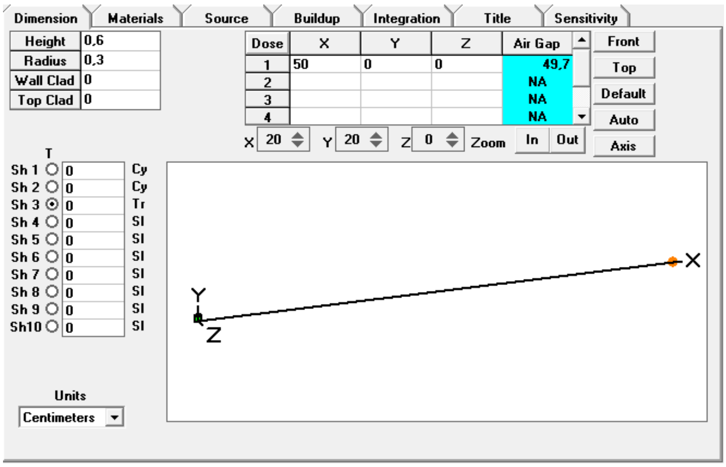


Figure A.2: Simulation geometry for the body at 50 cm without attenuation.

The results indicate that the dose that would be received by the hand would be **39.4 mSv/h** and the body would receive **118 µSv/h**.

Received doses during transport

Figure A.3 shows the geometry used for transport simulation considering, as explained above, a distance of 1 m and with the shielding closed.

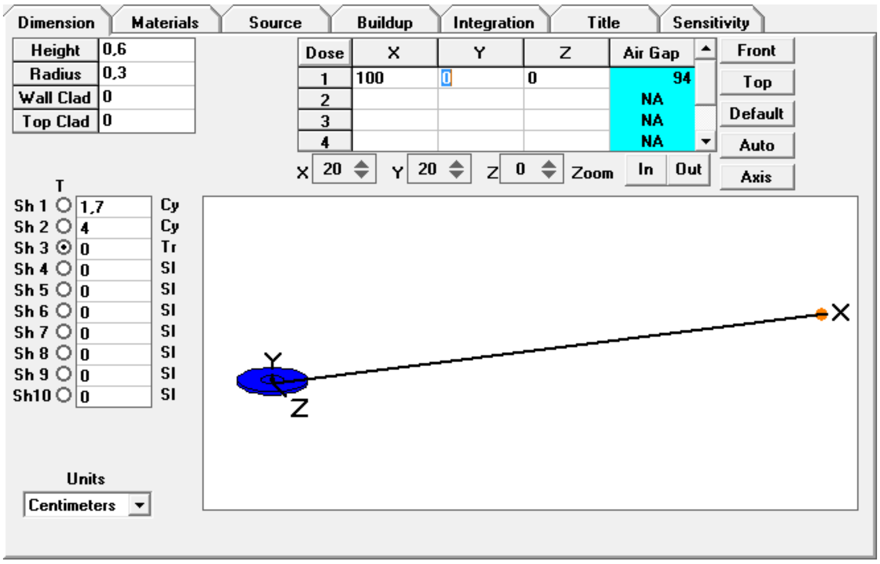


Figure A.3: Simulation geometry for the body at 1 m with closed shielding.

As a result, an effective dose of **0.5 µSv/h** is observed.

Received doses during shielding manipulation

Figure A.4 shows the geometry used for the simulation of the shielding manipulation for the hand and, in figure A.5, for the body, being in contact and at 30 cm respectively.

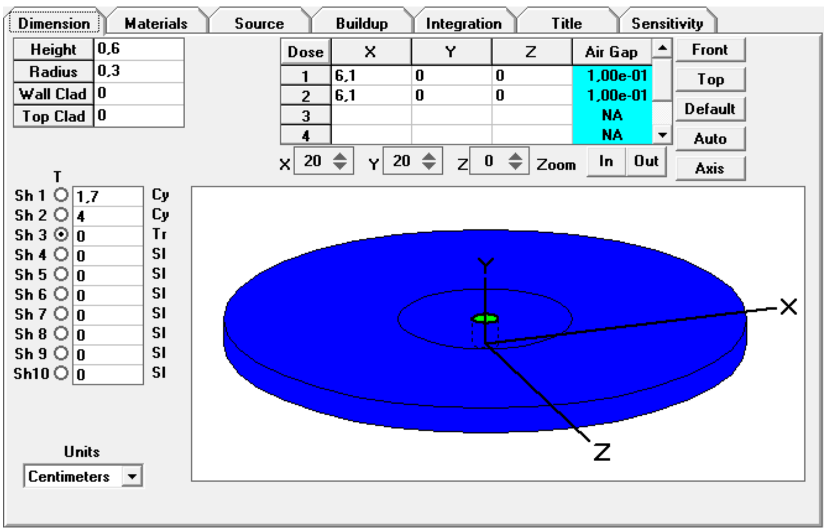


Figure A.4: Simulation geometry for the hand in contact with the shielding.

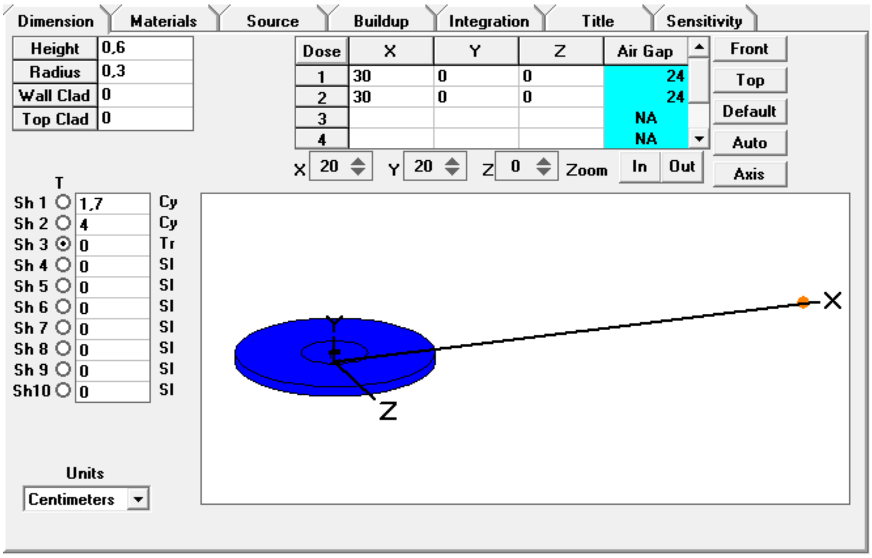


Figure A.5: Simulation geometry for the body at 30 cm with shielding.

The simulation results are **159 µSv/h** for the hand and **5.5 µSv/h** for the body.

Received doses during utilization

During utilization, it has been already mentioned that it can be splitted in two cases.

The first, for members of the public, which, in the worst case, would be at least 5m from the source with the lead shielding between them. In figure A.6 one can see the geometry used in this case and the results indicate that they would receive a dose of **19 nSv/h**.

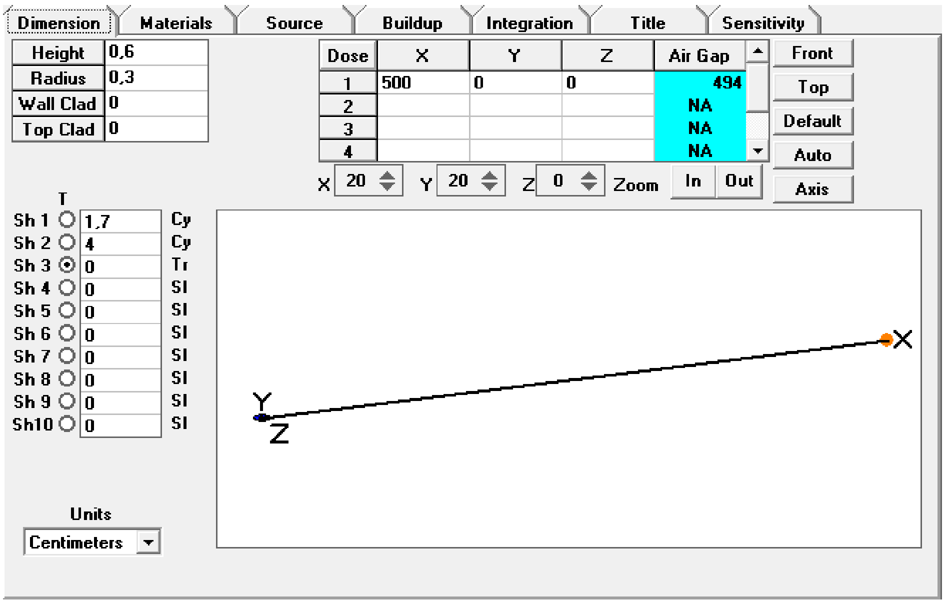


Figure A.6: Simulation geometry for the body at 5 m with shielding.

The second case, corresponding to the professionally exposed worker, has been conservatively considered that the 10 s that it takes to make a change of attenuator or collimator is next to the source. This implies that this case is identical to the one explained above and that the geometries for hand and body are the same as those observed in figures A.1 and A.2.

Consequently, the results will also be those presented above of **39.4 mSv/h** in hand and **118 µSv/h** for the body.

<u>Received doses during leakage tests of the encapsulated source</u>

During the operation, the geometries for the hand and the body are the same as those shown in figures A.4 and A.5 and, therefore, the doses in hand and body correspond to **159 µSv/h** and **5.5 µSv/h** respectively.

During the smear, the body is considered to be 50 cm away without shielding, as in the case of figure A.2 and the effective dose is **118 µSv/h**. For the hand, one can observe the simulation geometry in figure A.7, resulting in an equivalent dose of **1502 mSv/h**.

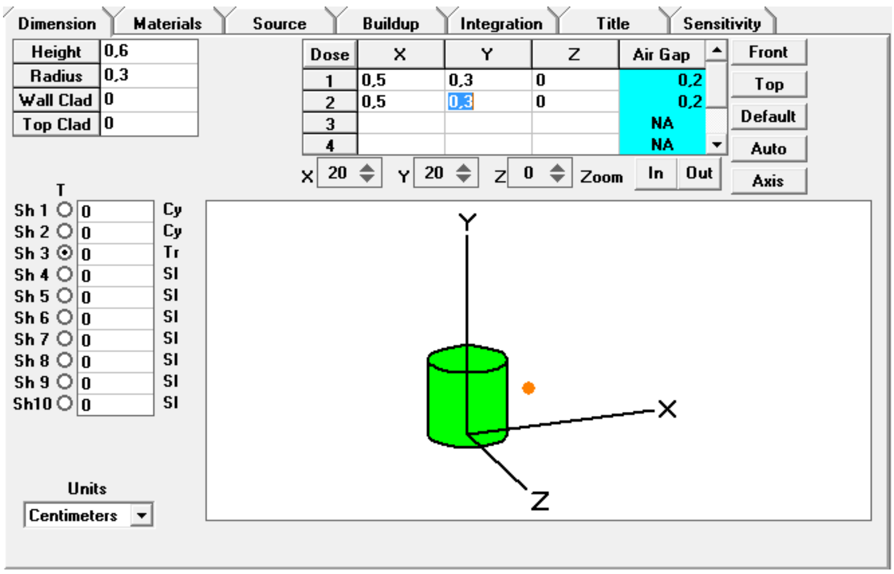


Figure A.7: Simulation geometry for the hand at 5 mm during leakage test's smear.

Received doses during exposure rate tests of the transport package

In this case, the hand has been considered to be 40 cm from the source as indicated by the geometry of figure A.8, giving an equivalent dose of **3.7 µSv/h** and the body at a distance of 1 meter as in the geometry of the figure A.3, with a result of **0.5 µSv/h**.

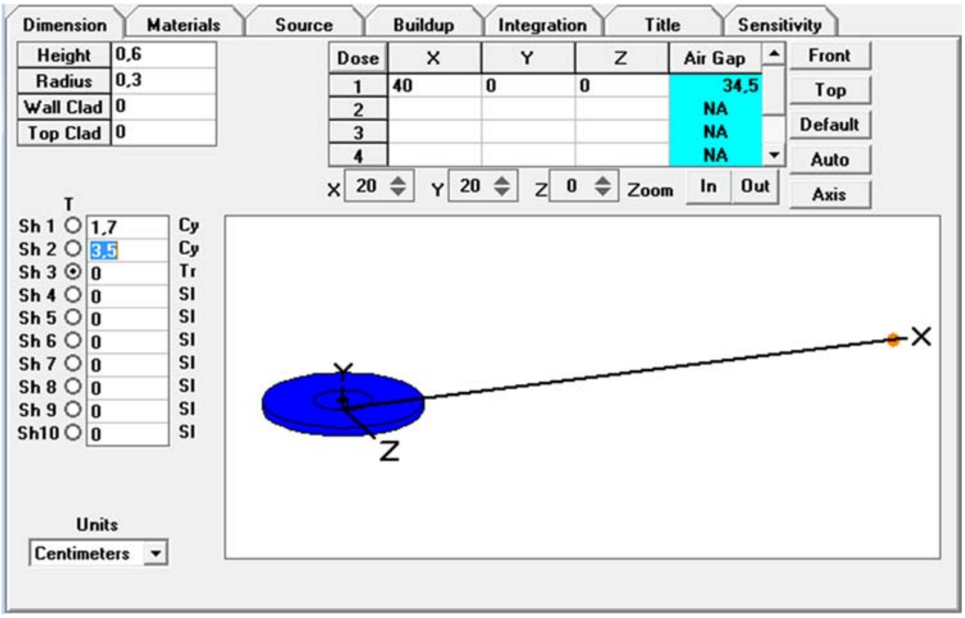


Figure A.8: Simulation geometry for the body at 40 cm with shielding.

A.1.3. Annual received doses

With all the results extracted from the relevant simulations, the following summary tables are presented to compute:

- The annual effective dose received in body for the realistic case (table A.1)
- The annual equivalent dose received in the hand for the realistic case (table A.2).
- The annual effective dose received in body for the critical case (table A.3)
- The annual equivalent dose received in hand for the critical case (table A.4).

Table A.1: Annual effective dose received in the body for the realistic case.

Task	**Exposure rate (µSv/h)**	**Exposure time (h/year)**	**Worker annual dose (µSv/year)**
Installation	118	1/120	1
Transport	0.5	30	15
Manipulation	5.5	1/15	0.4
Utilization 5m	0.019	72	1.4
Attenuators and disks change	118	1/3	40
Leakage tests	5.5 118	1/60 1/720	0.1 0.2
Dose tests	0.5	13/60	0.1
TOTAL			**58**

Table A.2:Annual equivalent dose received in the hand for the realistic case.

Task	**Exposure rate (mSv/h)**	**Exposure time (h/year)**	**Worker annual dose (mSv/year)**
Installation	39.4	1/120	0.33
Manipulation	0.159	1/15	0.011
Attenuators and disks change	39.4	1/3	13.13
Leakage tests	0.159 1502	1/60 1/720	0.003 2.09
Dose tests	0.004	13/60	0.001
TOTAL			**15.6**

Table A.3: Annual effective dose received in the body for the critical case.

Task	Exposure rate (μSv/h)	Exposure time (h/year)	Worker annual dose (μSv/year)
Installation	118	1/10	11.8
Transport	0.5	250	125
Manipulation	5.5	1	5.5
Utilization 5m	0.019	72	1.4
Attenuators and disks change	118	2	236
Leakage tests	5.5 118	1/10 1/120	0.6 1
Dose tests	0.5	2	1
TOTAL			**382.3**

Table A.4: Annual equivalent dose received in the hand for the critical case.

Task	Exposure rate (mSv/h)	Exposure time (h/year)	Worker annual dose (mSv/year)
Installation	39.4	1/10	3.94
Manipulation	0.159	1	0.159
Attenuators and disks change	39.4	2	78.8
Leakage tests	0.159 1502	1/10 1/120	0.016 12.52
Dose tests	0.004	2	0.007
TOTAL			**95.4**

With the dose values at sight, it can be concluded that, even with the exposures of the critical case, the acquisition of this radioactive source is not going to suppose the exceeding of the limits established for a professionally exposed worker.

These limits are that, the annual effective dose received by professionally exposed workers will not exceed **20 mSv/year** and the equivalent dose in hand of professionally exposed workers will not exceed **500 mSv/year**.

In the case of an attendant without a license, such as a student in the internship period, considered as a member of the public, only will be affected by the dose of transport and utilization at 5 m from the source since the other tasks are performed by the worker with license. This implies an annual effective dose of 0**.13 mSv/year**, being still far from the limit for members of the public, established at **1 mSv/year**.

Finally, the other people present in the flight sessions would receive a minimum dose due to the utilization at 5 m from the source. In the case that they stay the whole time at this distance and taking into account the critical case, they would receive an effective annual dose of **0.0014 mSv/year** and, as they are considered members of the public, they would not exceed the limit of **1 mSv/year**.

A.2. Incidents, prevention and procedures

A.2.1. Abnormal situations, incidents and accidents

When evaluating which are the diverse abnormal situations that can occur during the manipulation, transport and use of the source, basically it is possible to highlight the following cases:

- Loss of tightness of the encapsulated source.
- Breakage of the encapsulated thread.
- Breakage of the shielding.
- Loss or theft of the package.
- Accident of the transport vehicle.
- Fire of the storage laboratory.
- Accident of the UAV, directly affecting the source during the flight sessions.

Later, emergency plans will be seen in case of any occurrence.

<u>Loss of tightness of the encapsulated source</u>

Due to the design of the source, it is an unlikely event, which may be due to one of the following two causes:

- Gradual degradation of the integrity of the sheath, as a result of a corrosion and oxidation problem.
- Damages due to an important mechanical aggression (drop, impact, crushing, ...).

Nevertheless, annual leakage tests will be performed to ensure that the source encapsulation keeps its tightness.

Breakage of the encapsulated thread

In the unlikely case that, due to a major mechanical aggression, already impact or drop, the source will lose its anchorage, but even so, it will remain within the shielding.

Breakage of the shielding

In case of drop or impact, there is a remote possibility that the steel support rods break by shear. This would be a critical accident, since the ability to close the shielding when the source is not in use would be lost.

Loss of theft of the package

This case is extremely improbable, although the possibility exists. This would mean theft of the car during one of the two long trips discussed above.

Accident of the transport vehicle

There is a remote possibility that the vehicle that carries the source during the days in which it will be used has an accident. Unless it is a total loss, the package, along with the shielding, should be prepared to withstand a strong blow and maintain the tightness of the source.

Fire of the storage Laboratory

A fire at the Laboratories, which is highly unlikely, could essentially affect the equipment, furniture, doors and walls, and in the particular case of the calibration Laboratory, could affect the integrity of the source stored in it.

UAV accident

Considering the worst-case scenario, it can occur that during a flight session, the UAV loses control, either due to electronic, mechanical or electrical failure or due to weather conditions. In addition, it is considered that, when falling, collides directly with the source while it is in use, in such a way that it breaks the encapsulation, overturns the shield and the ceramic active element confined inside it is broken and scattered by the surrounding terrain. As expected, this situation is highly unlikely, but it should be taken into account.

A.2.2. Prevention systems

Hereunder, one can find the different prevention systems for the correct operation and fulfillment of the limits exposed until now:

- The package will be stored in the irradiation room of the calibration laboratory, located in Hall C, floor -1 and classified as a prohibited access area and, consequently, its access will be limited to qualified INTE personnel.
- The package will be locked, so only authorized personnel will have access to the source.
- The relevant radiation hazard warning label will be placed on the package so that third parties are aware of the danger. This label corresponds to the category I-WHITE.
- The transport vehicle must also be properly marked as will be seen below.
- During the flight sessions, a fence of 5 m radius will be placed around the source so that the attendees will not be able to approach and that the photon beam do not hit them directly. In this way, only the professional exposed worker in charge of making the changes of the attenuators and collimators will be able to approach the source.
- The professional exposed worked, who will be in charge of carrying out the manipulations near the source, will carry a personal dosimeter to verify that his exposure has not been too high.
- During long trips, it will be specifically requested to the hotels the possibility that the vehicle containing the source remains in a closed and guarded place.

A.2.3. Labels and panels

In this section, all the documentation related to the labeling and panels that must be placed both in the package and in the transport vehicle will be presented. This documentation has been taken from a CSN journal [2].

[2] CSN, Consejo de Seguridad Nuclear. *Seguridad Nuclear, Revista número 34.* Madrid, 2005, p. 24-32

ETSEIB

Hazard class

All hazardous materials must be properly marked. Depending on the type of danger, the classes shown in table A.5 are distinguished:

Table A.5: Hazard class classification.

Hazard class	Hazardous substance
1	Explosives
2	Flammable and/or toxic gases
3	Flammable liquids
4	Flammable solids
5	Oxidizing substances / Organic peroxides
6	Toxic or infectious substances
7	**Radioactive material**
8	Corrosive substances
9	Other hazardous substances

In the present project, the package will be cataloged as class 7, Radioactive material.

Category

Within hazard class 7 there are four categories: I-White, II-Yellow, III-Yellow and Material fissile, each one having its corresponding label. Setting the fourth apart, from the first to the third increases the dose intensity outside the package and, consequently, the risk of external irradiation. Thus, the category depends on the intensity of the maximum radiation on the surface of the package and the Transport Index (IT) as can be seen in table A.6. When, according to the intensity of radiation on the surface, a category should be considered and, according to the IT another, the most restrictive one has to be chosen.

Table A.6: Class 7 category classification.

Condiciones		Categoría
IT	*Nivel de radiación* máximo en cualquier punto de la superficie externa	
0[a]	Hasta 0,005 mSv/h	I-BLANCA
Mayor que 0 pero no mayor que 1[a]	Mayor que 0,005 mSv/h pero no mayor que 0,5 mSv/h	II-AMARILLA
Mayor que 1 pero no mayor que 10	Mayor que 0,5 mSv/h pero no mayor que 2 mSv/h	III-AMARILLA
Mayor que 10	Mayor que 2 mSv/h pero no mayor que 10 mSv/h	III-AMARILLA[b]

[a] If IT is less than 0.05, its value can be considered 0.

The IT is calculated by measuring the dose at 1 meter of the surface of the package in mSv / h and multiplying the resulting value by 100. Thus, the package object of this report corresponds to the following IT:

$$IT = E(1{,}4m)\ \left[\frac{mSv}{h}\right] \cdot 100 = 2.505 \cdot 10^{-4} \cdot 100 = \mathbf{0.02505 > 0.05}$$

The radiation level was already calculated in section A.1.2 and has a value of **0.0031 mSv/h**.

It can therefore be stated that the transport package meets the requirements to enter the category I-White and it must have a label like the one shown in figure A.9.

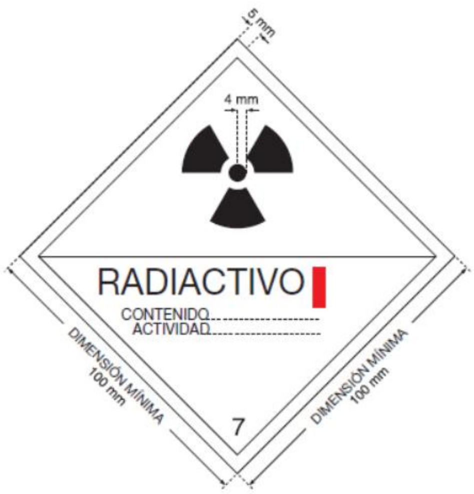


Figure A.9: I-WHITE category label.

United Nations number (UN)

The UN number is a four-digit number, assigned by the United Nations Committee of Experts on the Transport of Dangerous Goods, which identifies a specific hazardous substance. In the case of radioactive substances, there are a total of 25 and each one represents a type of material and/or radioactive package. In the case of excepted packages, there are 5 assigned numbers, which can be seen in figure A.10. In this case, the number of the UN is "UN 2910".

Asignación de los números de las NU	NOMBRE CORRECTO DE EXPEDICIÓN y descripción[a]
Bultos exceptuados	
UN 2908	MATERIALES RADIACTIVOS, BULTOS EXCEPTUADOS — EMBALAJES VACÍOS
UN 2909	MATERIALES RADIACTIVOS, BULTOS EXCEPTUADOS — ARTÍCULOS MANUFACTURADOS DE URANIO NATURAL o URANIO EMPOBRECIDO o TORIO NATURAL
UN 2910	MATERIALES RADIACTIVOS, BULTOS EXCEPTUADOS — CANTIDADES LIMITADAS DE MATERIALES
UN 2911	MATERIALES RADIACTIVOS, BULTOS EXCEPTUADOS — INSTRUMENTOS o ARTÍCULOS
UN3507	HEXAFLUORURO DE URANIO, MATERIALES RADIACTIVOS, BULTOS EXCEPTUADOS, inferior a 0,1 kg por bulto, no fisionable o fisionable exceptuado[b]

Figure A.10: UN numbers for excepted packages.

Vehicles signage

Road vehicles transporting radioactive materials must have a rhomboidal label like the one in figure A-11 on the back and two others on both sides, in order to inform, without further detail on the content, that this vehicle transports a material with "RADIOACTIVE" risk, because next to this word also appear the clover and the number 7, indicative of this kind of dangerous material.

Figure A.11: Road vehicles required label when transporting radioactive materials.

In addition, an orange reflective panel must be placed on the vehicle, which by itself, without any indication inside, already informs that a dangerous good is being transported. When the hazardous material that is transported is all of the same type, the panel will collect certain written information. Thus, in the case of radioactive material, in the upper part there are only two possible danger numbers: 70 and 78. If one sees 70, it means that there is only radioactive risk (class 7), but if there is a 78 it would indicate a radioactive material that is also corrosive (class 8), such as uranium hexafluoride. In the lower part the UN number will be indicated, which has already been mentioned previously.

For the package object of this report, in the upper part the number 70 would appear and in the lower one the corresponding UN number, as can be seen in figure A.12:

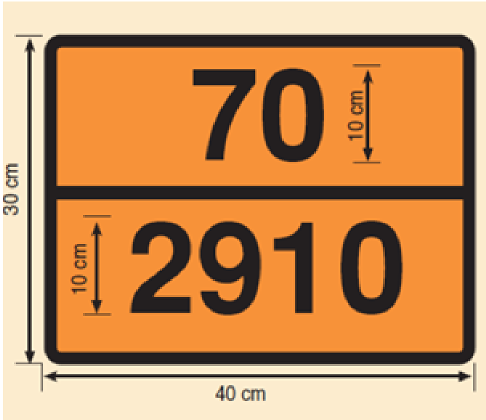


Figure A.12: Road vehicles required panel when transporting radioactive materials.

A.2.4. Administratives and technical procedures

Purchase and reception of the radioactive source

The purchase of radioactive material will be controlled by the supervisor and the Radiological Protection Service of the UPC, who will supervise the process of receiving the source.

The purchase and receipt of material will be carried out in accordance with the stipulated procedures SPR009 'Acquisition of radioactive equipment or materials' and SPR010 'Reception of equipment or radioactive materials' of the Radiological Protection Manual of the UPC. In summary, the procedure will be as follows:

- In advance of the purchase of the material, the Radiological Protection Service will be informed, through the standardized application form, of the characteristics and activity of the material to be acquired.
- The purchase of the material will only be made after being approved by the Radiological Protection Service.
- The reception of the material will be carried out by the supervisor, and radioactive material that is not known or in other quantities than those requested should not be accepted.
- At the reception of the material, the correct condition of the package will be examined and it will be verified that the material received corresponds to the previously requested material.

- If any spill is seen, the possible contamination of the container will be evaluated and the affected tools and areas will be decontaminated.
- The person in charge will notify the Radiological Protection Service of the entry of radioactive material at the UPC premises through the standardized notification form.

Installation of the radioactive source in the shielding

When receiving of the source, it will proceed to remove the source of its original package and fix it to the base of the shielding. This manipulation can only be carried out by the authorized personnel and must follow the procedure that will be described below to avoid receiving more dose than necessary:

- Before starting to manipulate the source, all the parts of the shielding must be assembled, with the exception of the base, and the necessary screws and screwdriver must be already prepared.
- The person in charge, wearing lead gloves and a personal dosimeter at all times, will take the base of the shielding with one hand and with the other the source and, maintaining the greatest possible distance, will proceed to the threading of it.
- After that, it will fit the base to the body of the shielding and will screw the fastening screws.
- Then, the shielding will be placed inside the transport package.
- Finally, tests will be carried out to verify that the source is the desired isotope and has the requested activity.

Change of attenuators and collimators during flight sessions

This process must also be carried out only by authorized personnel, who will be the only people with permission to cross the fence located 5 m from the source during the flight sessions.

To perform this operation, the supervisor must wear a personal dosimeter, must have the attenuators and collimators that want to use previously prepared and, to perform it as quickly as possible, must remove the one being used and put the following with the two hands to increase accuracy.

Leakage tests of the encapsulated source

Leakage tests of the encapsulated source will be carried out by the licensed supervisor, who will be responsible of performing them with an annual periodicity.

To make these controls, the direct smear method will be used, which consists in rubbing a handkerchief through the encapsulation containing the active element and later, it will be transferred to the laboratories of the Radiological Protection Service for a further study.

The results will be recorded in the source Operations Diary.

Exposure rate tests of the transport package

The dose rate controls on the surface of the transport package will be performed, by the licensed supervisor, the first time when receiving the source and before each departure from the ETSEIB dependencies.

This procedure will consist on bringing a direct reading dosimeter close to the surface of the package and verify that the dose is less than 5 μSv/h. This process will be carried out in the center of all the faces of the transport package.

The results will be recorded in the source Operations Diary.

Waybill

The waybill is a document that contains the basic information of the radioactive source that is transported and always has to travel with it. This information is the following:

- Hazardous class and UN number.
- Radioactive material, physical state and activity.
- Package category.

Hereunder, it can be seen in figure A.13 the waybill filled with the information referring to the source object of this report:

DOCUMENTO DE TRANSPORTE:

MATERIALES RADIACTIVOS, BULTOS EXCEPTUADOS-CANTIDADES LIMITADAS DE MATERIALES

Clasificación de las Naciones Unidas: **7**
Número de las Naciones Unidas asignado: **UN2910**
Radisótopos transportados: **Cs-137**
Forma física: **Sólido**
Actividad transportada: **370 MBq**
Categoría del bulto: **I-Blanca**

Declaración del remitente:

"Declaro que el contenido de esta remesa queda total y exactamente descrito más arriba mediante el nombre correcto de la expedición; asimismo, que se ha clasificado, embalado, marcado y etiquetado y se halla en todo respecto en condiciones adecuadas para su transporte de conformidad con los reglamentos internacionales y nacionales pertinentes".

Fecha y firma:

Figure A.13: Waybill filled with information referred to the Cs-137 source

Radioactive waste management

The radioactive waste generated at the end of the life of the source will be stored in the laboratory itself until the moment of its evacuation. The management of such waste will preferably be carried out through the supplier of the source and, when it is not possible, its withdrawal will be arranged with ENRESA.

A.3. Emergency plan

A.3.1. Authority lane

Any incident that occurs in the installation and that will affect its safety and the radiation protection, will be immediately reported to the supervisor and the Radiation Protection Service, so that they determine the actions to be taken in order to recover the levels of radiological safety in the installation and mitigate the possible consequences.

A.3.2. General rules in case of accident

In a generic way, the following guidelines must be taken into account:

- Maintain serenity at all times.
- In case of a fire, it will be extinguished, either by its own or external means, taking into account the radiation risks that may arise.
- Immediate delimitation of the area and signaling of it, defining the controlled area, which will be prohibited to access by personnel not involved in the operation.
- Notification to the person in charge of the installation, to the supervisor and to the Radiological Protection Service.
- Notification to the "Consejo de Seguridad Nuclear" and the "Servei de Coordinació d'Activitats Radioactives" within a period of less than 1 h-24 h depending on the severity of the incident.
- Planning of measures to take.
- Application of such measures.
- Writing a full report on the accident for processing to the authorities.

A.3.3. Identification of foreseeable accidents

The accidents that may occur during the use of the radioactive source object of this report have already been advanced in the Safety Study:

- Loss of tightness of the encapsulated source.
- Breakage of the encapsulated thread.
- Breakage of the shielding.
- Loss or theft of the package.
- Accident of the transport vehicle.
- Fire of the storage laboratory.
- Accident of the UAV, directly affecting the source during the flight sessions.

A.3.4. Stablished plans to deal with accidents

The guidelines to follow in the case of loss of hermeticity of an encapsulated source can be included in the measures to be taken in the event of an incident with external contamination of people or work areas, or an incident with internal contamination of people.

External contamination of personnel or areas

If any contamination of personnel or work areas is detected, the supervisor of the installation and the Radiological Protection Service of the UPC will be notified. The decontamination will be carried out in accordance with stipulated procedures SPR005 'Methods of external decontamination of person' and SPR006 'Methods of decontamination of materials or work surfaces' of the Radiological Protection Manual of the UPC.

Briefly, in the case of contamination of people will act as follows:

- The decontamination will be aimed at preventing the entry of the radionuclide into the body, so that aggressive procedures or products that can damage the skin will not be used.
- The decontamination will start from the natural holes that may have been affected: eyes, nostrils ...
- The affected area will be washed with warm water and neutral soap, trying not to spread the contamination. Do not use very hot water or organic solvents to prevent the penetration of the radioisotope through the skin. In the case of open wounds of little consideration, these will be washed by opening the wound until blood, apply an antiseptic and cover.

In the case of contamination of a work area:

- The contaminated area will be delimited, preventing the entrance to the area of all the personnel other than the decontamination tasks.
- Before proceeding with the decontamination, the value of the element to be decontaminated will be compared with the cost of the operation, as well as if the polluting radionuclide has a short half-life, the possibility of storage until its activity decreases will be assessed.
- In general, it will be decontaminated with water and conventional detergents or EDTA.

Internal contamination of people

In the event of internal contamination of a person due to the ingestion or inhalation of radioactive material, highly unlikely following the basic rules of radiation protection, will act as follows:

- Estimation of the amount ingested or inhaled.
- In the event that the annual limit for ingestion or inhalation for members of the public is exceeded, action will be taken in accordance with the procedure SPR008 'Actions in case of radiological accident' of the Radiological Protection Manual of the UPC.

Which is summarized in:

- Give notice to the Medical Service.
- If the severity of the case requires it, a center for irradiated and contaminated level I or II treatment will be contacted:
  Centro de Radiopatología y Radioprotección. Hospital Gregorio Marañón (Madrid). Tel. 91 586 80 00, ext. 8180.

Breakage of the encapsulated thread

In the case of the breakage of the encapsulation thread, the shielding will be closed and taken back to its storage place. A leakage test will be carried out and the access will be limited until it can be repaired or changed.

In the case of losing the possibility of closing the shielding, there would be two procedures depending on the current location of the source:

- If it occurs within or close to the ETSEIB facilities, the source would be moved to its original transport packaging, since it must also comply with the radioactive material transport regulations. Later it would be stored in its original storage laboratory and its access would be limited until the shielding support bars can be repaired / replaced.
- If it occurs outside the ETSEIB, the shielding would be immediately placed inside its transport package, with the cover on top, and closed, since the package, although it admits some movement, would keep the cover above the shielding. Upon arriving at the ETSEIB, the procedure described above will be followed.

Theft of radioactive material

In the event of theft, the most widespread dissemination of this event will occur immediately, in order to avoid as much as possible the risk of direct manipulation of the sources, breakage and consequent contamination of people and areas.

With the same haste, the Competent Authority will be notified of such incident, providing the elementary recommendations, from the point of view of radioprotection, for the manipulation of the material at the time of recovery.

Accident of the transport vehicle

In the event of a collision, a quick on-site visual inspection will be carried out to verify that the integrity of the package and the shield remain intact. Even so, it would be transported as quickly as possible to the premises of the ETSEIB to perform a leakage test and evaluation of the possible damages received that were not noticed by the naked eye.

Fire

In the event of a fire, it will proceed immediately to achieve its extinction by the proper means of the installation, at the same time that notice will be given to the public service against fires. The performance of this service will be advised at all times by the supervisor and the Radiological Protection Service in relation to aspects related to radiation protection.

The guidelines in case of fire are:

- Do not act alone and ask for help immediately.
- Close of the air recirculation systems' path.
- Give notice to the supervisor.
- Shut off the path of people external to the control and extinction of the fire.
- Prevent the fire from spreading, closing the doors and reducing as much as possible the air currents. Make use of fire extinguishers near the installation.
- If possible, remove the radioactive material to a safe area.

Since the fire can be detected by the Surveillance Service, it will have a key to the Laboratory. In this situation, the actions to be followed are:

- The surveillance service will use the key to access the interior of the Laboratory.
- Will make use of the extinguishers and, if necessary, external extinguishing services will be requested.
- It will prevent the passage to any unauthorized person.
- The situation will be reported to the person in charge of the installation, to the supervisor and to the Radiological Protection Service, who will appear as soon as possible in the Laboratory to take charge of the direction of the emergency plan.

Once the extinction is finished, a control of the affected radioactive material will be carried out, verifying the tightness of the sources. In addition, the mandatory report will be drafted to the “Consejo de Seguridad Nuclear” and the “Servei de Coordinació d'Activitats Radioactives”.

UAV accident

The action in front of this event explained above, consists on the following guidelines:

- If it exists, extinguish the fire with a foam extinguisher as they are ideal for extinguishing type B fires (caused by liquid fuels such as gasoline).
- Once there is no fire, cover the affected area with a radiation detector and locate the debris of active element that may have spread.
- At the same time, delimit the area with a fence at a distance large enough so that the dose received (measured with the detector) is not greater than 0.5 μSv / h. This value is taken as the limit since if a person were the 2000 working hours of a year receiving that dose would not exceed the limit of 1 mSv / year for members of the public.
- Once the exclusion area is bounded, the competent organizations should be informed of the event.

A.3.5. Accident report

Once the emergency situation has been overcome, the Supervisor, together with the Radiological Protection Service of the Univertitat Politècnica de Catalunya, will proceed to collect the following data to transmit it to the competent bodies:

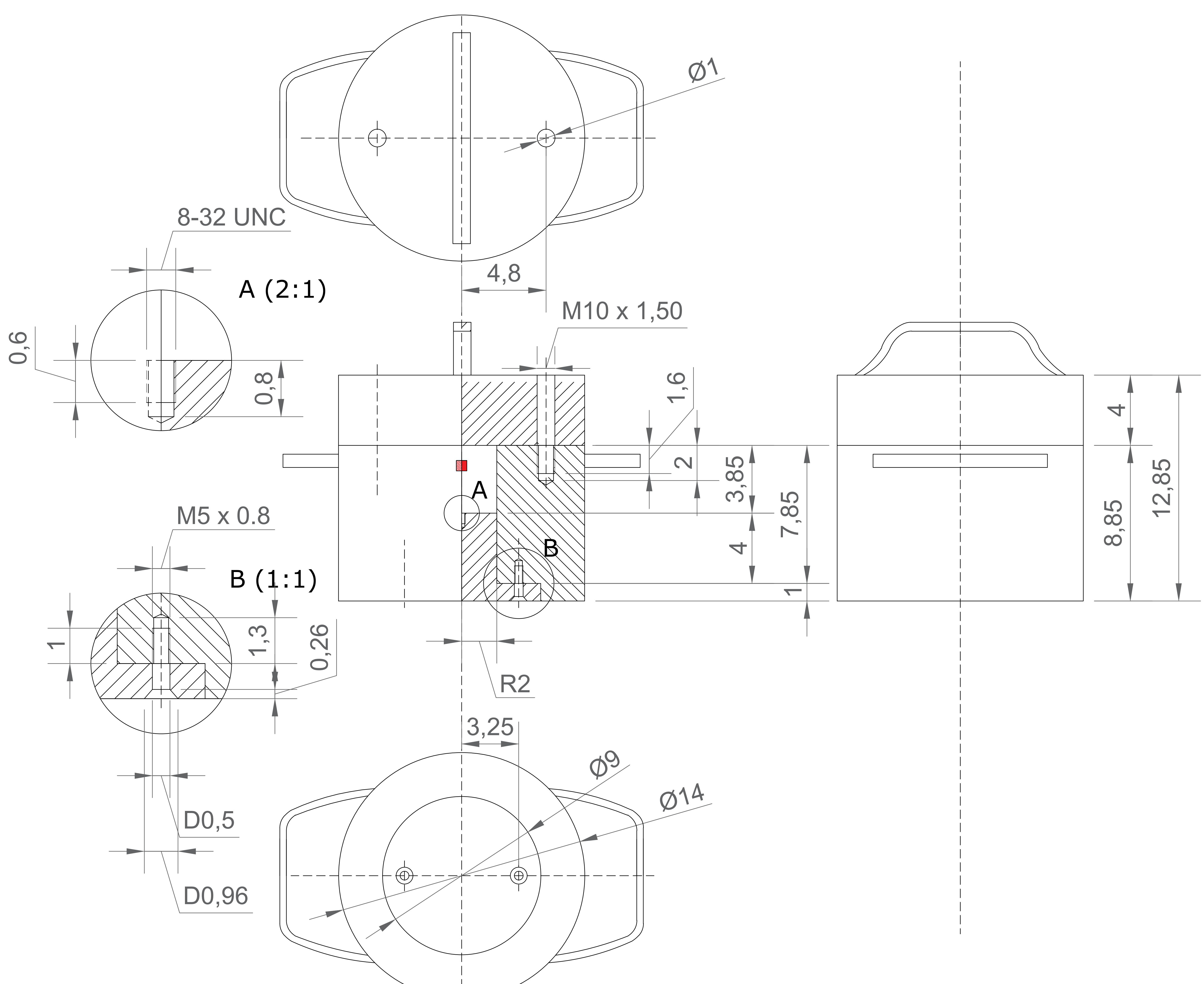
- Description of the type of accident.
- Date and time that occurred.
- People who have intervened in the emergency.
- External people that were present during the event.
- If applicable, medical report on clinical examinations, analyzes performed and possible injuries.
- Individualized equivalent doses estimated or measured.
- Estimated exposure time.
- Enumeration of the adopted measures.
- Relationship of the instrumentation and material used in the solution of the emergency.
- Treatment of radioactive waste produced.

B. Drawings

The following drawings referred to the source, the shield and the attenuators and collimators that will be used for the flight sessions are attached:

1. Shielding
2. Shielding_body
3. Shielding_support
4. Shielding_cover
5. 20º collimator disc
6. 40º collimator disc
7. 60º collimator disc
8. Collimator
9. 5 mm attenuator
10. Support rods
11. DIN 963 M5 screw
12. DIN 315 M10 wing nuts, German shape
13. Encapsulation
14. Active element

Note that drawings 13 and 14 are provided by the distribution company of the encapsulated source.



Cotas en cm

FUNCIÓN

BLINDAJE FUENTE RADIACTIVA DE Cs–137; 370 MBq

MATERIAL

PLOMO

UNIDADES

1 UNIDAD

ELEMENTO

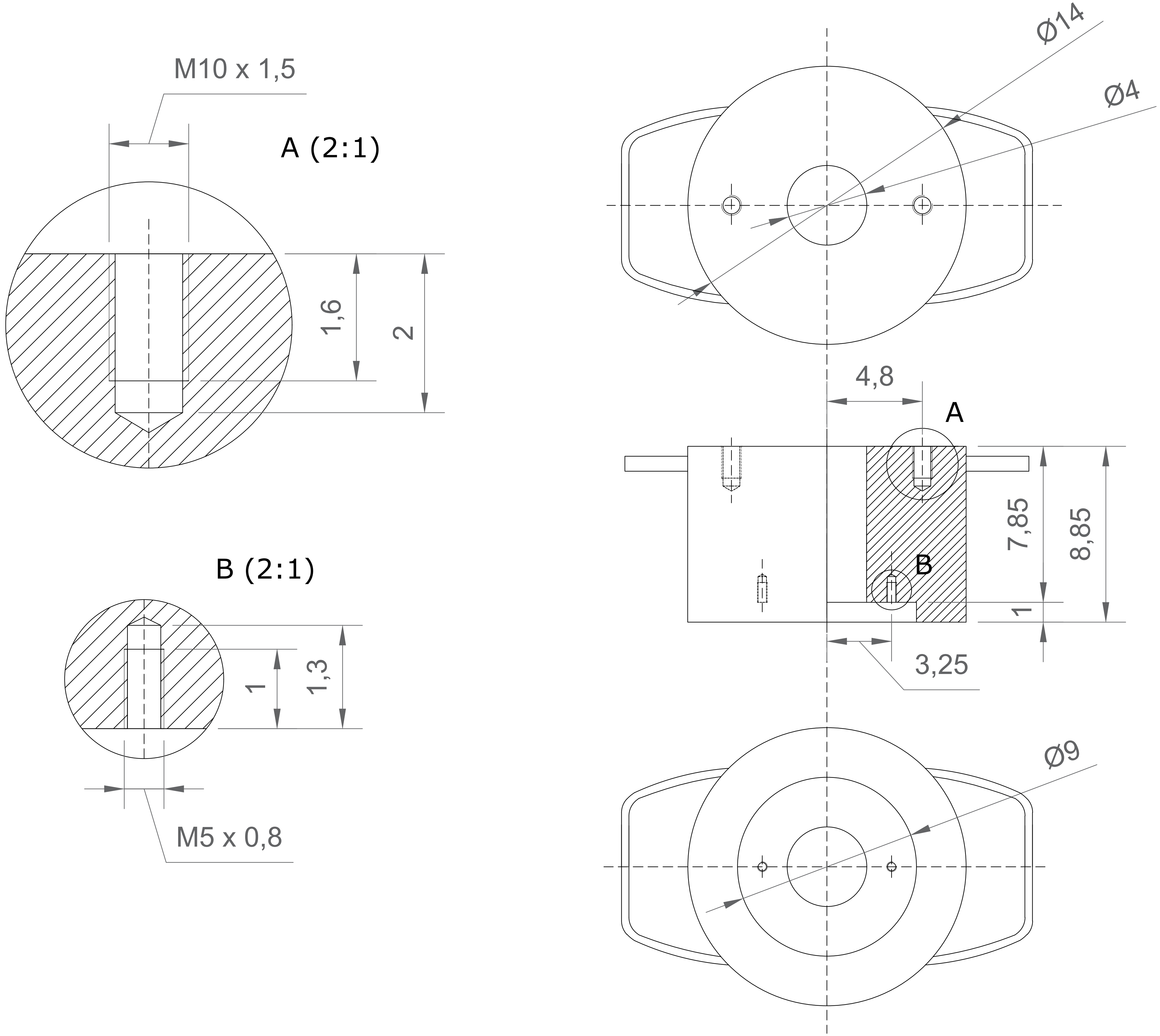
CONJUNTO

ESCALA	FECHA	N. PLANO
A3:1/2	Enero 2018	N – 01

DISEÑADOR

Arnau Prats Bota

Institut de Tècniques Energètiques (INTE)
- UPC -



Cotas en cm

FUNCIÓN
BLINDAR LAS PARTES LATERALES

MATERIAL
PLOMO

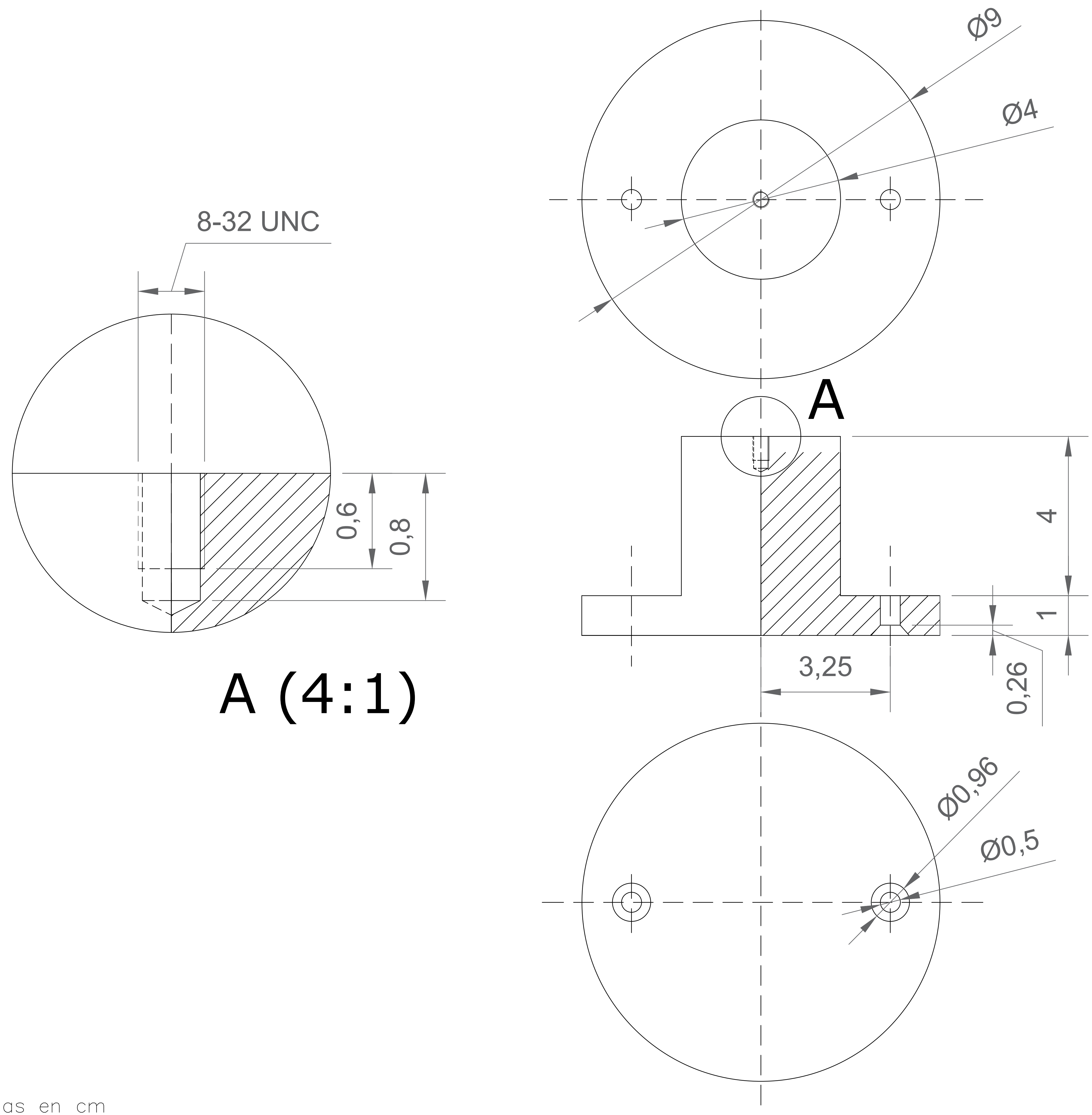
UNIDADES
1 UNIDAD

ELEMENTO		
PAREDES BLINDAJE		
ESCALA	FECHA	N. PLANO
A3:1/2	Enero 2018	N – 02

DISEÑADOR

Arnau Prats Bota

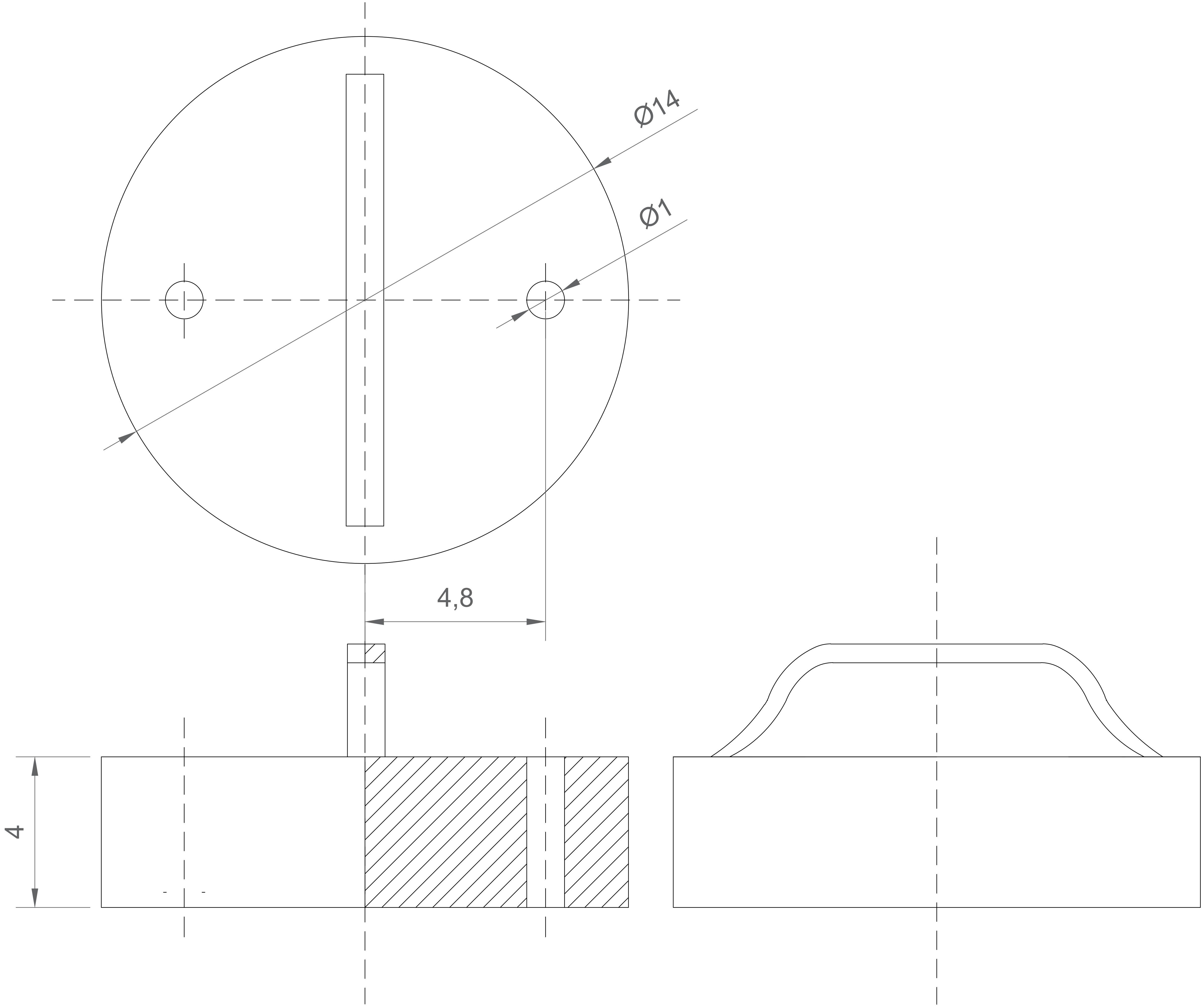
Institut de Tècniques Energètiques (INTE)
- UPC -



Cotas en cm

FUNCIÓN	SOPORTE PARA LA FUENTE Y BLINDAR LA PARTE INFERIOR
MATERIAL	PLOMO
UNIDADES	1 UNIDAD
ELEMENTO	SOPORTE FUENTE
ESCALA	A3:1/1
FECHA	Enero 2018
N. PLANO	N – 03
DISEÑADOR	Arnau Prats Bota

Institut de Tècniques Energètiques (INTE)
- UPC -



Cotas en cm

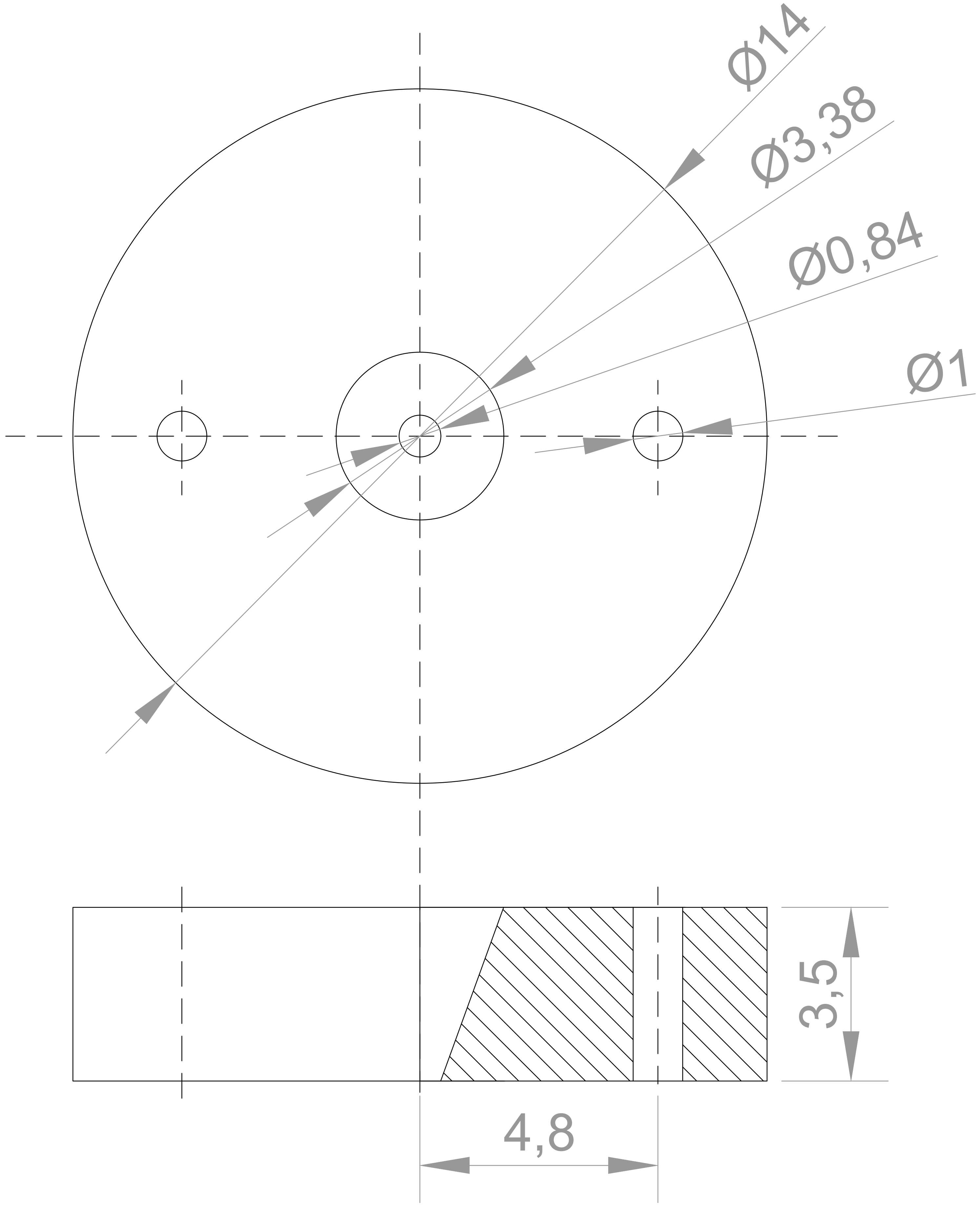
FUNCIÓN
CERRAR EL BLINDAJE Y BLINDAR LA PARTE SUPERIOR
MATERIAL
PLOMO
UNIDADES
1 UNIDAD
ELEMENTO
TAPA

ESCALA	FECHA	N. PLANO
A3:1/1	Enero 2018	N – 04

DISEÑADOR

Arnau Prats Bota

Institut de Tècniques Energètiques (INTE)
- UPC -



Cotas en cm

FUNCIÓN

FIJAR EL ÁNGULO DE IRRADIACIÓN DE LA FUENTE

MATERIAL

PLOMO

UNIDADES

1 UNIDAD

ELEMENTO

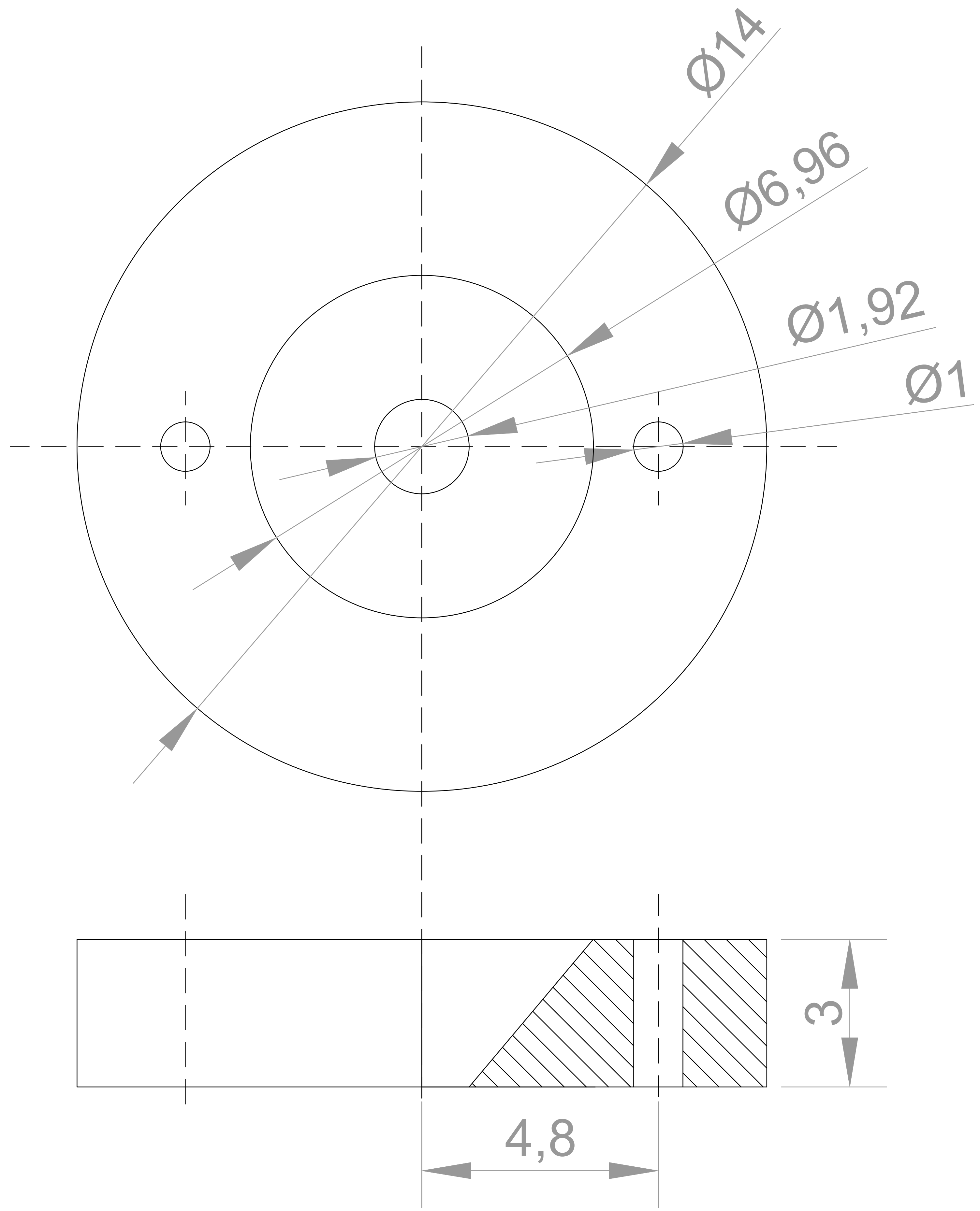
DISCO 20°

ESCALA	FECHA	N. PLANO
A3:1/1	Enero 2018	N – 05

DISEÑADOR

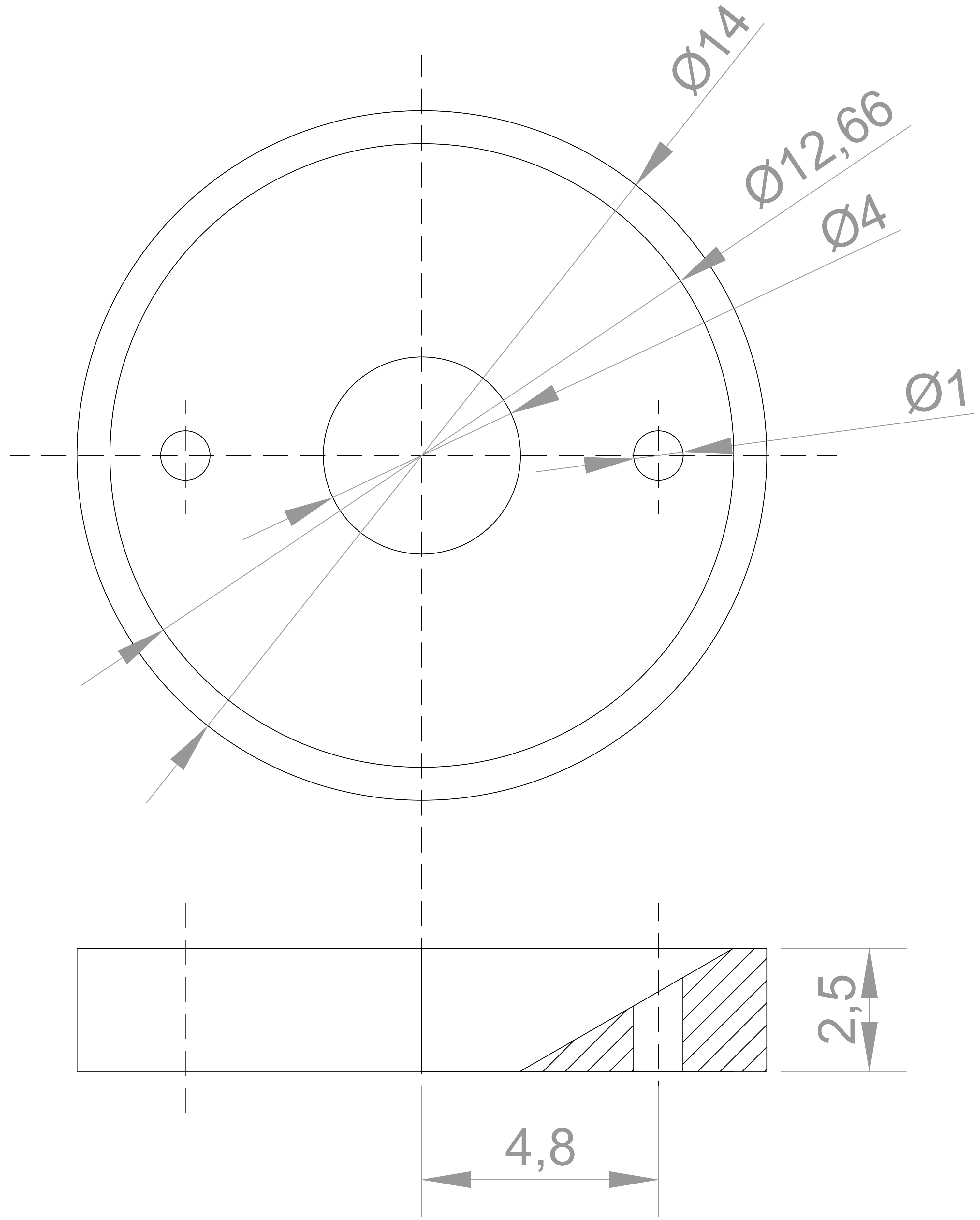
Arnau Prats Bota

Institut de Tècniques Energètiques (INTE)
- UPC -



Cotas en cm

FUNCIÓN		
FIJAR EL ÁNGULO DE IRRADIACIÓN DE LA FUENTE		
MATERIAL		
PLOMO		
UNIDADES		
1 UNIDAD		
ELEMENTO		
DISCO 40°		
ESCALA	FECHA	N. PLANO
A3:1/1	Enero 2018	N – 06
DISEÑADOR		
Arnau Prats Bota		
Institut de Tècniques Energètiques (INTE) - UPC -		



Cotas en cm

FUNCIÓN

FIJAR EL ÁNGULO DE
IRRADIACIÓN DE LA FUENTE

MATERIAL

PLOMO

UNIDADES

1 UNIDAD

ELEMENTO

DISCO 60°

ESCALA	FECHA	N. PLANO
A3:1/1	Enero 2018	N – 07

DISEÑADOR

Arnau Prats Bota

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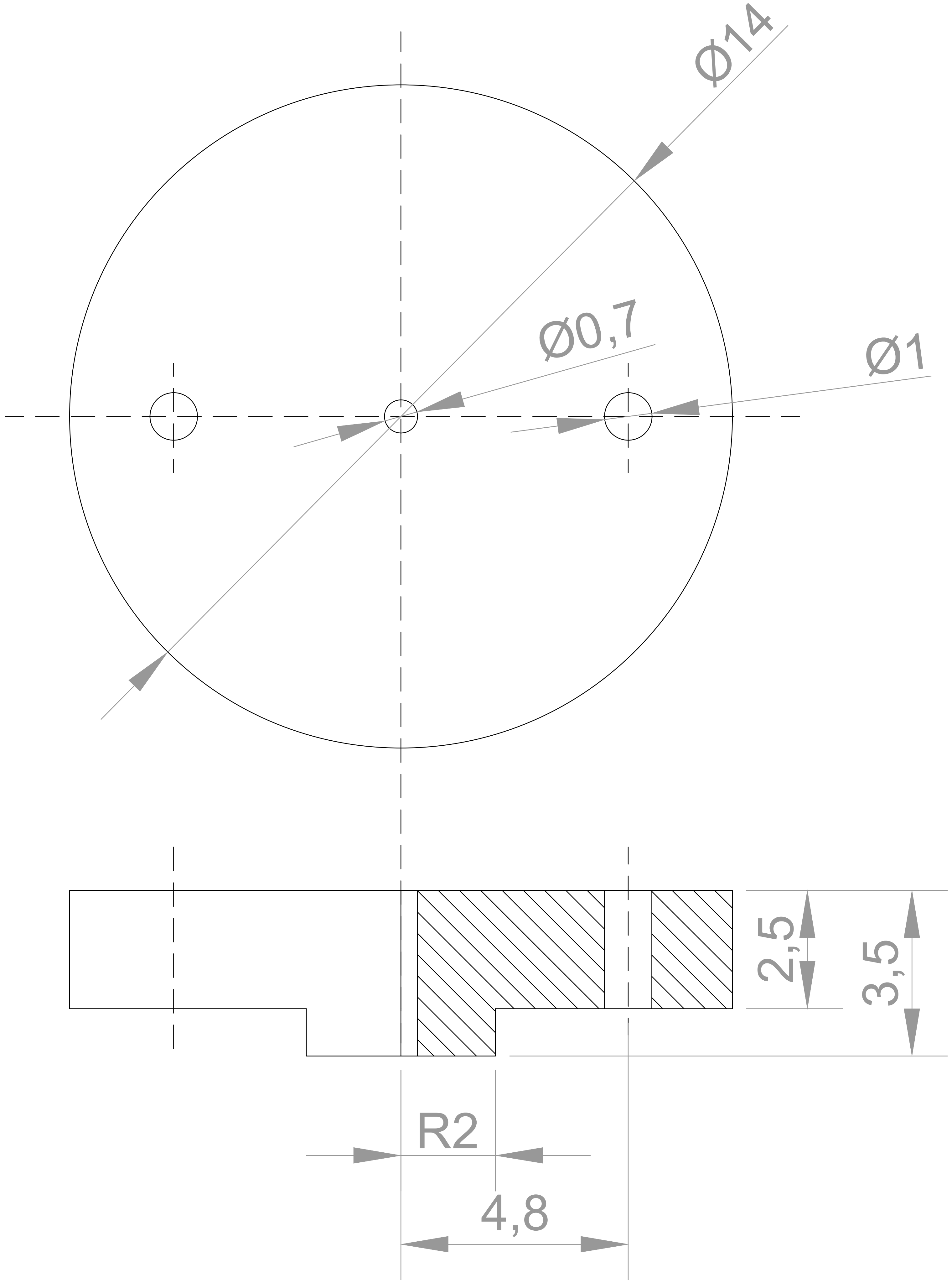
Energètiques (INTE)
- UPC -



Cotas en cm

FUNCIÓN

COLIMAR PERPENDICULARMENTE
EL HAZ DE FOTONES

MATERIAL

PLOMO

UNIDADES

1 UNIDAD

ELEMENTO

COLIMADOR

ESCALA	FECHA	N. PLANO
A3:1/1	Enero 2018	N – 08

DISEÑADOR

Arnau Prats Bota

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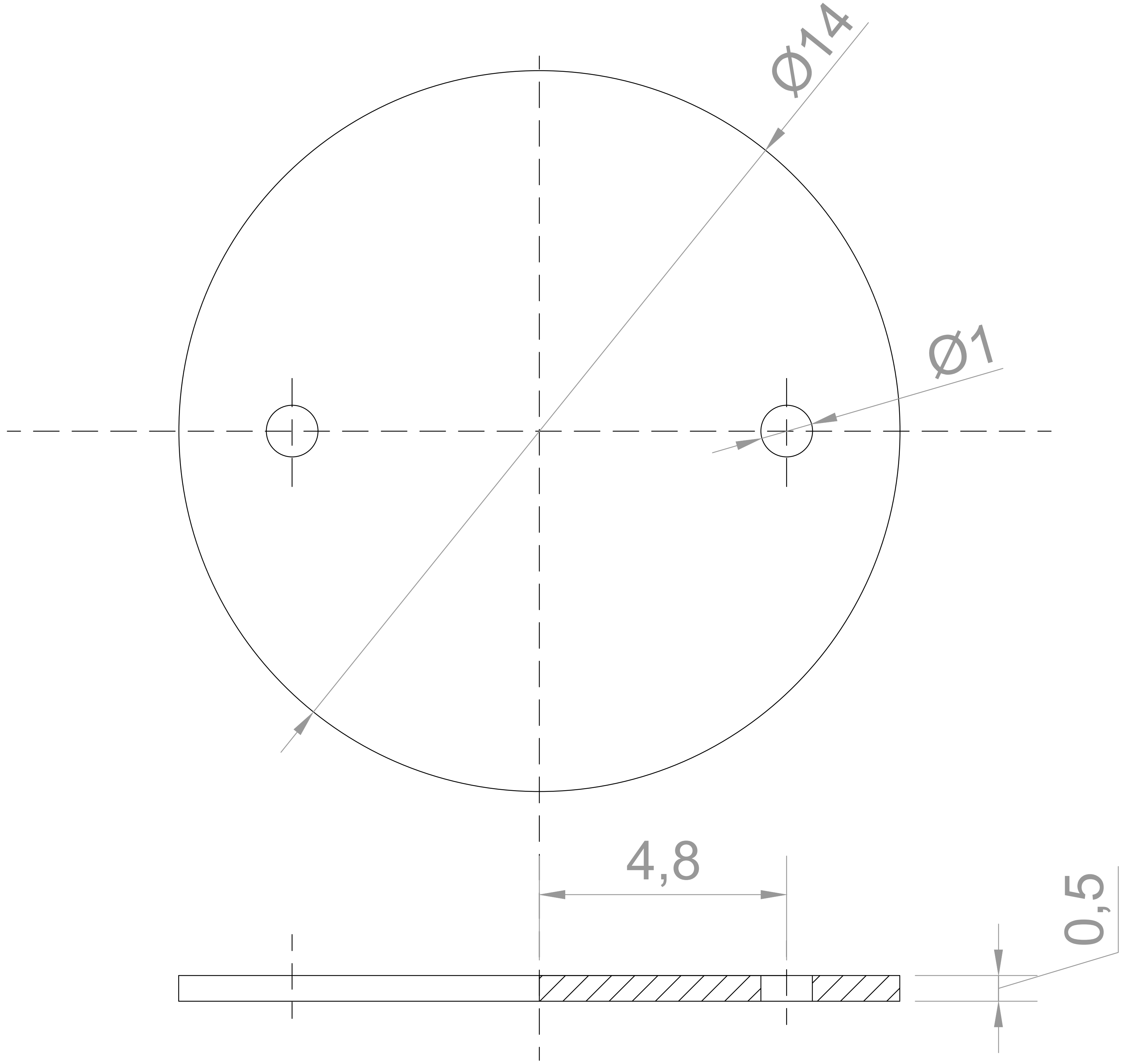
Energètiques (INTE)
- UPC -



Cotas en cm

FUNCIÓN

ATENUAR EL FLUJO DE FOTONES

MATERIAL

PLOMO

UNIDADES

3 UNIDADES

ELEMENTO

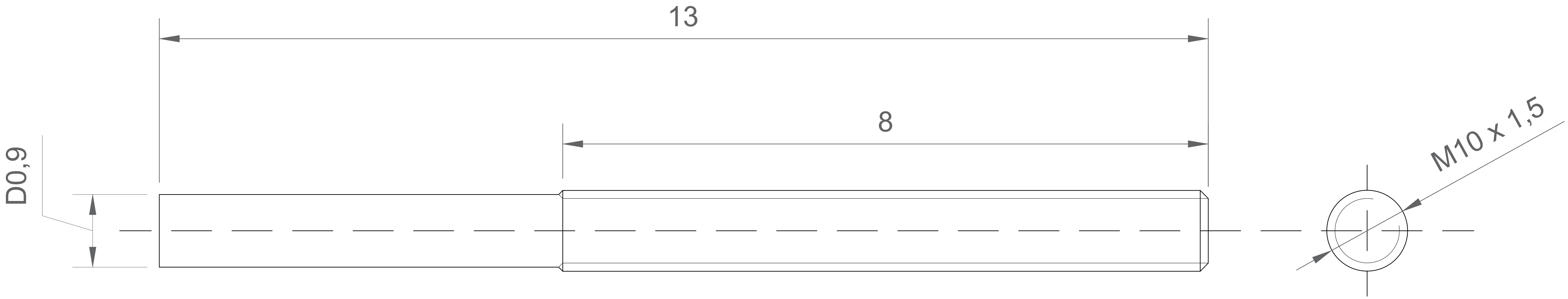
ATENUADOR 5mm

ESCALA	FECHA	N. PLANO
A3:1/1	Enero 2018	N – 09

DISEÑADOR

Arnau Prats Bota

Institut de Tècniques Energètiques (INTE)
- UPC -



FUNCIÓN

SOPORTE PARA LA TAPA, DISCOS
Y ATENUADORES

MATERIAL

ACERO

UNIDADES

4 UNIDADES

ELEMENTO

BARRA DE SOPORTE

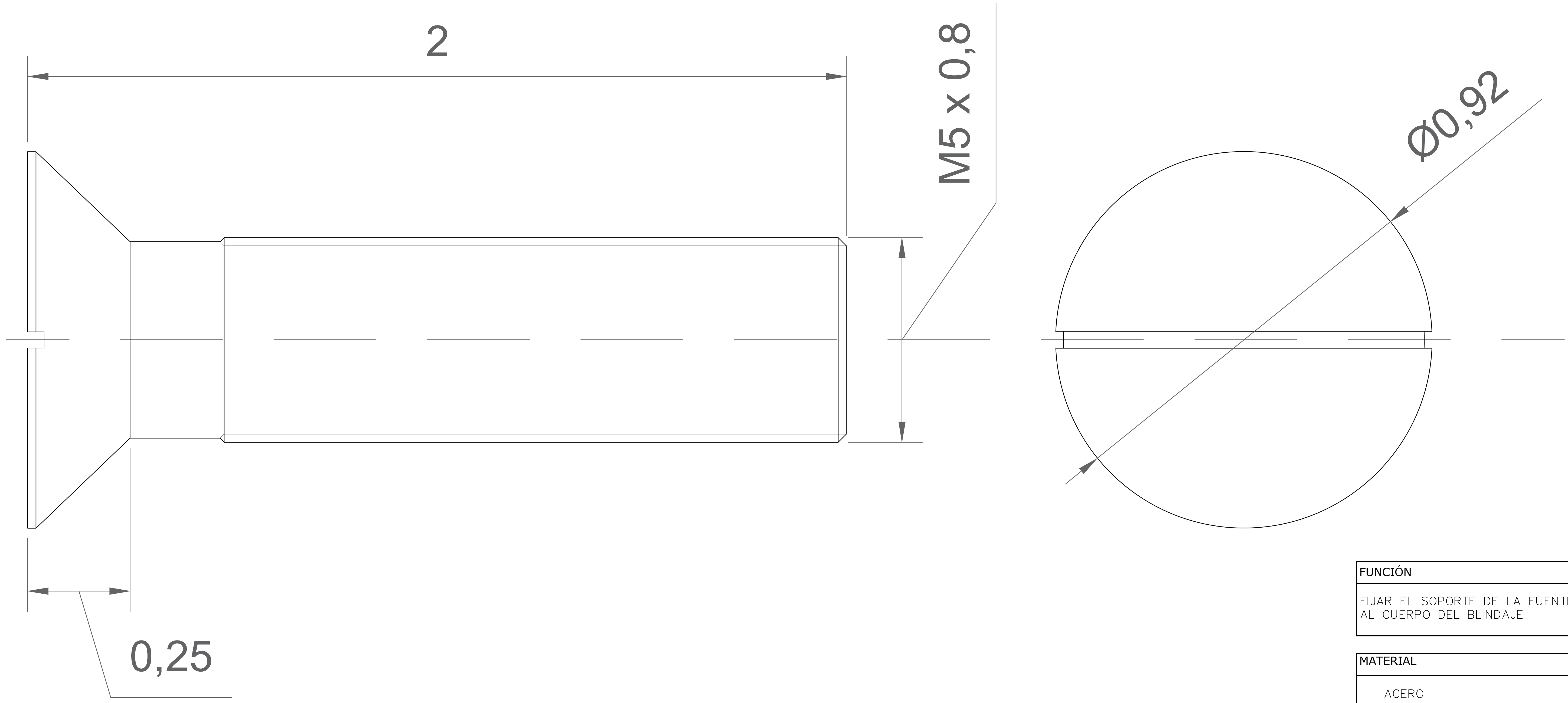
ESCALA	FECHA	N. PLANO
A3:2/1	Enero 2018	N – 10

DISEÑADOR

Arnau Prats Bota

Institut de Tècniques
Energètiques (INTE)
- UPC -

Cotas en cm



Cotas en cm

FUNCIÓN

FIJAR EL SOPORTE DE LA FUENTE AL CUERPO DEL BLINDAJE

MATERIAL

ACERO

UNIDADES

2 UNIDADES

ELEMENTO

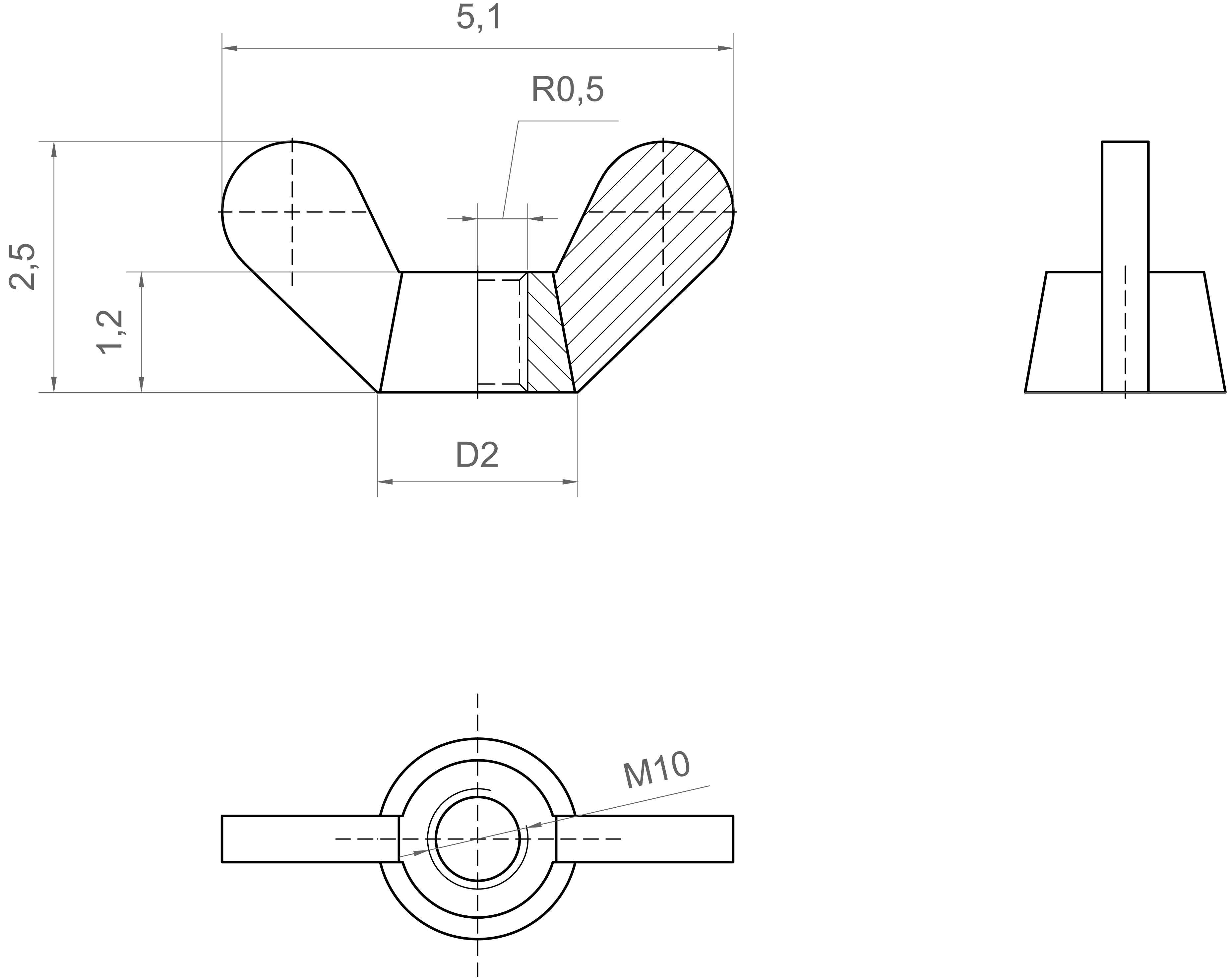
TORNILLO DIN 963 M5

ESCALA	FECHA	N. PLANO
A3:10/1	Enero 2018	N – 11

DISEÑADOR

Arnau Prats Bota

Institut de Tècniques Energètiques (INTE)
- UPC -



Cotas en cm

FUNCIÓN

FIJAR LA TAPA DEL BLINDAJE AL CUERPO

MATERIAL

ACERO

UNIDADES

2 UNIDADES

ELEMENTO

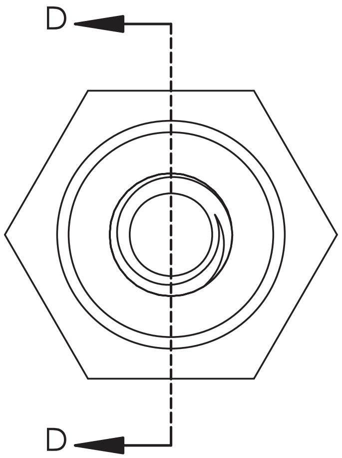
TUERCA DE MARIPOSA DIN 315 M10, FORMA ALEMANA

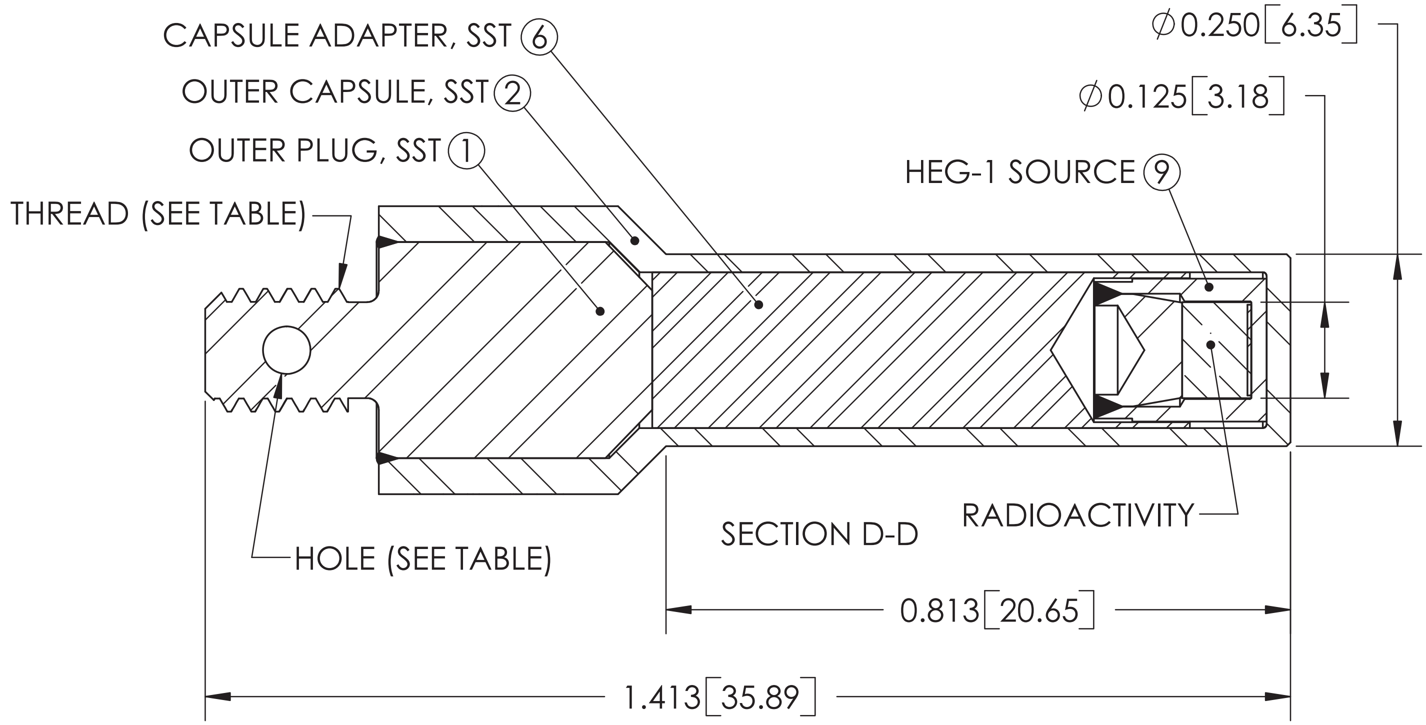
ESCALA	FECHA	N. PLANO
A3:2/1	Enero 2018	N – 12

DISEÑADOR

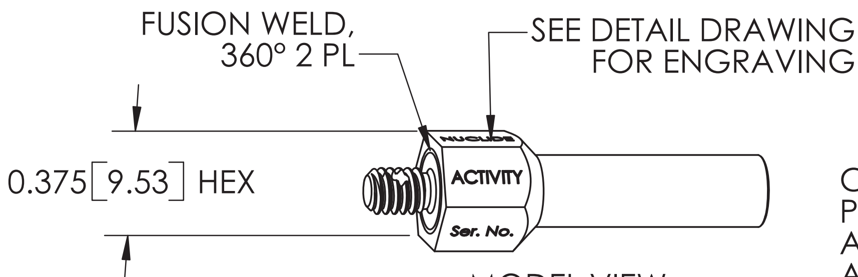
Arnau Prats Bota

Institut de Tècniques Energètiques (INTE)
- UPC -





SECTION D-D



MODEL VIEW
(NOT TO SCALE)

CONFIGURATION TABLE

P/N	THREAD	HOLE
A3011-4-1	8-32 UNC-3A	∅0.062 THRU
A3011-4-2	6-32 UNC-3A	NONE

2. FUSION WELD AS REQUIRED.
1. ASSEMBLE PER ENGINEERING DRAWING
NOTES: UNLESS OTHERWISE SPECIFIED

P/N A3011-4 SOURCE WITH S3000 INNER

Isotope Products Laboratories
An Eckert & Ziegler Company
VALENCIA, CALIFORNIA 91355

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCH-SIZES. METRIC UNITS [mm] ARE IN MILLIMETERS.

TOLERANCES (UNLESS OTHERWISE SPECIFIED)

X.XXX	± .002	INCH	ANGULAR TOLERANCE OF 0°±30'
X.XX	± .005	INCH	FRACTIONAL DIMENSIONS ± 1/32"
X.X	± .03	INCH	REFERENCE DIMENSIONS () N/A
X.	± .1	INCH	SURFACE ROUGHNESS µINCH MAX

ALL DIMENSIONS ARE FINISHED DIMENSIONS

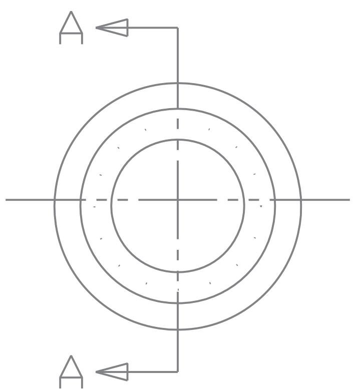
THIRD ANGLE PROJECTION

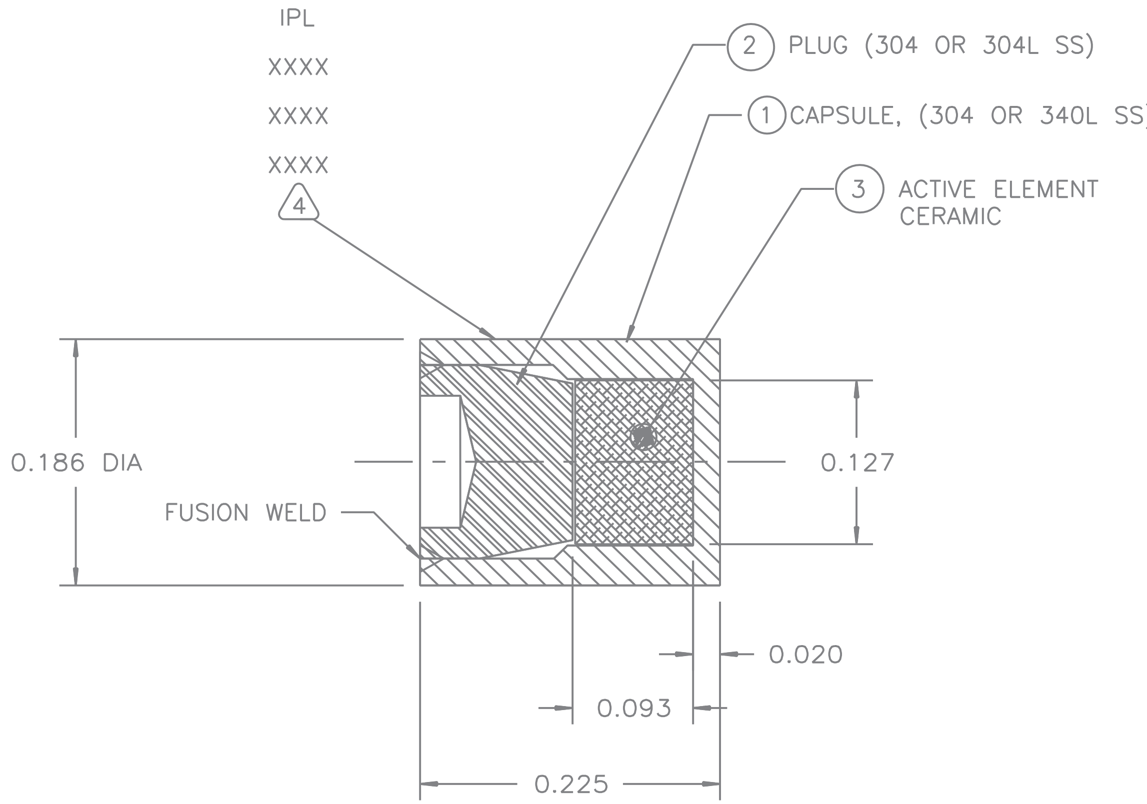
DRAWN JJK/RLT
ME/CHECKER LF/GG
ENGINEER JMD/RT
SCALE NONE
SIZE A

TITLE
HIGH INTENSITY GAMMA SOURCE MODEL HEG

SERIES TITLE
HIGH INTENSITY GAMMA AND NEUTRON SOURCES (HEG SERIES CAPSULES 193, 225 AND N-252)

CAGE CODE	DRAWING NO.	REV	SHEET
32993	3011	K	8 OF 15





P/N: A3025 ASSEMBLY

SECTION A—A

5. PACKAGE AND IDENTIFY PART NUMBER THEREON

4. ENGRAVE CHARACTERS 0.060 HIGH x 0.003 DEEP MAX
ON CIRCUMFERENCE AND BLACK FILL WHEN NOT INSTALLED IN SECONDARY CAPSULE:
IPL
ISOTOPE
ACTIVITY
SERIAL NUMBER

3. TOLERANCES: 0.XXX ± 0.002, 0.XX ± 0.01, 0.X ± 0.1, ANGLE ± 0.5 °
2. DIMENSIONS ARE IN INCHES
1. ASSEMBLE COMPLETE PER ENGINEERING DRAWING
AND FUSION WELD AS REQUIRED

NOTE: UNLESS OTHERWISE SPECIFIED

DATE: 12/29/94	SCALE: NTS	DRAWING NUMBER 3025	SHEET: 3 OF 3
DESIGNED: JMD/RLT	REV/CHG: –		

C. Microshield results

The complete results of the following simulations carried out with the MicroShield® are attached for the different cases described in Annex A "SAFETY STUDY":

- Sensitivity analysis to determine the lead thickness of the shielding and effective dose on the surface of the package.
- Equivalent dose in hand at 3cm for the source installation.
- Effective dose at 50 cm without shielding for installation and changes of attenuators and collimators.
- Effective dose at 1 m for transport.
- Equivalent dose in hand in contact with the shielding for the handling of the shielding.
- Effective dose at 30 cm for the handling of the shielding.
- Equivalent dose in hand in contact with the encapsulation for the smear of the leakage tests.
- Effective dose at 5 m for the people present during the flight sessions.
- Equivalent dose in hand in contact with the package for exposure rate tests.

MicroShield 7.00 (06-MSD-7.00-1120)
UPC
Conversion of calculated exposure in air to dose
FILE: C:\Users\TEMP\Desktop\point source.ms6
Case Title: Side-shield sensitivity analysis for lead thickness determination
This case was run on martes, febrero 13, 2018 at 10:36:24 Dose Point # 1 - (40,0,0) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Reference Case for Shield #2			
Photon Fluence Rate (flux)	Photons/cm²/sec	2,460e+002	4,571e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,627e+002	3,024e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	3,155e-001	5,863e-001
Absorbed Dose Rate in Air	mGy/hr	2,754e-003	5,118e-003
"	mrad/hr	2,754e-001	5,118e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,261e-003	6,060e-003
o Opposed	"	2,611e-003	4,852e-003
o Rotational	"	2,611e-003	4,852e-003
o Isotropic	"	2,309e-003	4,290e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,466e-003	6,441e-003
o Opposed	"	3,292e-003	6,117e-003
o Rotational	"	3,292e-003	6,117e-003
o Isotropic	"	2,468e-003	4,586e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,883e-003	5,358e-003
o Posterior/Anterior	"	2,545e-003	4,730e-003
o Lateral	"	1,887e-003	3,507e-003
o Rotational	"	2,274e-003	4,227e-003
o Isotropic	"	1,936e-003	3,598e-003
Sensitivity Case Number 1 of 11	Variable:	Shield #2	(3 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	4,448e+002	7,890e+002
Photon Energy Fluence Rate	MeV/cm²/sec	2,943e+002	5,220e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	5,706e-001	1,012e+000
Absorbed Dose Rate in Air	mGy/hr	4,981e-003	8,835e-003
"	mrad/hr	4,981e-001	8,835e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	5,898e-003	1,046e-002
o Opposed	"	4,722e-003	8,375e-003
o Rotational	"	4,722e-003	8,375e-003
o Isotropic	"	4,175e-003	7,406e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6,268e-003	1,112e-002
o Opposed	"	5,954e-003	1,056e-002
o Rotational	"	5,954e-003	1,056e-002
o Isotropic	"	4,464e-003	7,917e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	5,215e-003	9,249e-003
o Posterior/Anterior	"	4,603e-003	8,164e-003
o Lateral	"	3,413e-003	6,054e-003
o Rotational	"	4,113e-003	7,295e-003
o Isotropic	"	3,502e-003	6,211e-003

Results (Summed over energies)	Units	Without Buildup	With Buildup
Sensitivity Case Number 2 of 11	Variable:	Shield #2	(3,1 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	3,951e+002	7,076e+002
Photon Energy Fluence Rate	MeV/cm²/sec	2,614e+002	4,682e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	5,068e-001	9,077e-001
Absorbed Dose Rate in Air	mGy/hr	4,425e-003	7,924e-003
"	mrad/hr	4,425e-001	7,924e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	5,239e-003	9,382e-003
o Opposed	"	4,194e-003	7,511e-003
o Rotational	"	4,194e-003	7,511e-003
o Isotropic	"	3,709e-003	6,642e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	5,568e-003	9,971e-003
o Opposed	"	5,288e-003	9,471e-003
o Rotational	"	5,288e-003	9,471e-003
o Isotropic	"	3,965e-003	7,101e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	4,632e-003	8,296e-003
o Posterior/Anterior	"	4,089e-003	7,322e-003
o Lateral	"	3,032e-003	5,430e-003
o Rotational	"	3,654e-003	6,543e-003
o Isotropic	"	3,110e-003	5,571e-003
Sensitivity Case Number 3 of 11	Variable:	Shield #2	(3,2 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	3,510e+002	6,345e+002
Photon Energy Fluence Rate	MeV/cm²/sec	2,322e+002	4,198e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	4,502e-001	8,139e-001
Absorbed Dose Rate in Air	mGy/hr	3,930e-003	7,106e-003
"	mrad/hr	3,930e-001	7,106e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4,653e-003	8,413e-003
o Opposed	"	3,725e-003	6,736e-003
o Rotational	"	3,725e-003	6,736e-003
o Isotropic	"	3,294e-003	5,956e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4,946e-003	8,941e-003
o Opposed	"	4,697e-003	8,493e-003
o Rotational	"	4,697e-003	8,493e-003
o Isotropic	"	3,522e-003	6,367e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	4,114e-003	7,439e-003
o Posterior/Anterior	"	3,632e-003	6,566e-003
o Lateral	"	2,693e-003	4,869e-003
o Rotational	"	3,245e-003	5,868e-003
o Isotropic	"	2,763e-003	4,995e-003
Sensitivity Case Number 4 of 11	Variable:	Shield #2	(3,3 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	3,117e+002	5,689e+002
Photon Energy Fluence Rate	MeV/cm²/sec	2,063e+002	3,764e+002

Results (Summed over energies)	Units	Without Buildup	With Buildup
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	3,999e-001	7,297e-001
Absorbed Dose Rate in Air	mGy/hr	3,491e-003	6,370e-003
"	mrad/hr	3,491e-001	6,370e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4,133e-003	7,542e-003
o Opposed	"	3,309e-003	6,039e-003
o Rotational	"	3,309e-003	6,039e-003
o Isotropic	"	2,926e-003	5,340e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4,393e-003	8,016e-003
o Opposed	"	4,172e-003	7,614e-003
o Rotational	"	4,172e-003	7,614e-003
o Isotropic	"	3,128e-003	5,708e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	3,655e-003	6,669e-003
o Posterior/Anterior	"	3,226e-003	5,887e-003
o Lateral	"	2,392e-003	4,365e-003
o Rotational	"	2,883e-003	5,260e-003
o Isotropic	"	2,454e-003	4,478e-003

Sensitivity Case Number 5 of 11	Variable:	Shield #2	(3,4 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	2,769e+002	5,100e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,832e+002	3,374e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	3,552e-001	6,541e-001
Absorbed Dose Rate in Air	mGy/hr	3,101e-003	5,711e-003
"	mrad/hr	3,101e-001	5,711e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,671e-003	6,761e-003
o Opposed	"	2,939e-003	5,413e-003
o Rotational	"	2,939e-003	5,413e-003
o Isotropic	"	2,599e-003	4,787e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,902e-003	7,186e-003
o Opposed	"	3,706e-003	6,825e-003
o Rotational	"	3,706e-003	6,825e-003
o Isotropic	"	2,779e-003	5,117e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	3,246e-003	5,978e-003
o Posterior/Anterior	"	2,865e-003	5,277e-003
o Lateral	"	2,125e-003	3,913e-003
o Rotational	"	2,561e-003	4,716e-003
o Isotropic	"	2,180e-003	4,014e-003

Sensitivity Case Number 6 of 11	Variable:	Shield #2	(3,5 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	2,460e+002	4,571e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,627e+002	3,024e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	3,155e-001	5,863e-001
Absorbed Dose Rate in Air	mGy/hr	2,754e-003	5,118e-003
"	mrad/hr	2,754e-001	5,118e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		

Results (Summed over energies)	Units	Without Buildup	With Buildup
o Parallel Geometry	mSv/hr	3,261e-003	6,060e-003
o Opposed	"	2,611e-003	4,852e-003
o Rotational	"	2,611e-003	4,852e-003
o Isotropic	"	2,309e-003	4,290e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,466e-003	6,441e-003
o Opposed	"	3,292e-003	6,117e-003
o Rotational	"	3,292e-003	6,117e-003
o Isotropic	"	2,468e-003	4,586e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,883e-003	5,358e-003
o Posterior/Anterior	"	2,545e-003	4,730e-003
o Lateral	"	1,887e-003	3,507e-003
o Rotational	"	2,274e-003	4,227e-003
o Isotropic	"	1,936e-003	3,598e-003

Sensitivity Case Number 7 of 11	Variable:	Shield #2	(3,6 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	2,185e+002	4,096e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,446e+002	2,710e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	2,802e-001	5,255e-001
Absorbed Dose Rate in Air	mGy/hr	2,447e-003	4,587e-003
"	mrad/hr	2,447e-001	4,587e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,897e-003	5,431e-003
o Opposed	"	2,319e-003	4,348e-003
o Rotational	"	2,319e-003	4,348e-003
o Isotropic	"	2,051e-003	3,845e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,079e-003	5,772e-003
o Opposed	"	2,924e-003	5,483e-003
o Rotational	"	2,924e-003	5,483e-003
o Isotropic	"	2,192e-003	4,110e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,561e-003	4,802e-003
o Posterior/Anterior	"	2,261e-003	4,239e-003
o Lateral	"	1,676e-003	3,143e-003
o Rotational	"	2,020e-003	3,788e-003
o Isotropic	"	1,720e-003	3,225e-003

Sensitivity Case Number 8 of 11	Variable:	Shield #2	(3,7 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	1,941e+002	3,671e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,284e+002	2,429e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	2,489e-001	4,709e-001
Absorbed Dose Rate in Air	mGy/hr	2,173e-003	4,111e-003
"	mrad/hr	2,173e-001	4,111e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,573e-003	4,867e-003
o Opposed	"	2,060e-003	3,897e-003
o Rotational	"	2,060e-003	3,897e-003
o Isotropic	"	1,822e-003	3,446e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		

Results (Summed over energies)	Units	Without Buildup	With Buildup
o Parallel Geometry	mSv/hr	2,735e-003	5,173e-003
o Opposed	"	2,597e-003	4,913e-003
o Rotational	"	2,597e-003	4,913e-003
o Isotropic	"	1,947e-003	3,684e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,275e-003	4,303e-003
o Posterior/Anterior	"	2,008e-003	3,799e-003
o Lateral	"	1,489e-003	2,817e-003
o Rotational	"	1,794e-003	3,394e-003
o Isotropic	"	1,528e-003	2,890e-003

Sensitivity Case Number 9 of 11	Variable:	Shield #2	(3,8 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	1,724e+002	3,289e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,141e+002	2,176e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	2,211e-001	4,219e-001
Absorbed Dose Rate in Air	mGy/hr	1,930e-003	3,683e-003
"	mrad/hr	1,930e-001	3,683e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,285e-003	4,361e-003
o Opposed	"	1,830e-003	3,492e-003
o Rotational	"	1,830e-003	3,492e-003
o Isotropic	"	1,618e-003	3,088e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,429e-003	4,635e-003
o Opposed	"	2,307e-003	4,402e-003
o Rotational	"	2,307e-003	4,402e-003
o Isotropic	"	1,730e-003	3,301e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,021e-003	3,856e-003
o Posterior/Anterior	"	1,784e-003	3,404e-003
o Lateral	"	1,323e-003	2,524e-003
o Rotational	"	1,594e-003	3,042e-003
o Isotropic	"	1,357e-003	2,589e-003

Sensitivity Case Number 10 of 11	Variable:	Shield #2	(3,9 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	1,531e+002	2,947e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,013e+002	1,950e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1,964e-001	3,780e-001
Absorbed Dose Rate in Air	mGy/hr	1,715e-003	3,300e-003
"	mrad/hr	1,715e-001	3,300e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,030e-003	3,907e-003
o Opposed	"	1,625e-003	3,128e-003
o Rotational	"	1,625e-003	3,128e-003
o Isotropic	"	1,437e-003	2,766e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,158e-003	4,153e-003
o Opposed	"	2,049e-003	3,944e-003
o Rotational	"	2,049e-003	3,944e-003
o Isotropic	"	1,536e-003	2,957e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		

Results (Summed over energies)	Units	Without Buildup	With Buildup
o Anterior/Posterior Geometry	mSv/hr	1,795e-003	3,455e-003
o Posterior/Anterior	"	1,584e-003	3,050e-003
o Lateral	"	1,175e-003	2,261e-003
o Rotational	"	1,416e-003	2,725e-003
o Isotropic	"	1,205e-003	2,320e-003
Sensitivity Case Number 11 of 11	Variable:	Shield #2	(4 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	1,360e+002	2,640e+002
Photon Energy Fluence Rate	MeV/cm²/sec	8,999e+001	1,747e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1,745e-001	3,387e-001
Absorbed Dose Rate in Air	mGy/hr	1,523e-003	2,957e-003
"	mrad/hr	1,523e-001	2,957e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,803e-003	3,500e-003
o Opposed	"	1,444e-003	2,803e-003
o Rotational	"	1,444e-003	2,803e-003
o Isotropic	"	1,277e-003	2,478e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,917e-003	3,720e-003
o Opposed	"	1,820e-003	3,534e-003
o Rotational	"	1,820e-003	3,534e-003
o Isotropic	"	1,365e-003	2,649e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1,594e-003	3,095e-003
o Posterior/Anterior	"	1,407e-003	2,732e-003
o Lateral	"	1,044e-003	2,026e-003
o Rotational	"	1,258e-003	2,441e-003
o Isotropic	"	1,071e-003	2,078e-003

MicroShield 7.00 (06-MSD-7.00-1120)
UPC
Conversion of calculated exposure in air to dose
FILE: C:\Users\TEMP\Desktop\end shield.ms6
Case Title: End-shield sensitivity analysis for lead thickness determination
This case was run on viernes, febrero 16, 2018 at 10:25:04 Dose Point # 1 - (0,40,3,0) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Reference Case for Shield #2			
Photon Fluence Rate (flux)	Photons/cm²/sec	2,474e+002	4,596e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,637e+002	3,041e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	3,173e-001	5,895e-001
Absorbed Dose Rate in Air	mGy/hr	2,770e-003	5,146e-003
"	mrad/hr	2,770e-001	5,146e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,280e-003	6,093e-003
o Opposed	"	2,626e-003	4,878e-003
o Rotational	"	2,626e-003	4,878e-003
o Isotropic	"	2,322e-003	4,314e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,486e-003	6,476e-003
o Opposed	"	3,311e-003	6,151e-003
o Rotational	"	3,311e-003	6,151e-003
o Isotropic	"	2,482e-003	4,612e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,900e-003	5,388e-003
o Posterior/Anterior	"	2,560e-003	4,756e-003
o Lateral	"	1,898e-003	3,526e-003
o Rotational	"	2,288e-003	4,250e-003
o Isotropic	"	1,947e-003	3,618e-003
Sensitivity Case Number 1 of 11	Variable:	Shield #2	(3 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	4,473e+002	7,931e+002
Photon Energy Fluence Rate	MeV/cm²/sec	2,960e+002	5,247e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	5,738e-001	1,017e+000
Absorbed Dose Rate in Air	mGy/hr	5,009e-003	8,881e-003
"	mrad/hr	5,009e-001	8,881e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	5,930e-003	1,051e-002
o Opposed	"	4,748e-003	8,418e-003
o Rotational	"	4,748e-003	8,418e-003
o Isotropic	"	4,199e-003	7,444e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6,303e-003	1,118e-002
o Opposed	"	5,986e-003	1,061e-002
o Rotational	"	5,986e-003	1,061e-002
o Isotropic	"	4,488e-003	7,958e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	5,244e-003	9,297e-003
o Posterior/Anterior	"	4,628e-003	8,206e-003
o Lateral	"	3,432e-003	6,085e-003
o Rotational	"	4,136e-003	7,333e-003
o Isotropic	"	3,521e-003	6,243e-003

Results (Summed over energies)	Units	Without Buildup	With Buildup
Sensitivity Case Number 2 of 11	Variable:	Shield #2	(3,1 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	3,973e+002	7,114e+002
Photon Energy Fluence Rate	MeV/cm²/sec	2,629e+002	4,707e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	5,097e-001	9,125e-001
Absorbed Dose Rate in Air	mGy/hr	4,449e-003	7,966e-003
"	mrad/hr	4,449e-001	7,966e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	5,268e-003	9,431e-003
o Opposed	"	4,218e-003	7,551e-003
o Rotational	"	4,218e-003	7,551e-003
o Isotropic	"	3,730e-003	6,677e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	5,599e-003	1,002e-002
o Opposed	"	5,318e-003	9,521e-003
o Rotational	"	5,318e-003	9,521e-003
o Isotropic	"	3,987e-003	7,138e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	4,658e-003	8,339e-003
o Posterior/Anterior	"	4,111e-003	7,361e-003
o Lateral	"	3,049e-003	5,458e-003
o Rotational	"	3,674e-003	6,578e-003
o Isotropic	"	3,128e-003	5,600e-003
Sensitivity Case Number 3 of 11	Variable:	Shield #2	(3,2 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	3,530e+002	6,379e+002
Photon Energy Fluence Rate	MeV/cm²/sec	2,335e+002	4,221e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	4,527e-001	8,183e-001
Absorbed Dose Rate in Air	mGy/hr	3,952e-003	7,143e-003
"	mrad/hr	3,952e-001	7,143e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4,679e-003	8,458e-003
o Opposed	"	3,747e-003	6,771e-003
o Rotational	"	3,747e-003	6,771e-003
o Isotropic	"	3,313e-003	5,988e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4,973e-003	8,989e-003
o Opposed	"	4,724e-003	8,538e-003
o Rotational	"	4,724e-003	8,538e-003
o Isotropic	"	3,542e-003	6,401e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	4,138e-003	7,478e-003
o Posterior/Anterior	"	3,652e-003	6,601e-003
o Lateral	"	2,708e-003	4,895e-003
o Rotational	"	3,264e-003	5,899e-003
o Isotropic	"	2,778e-003	5,022e-003
Sensitivity Case Number 4 of 11	Variable:	Shield #2	(3,3 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	3,135e+002	5,719e+002
Photon Energy Fluence Rate	MeV/cm²/sec	2,074e+002	3,784e+002

Results (Summed over energies)	Units	Without Buildup	With Buildup
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	4,022e-001	7,336e-001
Absorbed Dose Rate in Air	mGy/hr	3,511e-003	6,405e-003
"	mrad/hr	3,511e-001	6,405e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4,157e-003	7,583e-003
o Opposed	"	3,328e-003	6,071e-003
o Rotational	"	3,328e-003	6,071e-003
o Isotropic	"	2,943e-003	5,369e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4,418e-003	8,059e-003
o Opposed	"	4,196e-003	7,655e-003
o Rotational	"	4,196e-003	7,655e-003
o Isotropic	"	3,146e-003	5,739e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	3,675e-003	6,705e-003
o Posterior/Anterior	"	3,244e-003	5,918e-003
o Lateral	"	2,406e-003	4,389e-003
o Rotational	"	2,899e-003	5,289e-003
o Isotropic	"	2,468e-003	4,502e-003

Sensitivity Case Number 5 of 11	Variable:	Shield #2	(3,4 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	2,785e+002	5,127e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,843e+002	3,392e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	3,572e-001	6,577e-001
Absorbed Dose Rate in Air	mGy/hr	3,119e-003	5,741e-003
"	mrad/hr	3,119e-001	5,741e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,692e-003	6,798e-003
o Opposed	"	2,956e-003	5,442e-003
o Rotational	"	2,956e-003	5,442e-003
o Isotropic	"	2,614e-003	4,813e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,924e-003	7,225e-003
o Opposed	"	3,727e-003	6,862e-003
o Rotational	"	3,727e-003	6,862e-003
o Isotropic	"	2,795e-003	5,145e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	3,265e-003	6,011e-003
o Posterior/Anterior	"	2,882e-003	5,305e-003
o Lateral	"	2,137e-003	3,934e-003
o Rotational	"	2,575e-003	4,741e-003
o Isotropic	"	2,192e-003	4,036e-003

Sensitivity Case Number 6 of 11	Variable:	Shield #2	(3,5 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	2,474e+002	4,596e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,637e+002	3,041e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	3,173e-001	5,895e-001
Absorbed Dose Rate in Air	mGy/hr	2,770e-003	5,146e-003
"	mrad/hr	2,770e-001	5,146e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		

Results (Summed over energies)	Units	Without Buildup	With Buildup
o Parallel Geometry	mSv/hr	3,280e-003	6,093e-003
o Opposed	"	2,626e-003	4,878e-003
o Rotational	"	2,626e-003	4,878e-003
o Isotropic	"	2,322e-003	4,314e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,486e-003	6,476e-003
o Opposed	"	3,311e-003	6,151e-003
o Rotational	"	3,311e-003	6,151e-003
o Isotropic	"	2,482e-003	4,612e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,900e-003	5,388e-003
o Posterior/Anterior	"	2,560e-003	4,756e-003
o Lateral	"	1,898e-003	3,526e-003
o Rotational	"	2,288e-003	4,250e-003
o Isotropic	"	1,947e-003	3,618e-003

Sensitivity Case Number 7 of 11	Variable:	Shield #2	(3,6 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	2,198e+002	4,119e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,454e+002	2,725e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	2,819e-001	5,283e-001
Absorbed Dose Rate in Air	mGy/hr	2,461e-003	4,612e-003
"	mrad/hr	2,461e-001	4,612e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,914e-003	5,461e-003
o Opposed	"	2,333e-003	4,372e-003
o Rotational	"	2,333e-003	4,372e-003
o Isotropic	"	2,063e-003	3,866e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,097e-003	5,804e-003
o Opposed	"	2,941e-003	5,513e-003
o Rotational	"	2,941e-003	5,513e-003
o Isotropic	"	2,205e-003	4,133e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,576e-003	4,829e-003
o Posterior/Anterior	"	2,274e-003	4,262e-003
o Lateral	"	1,686e-003	3,161e-003
o Rotational	"	2,032e-003	3,809e-003
o Isotropic	"	1,730e-003	3,243e-003

Sensitivity Case Number 8 of 11	Variable:	Shield #2	(3,7 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	1,952e+002	3,691e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,292e+002	2,442e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	2,504e-001	4,735e-001
Absorbed Dose Rate in Air	mGy/hr	2,186e-003	4,134e-003
"	mrad/hr	2,186e-001	4,134e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,588e-003	4,894e-003
o Opposed	"	2,072e-003	3,918e-003
o Rotational	"	2,072e-003	3,918e-003
o Isotropic	"	1,832e-003	3,465e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		

Results (Summed over energies)	Units	Without Buildup	With Buildup
o Parallel Geometry	mSv/hr	2,751e-003	5,201e-003
o Opposed	"	2,613e-003	4,940e-003
o Rotational	"	2,613e-003	4,940e-003
o Isotropic	"	1,959e-003	3,704e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,288e-003	4,327e-003
o Posterior/Anterior	"	2,020e-003	3,820e-003
o Lateral	"	1,498e-003	2,832e-003
o Rotational	"	1,805e-003	3,413e-003
o Isotropic	"	1,537e-003	2,906e-003

Sensitivity Case Number 9 of 11	Variable:	Shield #2	(3,8 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	1,734e+002	3,308e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,147e+002	2,189e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	2,224e-001	4,243e-001
Absorbed Dose Rate in Air	mGy/hr	1,942e-003	3,704e-003
"	mrad/hr	1,942e-001	3,704e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,299e-003	4,385e-003
o Opposed	"	1,841e-003	3,511e-003
o Rotational	"	1,841e-003	3,511e-003
o Isotropic	"	1,628e-003	3,105e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,443e-003	4,661e-003
o Opposed	"	2,321e-003	4,427e-003
o Rotational	"	2,321e-003	4,427e-003
o Isotropic	"	1,740e-003	3,319e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,033e-003	3,878e-003
o Posterior/Anterior	"	1,794e-003	3,423e-003
o Lateral	"	1,331e-003	2,538e-003
o Rotational	"	1,603e-003	3,059e-003
o Isotropic	"	1,365e-003	2,604e-003

Sensitivity Case Number 10 of 11	Variable:	Shield #2	(3,9 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	1,540e+002	2,964e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,019e+002	1,961e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1,976e-001	3,802e-001
Absorbed Dose Rate in Air	mGy/hr	1,725e-003	3,319e-003
"	mrad/hr	1,725e-001	3,319e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,042e-003	3,929e-003
o Opposed	"	1,635e-003	3,146e-003
o Rotational	"	1,635e-003	3,146e-003
o Isotropic	"	1,446e-003	2,782e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,170e-003	4,176e-003
o Opposed	"	2,062e-003	3,967e-003
o Rotational	"	2,062e-003	3,967e-003
o Isotropic	"	1,546e-003	2,974e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		

Results (Summed over energies)	Units	Without Buildup	With Buildup
o Anterior/Posterior Geometry	mSv/hr	1,806e-003	3,474e-003
o Posterior/Anterior	"	1,594e-003	3,067e-003
o Lateral	"	1,182e-003	2,274e-003
o Rotational	"	1,424e-003	2,740e-003
o Isotropic	"	1,213e-003	2,333e-003

Sensitivity Case Number 11 of 11	Variable:	Shield #2	(4 cm)
Photon Fluence Rate (flux)	Photons/cm²/sec	1,368e+002	2,655e+002
Photon Energy Fluence Rate	MeV/cm²/sec	9,053e+001	1,757e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1,755e-001	3,406e-001
Absorbed Dose Rate in Air	mGy/hr	1,532e-003	2,973e-003
"	mrad/hr	1,532e-001	2,973e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,814e-003	3,520e-003
o Opposed	"	1,452e-003	2,819e-003
o Rotational	"	1,452e-003	2,819e-003
o Isotropic	"	1,284e-003	2,492e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,928e-003	3,742e-003
o Opposed	"	1,831e-003	3,554e-003
o Rotational	"	1,831e-003	3,554e-003
o Isotropic	"	1,373e-003	2,664e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1,604e-003	3,113e-003
o Posterior/Anterior	"	1,416e-003	2,748e-003
o Lateral	"	1,050e-003	2,037e-003
o Rotational	"	1,265e-003	2,455e-003
o Isotropic	"	1,077e-003	2,090e-003

MicroShield 7.00 (06-MSD-7.00-1120)
UPC
Conversion of calculated exposure in air to dose
FILE: C:\Users\TEMP\Desktop\point source.ms6
Case Title: Hand at 3 cm without shielding
This case was run on viernes, febrero 16, 2018 at 11:05:05
Dose Point # 1 - (3,0,0) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	2,829e+006	2,994e+006
Photon Energy Fluence Rate	MeV/cm²/sec	1,770e+006	1,826e+006
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	3,476e+003	3,602e+003
Absorbed Dose Rate in Air	mGy/hr	3,034e+001	3,145e+001
"	mrad/hr	3,034e+003	3,145e+003
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,578e+001	3,707e+001
o Opposed	"	2,852e+001	2,949e+001
o Rotational	"	2,849e+001	2,945e+001
o Isotropic	"	2,521e+001	2,605e+001
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,803e+001	3,940e+001
o Opposed	"	3,600e+001	3,725e+001
o Rotational	"	3,600e+001	3,725e+001
o Isotropic	"	2,699e+001	2,792e+001
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	3,147e+001	3,252e+001
o Posterior/Anterior	"	2,771e+001	2,860e+001
o Lateral	"	2,052e+001	2,117e+001
o Rotational	"	2,477e+001	2,557e+001
o Isotropic	"	2,108e+001	2,176e+001

MicroShield 7.00 (06-MSD-7.00-1120)
UPC
Conversion of calculated exposure in air to dose
FILE: C:\Users\TEMP\Desktop\point source.ms6
Case Title: Body at 50 cm without shielding
This case was run on viernes, febrero 16, 2018 at 11:00:53
Dose Point # 1 - (50,0,0) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	1,020e+004	1,086e+004
Photon Energy Fluence Rate	MeV/cm²/sec	6,392e+003	6,625e+003
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1,254e+001	1,306e+001
Absorbed Dose Rate in Air	mGy/hr	1,095e-001	1,140e-001
"	mrad/hr	1,095e+001	1,140e+001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,292e-001	1,345e-001
o Opposed	"	1,030e-001	1,070e-001
o Rotational	"	1,029e-001	1,068e-001
o Isotropic	"	9,101e-002	9,451e-002
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,373e-001	1,429e-001
o Opposed	"	1,300e-001	1,351e-001
o Rotational	"	1,300e-001	1,351e-001
o Isotropic	"	9,745e-002	1,013e-001
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1,136e-001	1,179e-001
o Posterior/Anterior	"	1,000e-001	1,037e-001
o Lateral	"	7,411e-002	7,680e-002
o Rotational	"	8,943e-002	9,274e-002
o Isotropic	"	7,613e-002	7,894e-002

MicroShield 7.00 (06-MSD-7.00-1120)
UPC
Conversion of calculated exposure in air to dose
FILE: C:\Users\TEMP\Desktop\point source.ms6
Case Title: Body at 1 m with shielding
This case was run on jueves, marzo 1, 2018 at 11:09:04
Dose Point # 1 - (100,0,0) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	2,164e+001	4,203e+001
Photon Energy Fluence Rate	MeV/cm²/sec	1,432e+001	2,781e+001
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	2,776e-002	5,391e-002
Absorbed Dose Rate in Air	mGy/hr	2,424e-004	4,707e-004
"	mrad/hr	2,424e-002	4,707e-002
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2,869e-004	5,573e-004
o Opposed	"	2,297e-004	4,462e-004
o Rotational	"	2,297e-004	4,462e-004
o Isotropic	"	2,032e-004	3,945e-004
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,050e-004	5,923e-004
o Opposed	"	2,897e-004	5,625e-004
o Rotational	"	2,897e-004	5,625e-004
o Isotropic	"	2,172e-004	4,218e-004
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,537e-004	4,927e-004
o Posterior/Anterior	"	2,240e-004	4,349e-004
o Lateral	"	1,661e-004	3,225e-004
o Rotational	"	2,001e-004	3,887e-004
o Isotropic	"	1,704e-004	3,309e-004

MicroShield 7.00 (06-MSD-7.00-1120)
UPC
Conversion of calculated exposure in air to dose
FILE: C:\Users\TEMP\Desktop\point source.ms6
Case Title: Hand in contact with the shielding
This case was run on jueves, marzo 1, 2018 at 11:17:47
Dose Point # 1 - (6,1,0,0) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	5,812e+003	1,129e+004
Photon Energy Fluence Rate	MeV/cm²/sec	3,846e+003	7,467e+003
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	7,455e+000	1,448e+001
Absorbed Dose Rate in Air	mGy/hr	6,508e-002	1,264e-001
"	mrad/hr	6,508e+000	1,264e+001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	7,706e-002	1,496e-001
o Opposed	"	6,169e-002	1,198e-001
o Rotational	"	6,169e-002	1,198e-001
o Isotropic	"	5,455e-002	1,059e-001
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	8,190e-002	1,590e-001
o Opposed	"	7,779e-002	1,510e-001
o Rotational	"	7,779e-002	1,510e-001
o Isotropic	"	5,832e-002	1,132e-001
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	6,813e-002	1,323e-001
o Posterior/Anterior	"	6,014e-002	1,168e-001
o Lateral	"	4,460e-002	8,660e-002
o Rotational	"	5,374e-002	1,044e-001
o Isotropic	"	4,575e-002	8,884e-002

MicroShield 7.00 (06-MSD-7.00-1120)
UPC
Conversion of calculated exposure in air to dose
FILE: C:\Users\TEMP\Desktop\point source.ms6
Case Title: Body at 30 cm with shielding
This case was run on jueves, marzo 1, 2018 at 11:28:52
Dose Point # 1 - (30,0,0) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	2,420e+002	4,697e+002
Photon Energy Fluence Rate	MeV/cm²/sec	1,601e+002	3,108e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	3,104e-001	6,025e-001
Absorbed Dose Rate in Air	mGy/hr	2,710e-003	5,260e-003
"	mrad/hr	2,710e-001	5,260e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,208e-003	6,227e-003
o Opposed	"	2,569e-003	4,986e-003
o Rotational	"	2,569e-003	4,986e-003
o Isotropic	"	2,271e-003	4,409e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3,410e-003	6,619e-003
o Opposed	"	3,239e-003	6,286e-003
o Rotational	"	3,239e-003	6,286e-003
o Isotropic	"	2,428e-003	4,713e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2,837e-003	5,506e-003
o Posterior/Anterior	"	2,504e-003	4,860e-003
o Lateral	"	1,857e-003	3,604e-003
o Rotational	"	2,238e-003	4,343e-003
o Isotropic	"	1,905e-003	3,698e-003

MicroShield 7.00 (06-MSD-7.00-1120)
UPC
Conversion of calculated exposure in air to dose
FILE: C:\Users\TEMP\Desktop\point source.ms6
Case Title: Hand in contact with the source for the leackage tests' smears
This case was run on jueves, marzo 1, 2018 at 11:31:28
Dose Point # 1 - (0,5,0,3,0) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	1,146e+008	1,146e+008
Photon Energy Fluence Rate	MeV/cm²/sec	6,970e+007	6,970e+007
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1,404e+005	1,404e+005
Absorbed Dose Rate in Air	mGy/hr	1,226e+003	1,226e+003
"	mrad/hr	1,226e+005	1,226e+005
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,413e+003	1,413e+003
o Opposed	"	1,125e+003	1,125e+003
o Rotational	"	1,123e+003	1,123e+003
o Isotropic	"	9,938e+002	9,939e+002
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,502e+003	1,502e+003
o Opposed	"	1,421e+003	1,421e+003
o Rotational	"	1,421e+003	1,421e+003
o Isotropic	"	1,065e+003	1,065e+003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1,240e+003	1,240e+003
o Posterior/Anterior	"	1,091e+003	1,091e+003
o Lateral	"	8,080e+002	8,080e+002
o Rotational	"	9,755e+002	9,756e+002
o Isotropic	"	8,304e+002	8,304e+002

MicroShield 7.00 (06-MSD-7.00-1120)
UPC
Conversion of calculated exposure in air to dose
FILE: C:\Users\TEMP\Desktop\point source.ms6
Case Title: Body at 5 m with shielding
This case was run on jueves, marzo 1, 2018 at 11:09:54
Dose Point # 1 - (500,0,0) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	8,338e-001	1,624e+000
Photon Energy Fluence Rate	MeV/cm²/sec	5,517e-001	1,074e+000
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1,070e-003	2,083e-003
Absorbed Dose Rate in Air	mGy/hr	9,337e-006	1,818e-005
"	mrad/hr	9,337e-004	1,818e-003
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,105e-005	2,153e-005
o Opposed	"	8,851e-006	1,723e-005
o Rotational	"	8,851e-006	1,723e-005
o Isotropic	"	7,827e-006	1,524e-005
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,175e-005	2,288e-005
o Opposed	"	1,116e-005	2,173e-005
o Rotational	"	1,116e-005	2,173e-005
o Isotropic	"	8,367e-006	1,629e-005
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	9,775e-006	1,903e-005
o Posterior/Anterior	"	8,628e-006	1,680e-005
o Lateral	"	6,398e-006	1,246e-005
o Rotational	"	7,710e-006	1,501e-005
o Isotropic	"	6,564e-006	1,278e-005

MicroShield 7.00 (06-MSD-7.00-1120)
UPC
Conversion of calculated exposure in air to dose
FILE: C:\Users\TEMP\Desktop\point source.ms6
Case Title: Hand in contact with the transport package
This case was run on martes, febrero 13, 2018 at 10:36:24 Dose Point # 1 - (40,0,0) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm"/sec	1,360e+002	2,640e+002
Photon Energy Fluence Rate	MeV/cm²/sec	8,999e+001	1,747e+002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1,745e-001	3,387e-001
Absorbed Dose Rate in Air	mGy/hr	1,523e-003	2,957e-003
"	mrad/hr	1,523e-001	2,957e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,803e-003	3,500e-003
o Opposed	"	1,444e-003	2,803e-003
o Rotational	"	1,444e-003	2,803e-003
o Isotropic	"	1,277e-003	2,478e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1,917e-003	3,720e-003
o Opposed	"	1,820e-003	3,534e-003
o Rotational	"	1,820e-003	3,534e-003
o Isotropic	"	1,365e-003	2,649e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1,594e-003	3,095e-003
o Posterior/Anterior	"	1,407e-003	2,732e-003
o Lateral	"	1,044e-003	2,026e-003
o Rotational	"	1,258e-003	2,441e-003
o Isotropic	"	1,071e-003	2,078e-003