

**NUCLEAR  
SHIELDS**

Case study

**Package design for transport and  
storage of LLW and ILW**

## Companies involved

**Nuclear Shields B.V.**  
**Nuclear Fields International B.V.**  
**D-NUCS - Nuclear Simulations**

Sales & aftersales  
Design & manufacturing  
Shielding calculations

### **Nuclear Shields B.V.**

Akkervoortweg 29  
5827AP, Vortum-Mullem  
The Netherlands

Contact person:  
Nick van Mullekom  
nick@nuclear-shields.com  
+31 (0)485 561 149

[www.nuclear-shields.com](http://www.nuclear-shields.com)



# NUCLEAR SHIELDS

### **Nuclear Fields International B.V.**

Akkervoortweg 29  
5827AP, Vortum-Mullem  
The Netherlands

Contact person:  
Nick van Mullekom  
nick@nuclear-shields.com  
+31 (0)485 561 149

[www.nuclearfields.com](http://www.nuclearfields.com)



# Nuclear Fields

### **D-NUCS - Nuclear Simulations**

Weitlingstr. 73  
10317, Berlin  
Germany

Contact person:  
Dr.rer.nat. Jan Philipp Dabruck  
dabruck@d-nucs.de  
+49 176 41244774

[www.d-nucs.de](http://www.d-nucs.de)

# D ▶ NUCS

## Nukleare Simulation

Dr. rer. nat. Jan Philipp Dabruck

# Package for transport and interim storage of low-level and intermediate-level radioactive waste

This self shielded package has been designed for transport and interim storage of LLW and ILW. The design allows multiple container loading methods and waste situations. A wide range of shielding configurations is possible to accommodate optimal storage and transport situations for exclusive and non-exclusive use. The risk of leaks is minimized by the integration of multiple leak prevention layers:

## 1. High density PE drum baskets (optional)

A set of four additional leak prevention boxes made from high density PE that may be inserted into the drum handling system. These HDPE baskets will prevent steel-to-steel contact from the drum to the 20 mm steel inner liner.

## 2. 20 mm steel inner box

This inner steel box will be completely welded to contain the radioactive waste.

## 3. Multi-layer coating

To prevent corrosion of the steel inner box, an epoxy or urethane coating with multiple protective layers will be applied to the interior of the container, depending on the requirements of the end-user.

## 4. Lead shielding enclosure (optional)

The lead shielding is designed without gaps so that neither radiation nor residues can escape unhindered.

## 5. Radiation resistant rubber seal

James Walker Shieldseal 663 Radiation grade to be used in radioactive environments. This seal will be used to fully seal the nuclear waste container.

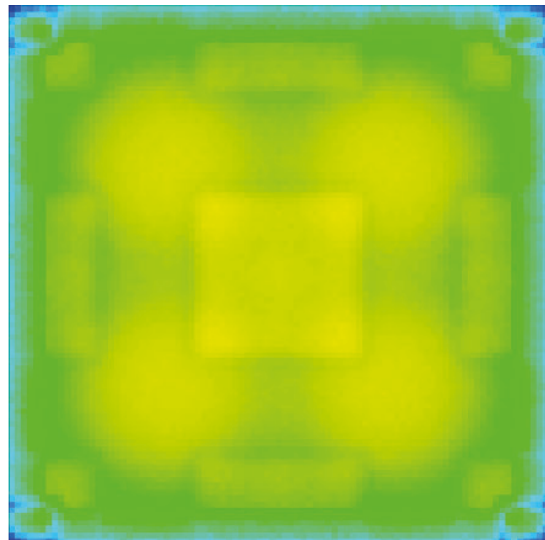
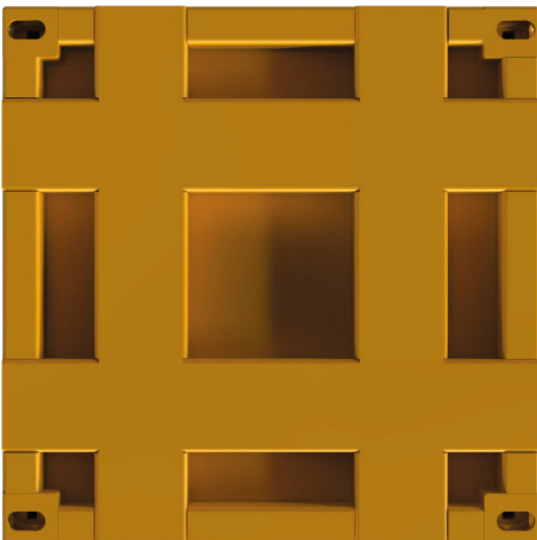
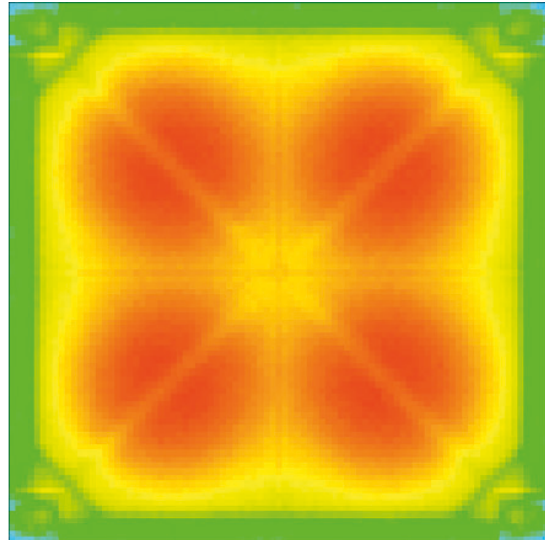
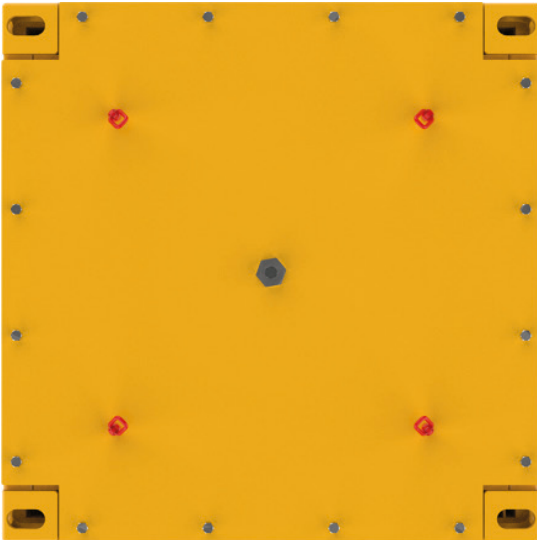
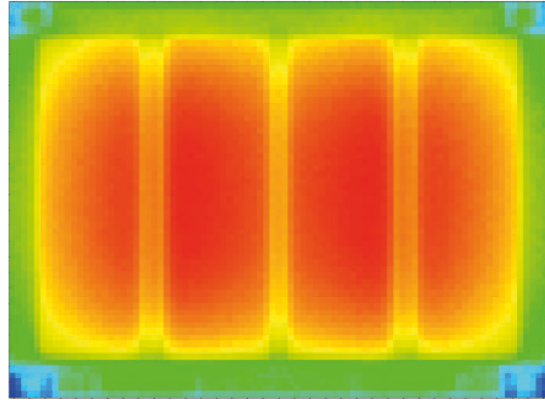
## Shielding properties - Simulation model

To give our customers a reasonable overview of the radiological properties of the different container configurations, the maximum possible  $^{60}\text{Co}$  activity inventory is calculated, for which the dose rate limits according to IAEA for non-exclusive (2 mSv/h at the surface) and exclusive use (10 mSv/h at the surface) are not exceeded. Other nuclides are not considered, since  $^{60}\text{Co}$  is one of the most important nuclides in the handling of nuclear waste and is a good benchmark for selecting the required shielding thickness.

A detailed simulation model is developed based on the technical drawings/CAD models created for the construction of the container. This procedure also serves the purpose of quality control, as possible weak points in the shielding of the container can be identified and eliminated. Furthermore, only in this way it can be determined at which location of the outer surface of the container the maximum dose rate can be expected. The dose rate value at this point is decisive for the determination of the maximum  $^{60}\text{Co}$  inventory.

In contrast to the actual container, the loaded waste is merely an idealized model in order to be able to make generally valid statements about the activity inventory. Because of the large number of free parameters (mass, arrangement, material composition and activity distribution) not all applications can be covered in a single model. Thus, the following container loadings are examined:

- 2,800 kg concrete-like waste
- 5,000 kg metallic waste
- 4 x 338 kg (200l) drums filled with concrete-like waste & drum loader NWC1-DHS



The results shown here are for orientation purposes only. We advise our customers to simulate each container as accurately as possible with its actual waste loading, as the real dose rate can deviate upwards or downwards significantly from this idealized view. The geometric arrangement of the waste can have a great influence, for example if a streaming effect occurs through cavities, which leads to dose rate hotspots. Especially the distinction between contamination and activation is hardly possible on the basis of homogenized models. Highly contaminated waste has a significantly lower self-shielding effect and can lead to higher dose rates at the container surface. It is also important to consider the entire nuclide vector beyond  $^{60}\text{Co}$ , since the different photon energies and intensities of other nuclides may have a very large influence on the dose rate.

## Multiple methods to store your waste

To offer flexibility to our customers we provide multiple ways to store radioactive waste. The method of storage will impact the activity that may be stored inside the container. The methods of storage are (but not limited to) the following:

- Direct disposal in the container (may be filled with concrete)
- Storage of radioactive waste inside 200l drums in drum handling system

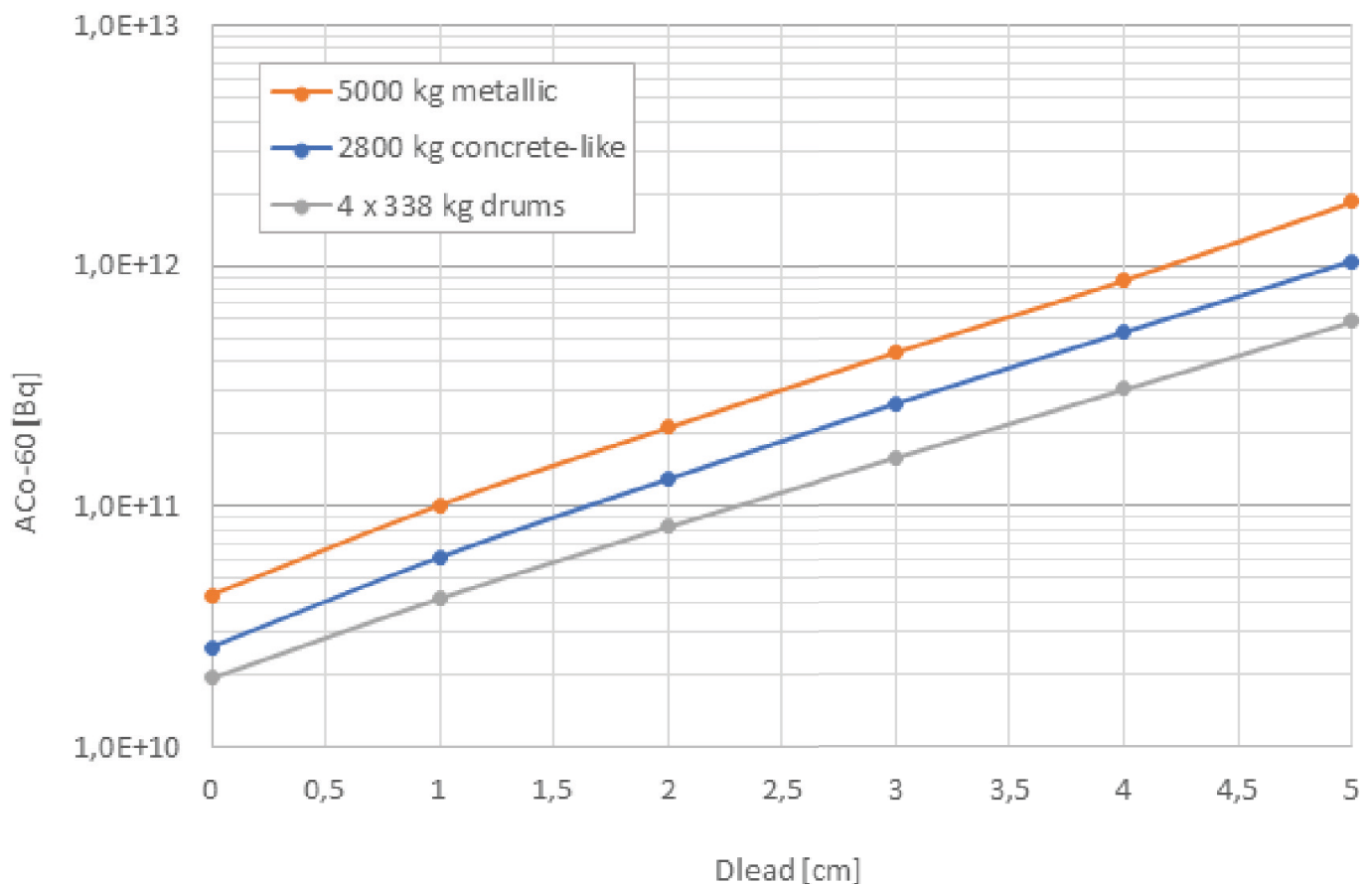
Waste may be disposed directly into the container, or stored in 200l drums, placed on the drum handling system and placed inside the container. It is possible to fill it with a concrete-like material for extra stability, strength and shielding when disposing the waste directly into the container.

## Shielding properties - Maximum $^{60}\text{Co}$ inventory

The outcome of the simulations is given as dose rate per activity  $H^*(10)/t/A$ , so that the maximum possible  $^{60}\text{Co}$  activity inventory can be determined based on the two limiting values for (non-) exclusive use of 2 mSv/h and 10 mSv/h. The activity values for the shielding configurations described above are listed in the following table.

| Type of waste          | $D_{\text{lead}}$ [cm] | non-excl. (2 mSv/h)<br>$A_{\text{Co-60}}$ [Bq] | excl. (10 mSv/h)<br>$A_{\text{Co-60}}$ [Bq] |
|------------------------|------------------------|--|---|
| 2,800 kg concrete-like | 0                      | 2.59E+10                                       | 1.30E+11                                    |
|                        | 1                      | 6.12E+10                                       | 3.06E+11                                    |
|                        | 2                      | 1.29E+11                                       | 6.46E+11                                    |
|                        | 3                      | 2.65E+11                                       | 1.33E+12                                    |
|                        | 4                      | 5.26E+11                                       | 2.63E+12                                    |
|                        | 5                      | 1.04E+12                                       | 5.19E+12                                    |
| 5,000 kg metallic      | 0                      | 4.29E+10                                       | 2.14E+11                                    |
|                        | 1                      | 1.02E+11                                       | 5.08E+11                                    |
|                        | 2                      | 2.13E+11                                       | 1.06E+12                                    |
|                        | 3                      | 4.38E+11                                       | 2.19E+12                                    |
|                        | 4                      | 8.71E+11                                       | 4.35E+12                                    |
|                        | 5                      | 1.84E+12                                       | 9.20E+12                                    |
| 4 x 338 kg drums       | 0                      | 1.93E+10                                       | 9.65E+10                                    |
|                        | 1                      | 4.16E+10                                       | 2.08E+11                                    |
|                        | 2                      | 8.26E+10                                       | 4.13E+11                                    |
|                        | 3                      | 1.60E+11                                       | 8.01E+11                                    |
|                        | 4                      | 3.08E+11                                       | 1.54E+12                                    |
|                        | 5                      | 5.91E+11                                       | 2.95E+12                                    |

The diagram shows an exponential course, as can be seen in the following figure (non-exclusive use). An approximate extrapolation to larger lead thicknesses is also possible. The shielding configuration may be adjusted to satisfy customer requirements if storage of higher activities per container is required.



The shielding calculations were performed by Dr. J. P. Dabruck, D-NUCS Nuclear Simulations, using the approved Monte Carlo code MCNP 6.2.

## Handling of the container

This nuclear waste container is accessible to a heavy forklift on all four sides and may be picked up by a crane using the lifting eyes on the container base, lid and drum loading system. These nuclear waste containers may be stacked up to three containers by inserting container stacking cones into the corner castings. The tare weight of the container has been calculated based on each lead shielding thickness configuration. The results can be found in the table on the next page.

## Drum handling system

This design enables quick and easy cleanup, transportation, storage and repacking or overpacking operations. The optional drum handling system makes it easy to repack and overpack radioactive waste drums for on the spot safe storage. Drums that are damaged or old can be placed inside the cylindrical HDPE tanks on the drum handling system, strapped and lifted into the nuclear waste container by crane. Bumpers have been attached to the drum handling system to prevent damage to the coating of the 20 mm thick steel inner box when placing the drum handling system inside the container. The lifting eyes may be removed once the drum handling system is placed inside the container.



## Digital drop test simulations

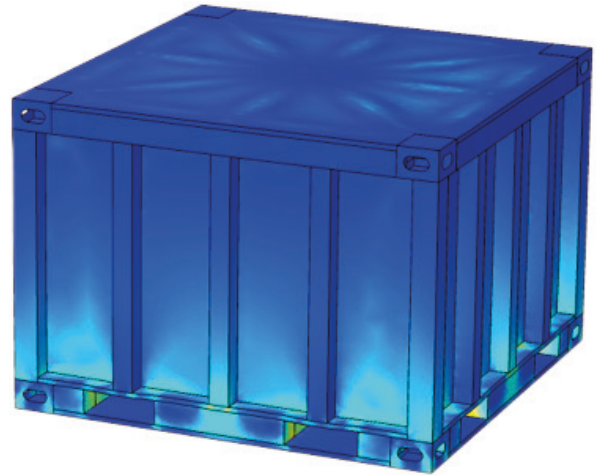
To present a reasonable overview of possible situations, digital drop test simulations have been performed for the following radioactive waste content scenarios:

1. Container completely filled with a mass of 5000 kg
2. Container filled with a mass of 5000 kg to a height of 315 mm
3. Container filled with drum handling system containing four drums with a total mass of 2044 kg

### Case 1

Container completely filled with a mass of 5.000 kg

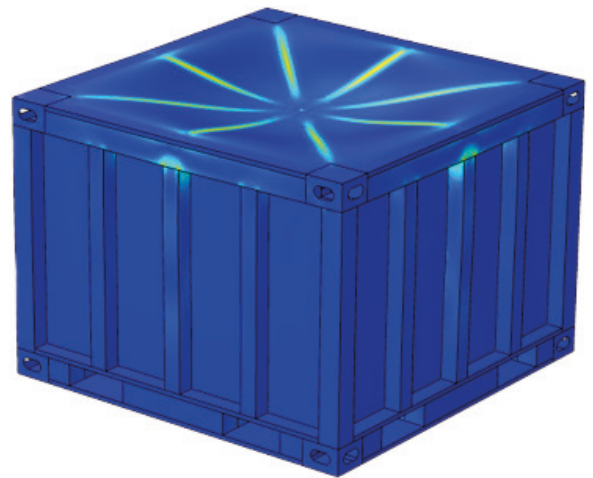
|                 |           |
|-----------------|-----------|
| Lead shielding: | 50 mm     |
| Drum loader:    | No        |
| Content mass:   | 5.000 kg  |
| Total mass:     | 14.279 kg |
| Drop height:    | 0,6 m     |



### Case 2

Container filled with a mass of 5.000 kg to a height of 315 mm

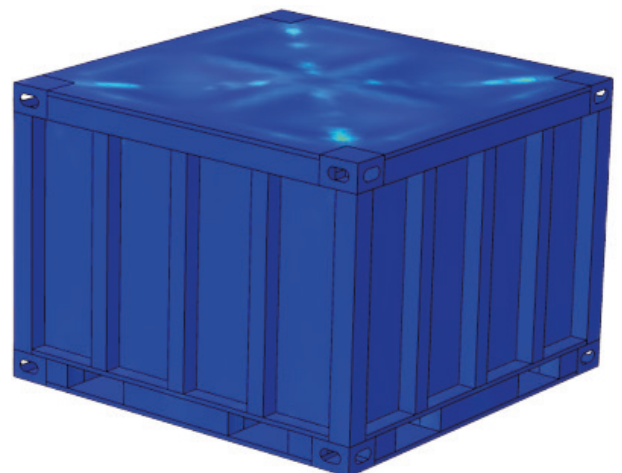
|                 |           |
|-----------------|-----------|
| Lead shielding: | 50 mm     |
| Drum loader:    | No        |
| Content mass:   | 5.000 kg  |
| Total mass:     | 14.279 kg |
| Drop height:    | 0,6 m     |

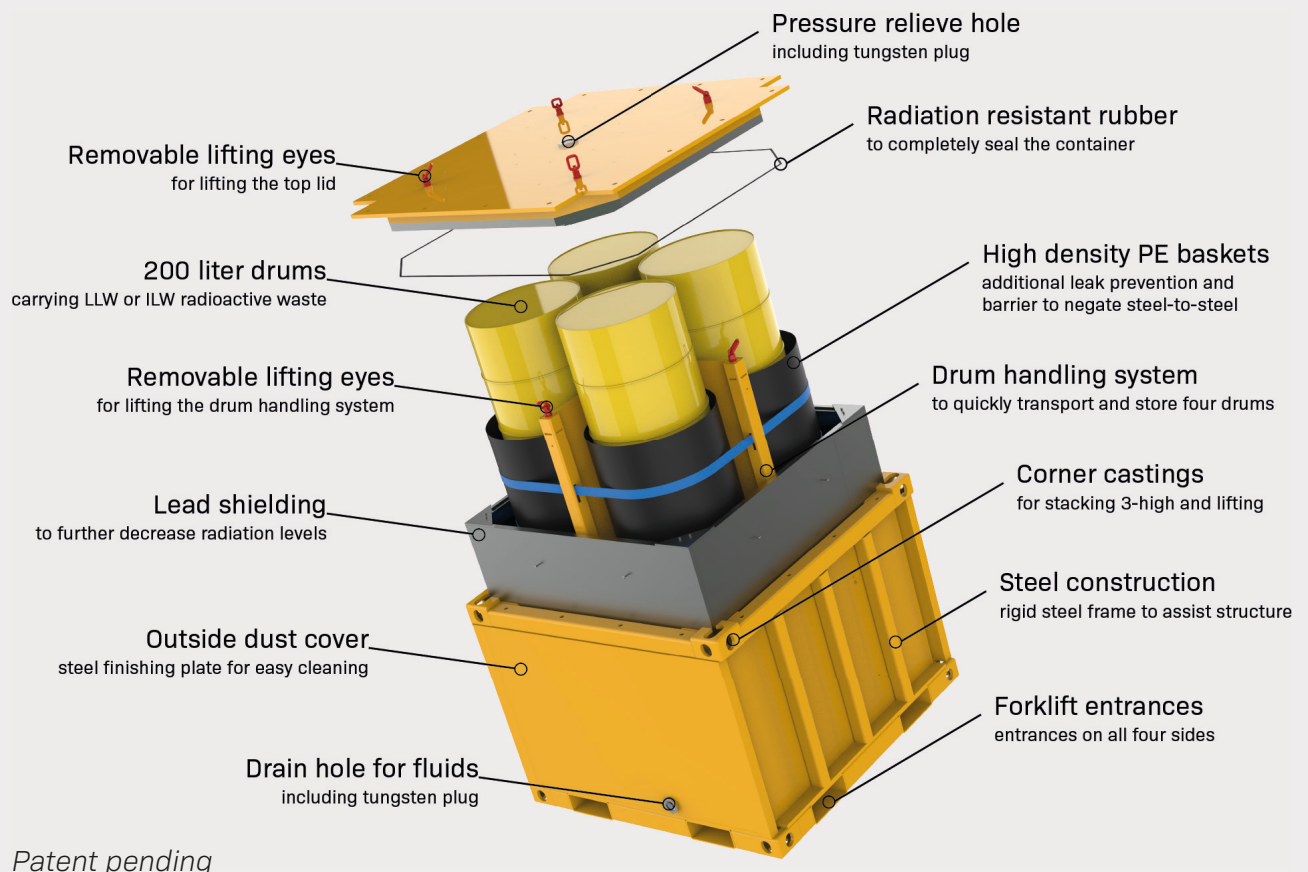


### Case 3

Container with drum handling system containing four waste drums

|                 |           |
|-----------------|-----------|
| Lead shielding: | 50 mm     |
| Drum loader:    | Yes       |
| Content mass:   | 2.044 kg  |
| Total mass:     | 11.311 kg |
| Drop height:    | 0,6 m     |





## SPECIFICATIONS

|                      |                                    |
|----------------------|------------------------------------|
| External dimensions  | 1,630 x 1,630 x 1,217 mm           |
| Internal dimensions  | 1,430 x 1,430 x 957 mm             |
| Volume               | 1.95 m <sup>3</sup>                |
| Tare weight          | See table on the right for results |
| Max payload          | Depending on configuration         |
| Certifications       | IP1 / IP2 (depending on testing)   |
| Applicable for       | LLW, ILW                           |
| Finishing material   | Coated steel                       |
| Coating              | Multi-layer protective coating     |
| Color                | RAL 1003 (yellow)                  |
| Max. stacking height | 3 containers                       |

## LEAD

## TARE WEIGHT

|       |           |
|-------|-----------|
| 0 mm  | 3,555 kg  |
| 10 mm | 4,810 kg  |
| 20 mm | 5,970 kg  |
| 30 mm | 7,100 kg  |
| 40 mm | 8,165 kg  |
| 50 mm | 9,255 kg  |
| 60 mm | 10,742 kg |
| 70 mm | 11,750 kg |
| 80 mm | 12,726 kg |



Document: NWC1-CS

| Revision | Modified On | Modified By       | Modifications   |
|----------|-------------|-------------------|-----------------|
| Rev A    | 19-10-2020  | Rens Korsten (NS) | Draft created   |
| Rev B    | 18-02-2021  | Rens Korsten (NS) | Added drop test |

**Nuclear Shields B.V.**

Akkervoortweg 29  
5827AP, Vortum-Mullem  
The Netherlands

**Contact person:**

Rens Korsten  
rens@nuclear-shields.com  
+31 (0)485 561 140



**NUCLEAR  
SHIELDS**

Rev. B  
**18-02-2021**