# NEW SCO-III REGULATIONS TO SHIP LARGE OBJECTS AS SURFACE CONTAMINATED OBJECTS

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## ABSTRACT

The decommissioning or refurbishment of nuclear facilities necessitates either the storage or disposal of large radioactive components such as steam generators, pressurizers, reactor pressure vessels and heads, and coolant pumps, to list the major contributors. These components or objects are large in size and mass, measuring up to approximately 6 meters in diameter, up to 20 meters in length, and weighing over 400 000 kg. In many situations, the components are transported off-site to a storage, disposal or recycling/treatment facility. Previously, many large objects had to be transported under special arrangement.

The latest 2018 edition of the International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Material, No. SSR-6 [1], incorporates regulations for the shipment of large objects as a new category of surface contaminated object, SCO-III, based on the IAEA "performance package" concept. This paper provides background and practical guidance on these regulations. Additionally, the experiences of BAM with the appoval of two steam converters of the NPP Lingen are presented as the first approval process for SCO-III objects in Germany.

The primary additions to SSR-6 include SCO-III classification and requirements, approval and administrative requirements for the new classification, and the addition of SCO-III to the proper shipping name for UN 2913. Advisory material drafted for the new requirements will be included in the next revision of SSG-26, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, expected to be published soon.

Note that at this time the proposed provisions for large objects do not include components such as reactor vessels, due to the more limited experience and greater radioactivity levels. The SCO-III concept lays the groundwork and may be extended to cover other large objects that are classified as low specific activity (LSA) material in the future.

## INTRODUCTION

Decommissioning or refurbishment of nuclear facilities necessitates either the storage or disposal of large radioactive components such as steam generators, pressurizers, reactor pressure vessels and heads, and coolant pumps, to list the major contributors. These components or objects are large in size and mass, measuring up to approximately 6 meters in diameter, up to 20 meters in length, and weighing over 400 000 kg. In many situations, the components are transported off-site to a storage, disposal or recycling/treatment facility.

Previously, many large objects had to be transported under special arrangement. As the volume of these components being transported has increased, e.g. the decommissioning of nuclear installations in Germany, and industry experience has correspondingly grown, however, provisions were developed for these increasingly routine shipments within the SSR-6 regulations. A set of standard provisions for transport of large components or objects as surface contaminated objects (a new SCO-III category), based on the IAEA "performance package" concept, were developed and are now incorporated into the SSR-6 Regulations [1], as well as the advisory material, SSG-26 [2], soon to be published. Many Member State and industry representatives were involved in the development of these requirements and guidance for large objects.

Note that the new provisions do not include components such as reactor vessels at this time, due to the more limited experience and greater radioactivity levels with these components. The SCO-III concept lays the groundwork and may be extended to low specific activity (LSA) large object provisions in the future to cover reactor vessels and other similar objects once more international experience is gained in transporting such items.

## DEVELOPMENT OF SCO-III REGULATIONS

A working group, led by Canada, was formed in 2012 to begin drafting proposed regulations for the shipment of large objects as surface contaminated objects. The working group built upon past work primarily by the United States, and by other Member States, which led to the guidance currently available in Appendix VII of the 2012 edition of the SSG-26 advisory material [3].

The surface contaminated object (SCO) category was chosen as the most logical place to insert requirements for large components or objects into the regulations. The term "large object" was selected to be more general in the definition and to align with the SCO terminology.

Proposed regulations for a new SCO-III, large object category were submitted to the IAEA for Member State review in 2013. These proposed regulations were discussed and revised based on Member State input at the 30th IAEA transport safety standards committee meeting (TRANSSC 30) and at a Member State meeting on SSR-6 change proposals in 2015. The final iteration of the regulations were accepted for publication in SSR-6 at the 34th IAEA transport safety standards committee meeting (TRANSSC 34) in 2017. The 2018 edition of SSR-6, including SCO-III, was published in July, 2018.

Proposed guidance for SCO-III was submitted to the IAEA for Member State review in 2017. The Member State comment period on revisions to the SSG-26 advisory material ended in January 2018. All comments were discussed and dispositioned at TRANSSC 39 in October 2019, and the new advisory material is expected to be published shortly.

The SCO-III transport object propagated in [1] took affect in Europe and also Germany with the release of the ADR 2021 [4]. The relevant changes in the regulations due to the new introduced SCO-III objects are summarized in the following section. The paragraphs mentioned refer to the SSR-6 [1].

## SCO-III REGULATIONS IN SSR-6

The key changes to the regulations to incorporate SCO-III for large objects are shown below. New text is shown in *italic*. The corresponding paragraphs of the ADR 2021 [4] are stated in parantheses.

### SSR-6, Table 1 (ADR Table 2.2.7.2.1.1):

Surface contaminated objects

| | |
|---|---|
| UN 2913 | RADIOACTIVE MATERIAL, SURFACE CONTAMINATED OBJECTS (SCO-I or SCO-II *or SCO-III*), non-fissile or fissile-excepted[b] |

**SSR-6, Para 413 (ADR 2.2.7.2.3.2):**

413. SCO shall be in one of ~~two~~ *three* groups:

(a) SCO-I… (as is)

(b) SCO-II… (as is)

*(c) SCO-III: A large solid object which because of its size cannot be transported in a type of package described in these Regulations and for which:*

*(i) All openings are sealed to prevent release of radioactive material during conditions defined in para. 520 (e);*

*(ii) The inside of the object is as dry as practicable;*

*(iii) The non-fixed contamination on the external surfaces does not exceed the limits specified in para. 508;*

*(iv) The non-fixed contamination plus the fixed contamination on the inaccessible surface averaged over 300 $cm^2$ does not exceed $8 \times 10^5$ $Bq/cm^2$ for beta and gamma emitters and low toxicity alpha emitters, or $8 \times 10^4$ $Bq/cm^2$ for all other alpha emitters.*

**SSR-6, Para 520 (ADR 4.1.9.2.4):**

520. LSA material and SCO in groups LSA-I, ~~and~~ SCO-I *and SCO-III* may be transported, unpackaged, under the following conditions:

(a) through (d) as is; …

*(e) For SCO-III;*

*(i) Transport shall be under exclusive use by road, rail, inland waterway or sea;*

*(ii) Stacking shall not be permitted;*

*(iii) All activities associated with the shipment, including radiation protection, emergency response and any special precautions or special administrative or operational controls which are to be employed during transport shall be described in a transport plan. The transport plan shall demonstrate that the overall level of safety in transport is at least equivalent to that which would be provided if the requirements of para. 648 (only for the test specified in para. 724, preceded by the tests specified in paras. 720 and 721) had been met.*

*(iv) The requirements of para. 624 for a Type IP-2 package shall be satisfied, except that the maximum damage referred to in para. 722 may be determined based on provisions in the transport plan, and the requirements of para. 723 are not applicable.*

*(v) The object and any shielding are secured to the conveyance in accordance with para. 607.*

*(vi) The transport shall be subject to multilateral approval.*

**SSR-6, Para 522 (ADR 7.5.11 CV 33 (2)):**

522. The total activity in a single hold or compartment of an inland waterway craft, or in another conveyance, for carriage of LSA material or SCO in a Type IP-1, Type IP-2, Type IP- 3 package or unpackaged, shall not exceed the limits shown in Table 6. *For SCO-III, the limits in Table 6 may be exceeded provided that the transport plan contains precautions which are to be employed during transport to obtain an overall level of safety at least equivalent to that which would be provided if the limits had been applied.*

*Note added to Table 6 to see paragraph 522 for SCO-III.*

**SSR-6, Para 827A (ADR 6.4.23.2.2):**

*827A. An application for approval of SCO-III shipments shall include:*

- *(a) A statement of the respects in which, and of the reasons why, the consignment is considered a SCO-III.*
- *(b) Justification for choosing SCO-III by demonstrating that:*
  - *(i) no suitable packaging currently exists;*
  - *(ii) designing and/or constructing a packaging or segmenting the object is not practically, technically or economically feasible;*
  - *(iii) no other viable alternative exists;*
- *(c) A detailed description of the proposed radioactive contents with reference to their physical and chemical states and the nature of the radiation emitted;*
- *(d) A detailed statement of the design of the SCO-III, including complete engineering drawings and schedules of materials and methods of manufacture;*
- *(e) All information necessary to satisfy the competent authority that the requirements of para. 520(e) and the requirements of para. 522, if applicable, are satisfied;*
- *(f) A transport plan;*
- *(g) A specification of the applicable management system as required in para. 306.*

## SCO-III ADVISORY MATERIAL IN SSG-26

Much of the guidance from Appendix VII of the 2012 edition of SSG-26 [3] was moved into the SSR-6 2018 [1] regulations or into the corresponding guidance paragraphs in the new SSG-26 advisory material. The only information left in Appendix VII of SSG-26 [3] is the guidance for the calculation of activity intake for transport of SCO-III based on the Q method. Guidance was added to SSG-26 [2] in the appropriate paragraphs to describe the large object concept, the sealing of openings, determination of surface contamination and dryness. Paragraph 310.5 guidance was also moved to paragraph 413.7 bis., removing any references to special arrangement.

## FIRST EXPERIENCES WITH THE APPROVAL OF SCO-III OBJECTS

The two steam converters of the NPP Lingen were the first approval process for SCO-III objects in Germany. The steam converters shall be transported from Lingen to Studsvik, Sweden via heavy duty transport, barge, and ship. In the frame of the application for the approval of shipment, Bundesanstalt für Materialforschung und -prüfung (BAM) is responsible for the assessment of the mechanical and thermal test conditions and for the quality management. Some of the main experiences from this assessment are presented in the following paragraphs.

The steam converters are tube bundle heat exchangers with a nearly rotationally symmetric shape (see Figure 1). There are multiple openings and nozzles for the operation and the maintenance. The openings are closed for the transport by welded lids. Additionally, six transport frames are attached to each steam

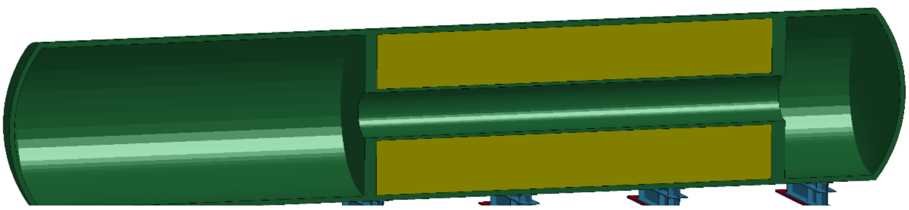

**Figure 1:** Sketch of the steam converter NPP Lingen (source Orano NCS)

converter. The total mass of the object is about 150,000 kg, the length about 16,000 mm, the height about 3,500 mm and the width about 3,700 mm.

Beside the general requirements for transport packages, SCO-III objects have to fulfil the requirements of Paragraph 624 for free drop test and Paragraph 648 for the penetration test (both under consideration of Paragraph 521). The requirements of Paragraph 624 resp. Paragraph 648 are:

(a) Loss or dispersal of the radioactive contents;
(b) More than a 20% increase in the maximum dose rate at any external surface of the package.

The penetration test is preceded by the water spray test. The general requirements include the assessment of the SCO-III objects under ambient temperatures.

The most severe test condition for a SCO-III is the free drop test according to [1] Paragraph 722. This test condition is also considered for the transport under special arrangement and so before the introduction of SCO-III. The drop height is usually 0.3 m for large components like steam converters or other big reactor components (Table 14 in [1]). According to [1] Paragraph 520 (e) (iv), “the maximum damage … may be determined based on provisions in the transport plan”. That means that the free drop test has not to be assessed with respect to the most damaging position, but the drop position can be limited, e.g., to the transport orientation. In this case, the free drop test is only considered with respect to the horizontal transport orientation. Additionally, the transport frames are considered as part of the transport object and serve as a kind of impact limiter. The assessment of the drop test is performed by explicit dynamic finite element calculations. Other methods of approval like experimental tests are usually not used since the transport objects already exist and the manufacturing of a drop test specimen would be very expensive. For the steam converters, different calculation cases (e.g., with different material models) are used to obtain the decisive loads for the components of the transport object. In this context, the deformation behavior of the transport frames is of special interest because they have to prevent the contact of the steam generator (especially of its protruding nozzles) with the unyielding target. So, a failure of the frames has to be prevented. Since the frames are designed as a welded steel sheet construction, buckling is a possible failure mechanism. BAM has performed two additional calculation variants to assess the sensitivity to failure due to buckling. In one case the finite element mesh was refined. In another case, the impact velocity of transport object was increased in the calculation by 25 % (see Figure 2). It can be noticed that a refined mesh has a low impact on the buckling sensitivity. An increase of the impact velocity causes pronounced buckling, but a failure of the structure does not occur. The steam converter itself shows only minor deformation. Plastic deformations occur only locally limited at the contact areas with transport frames.

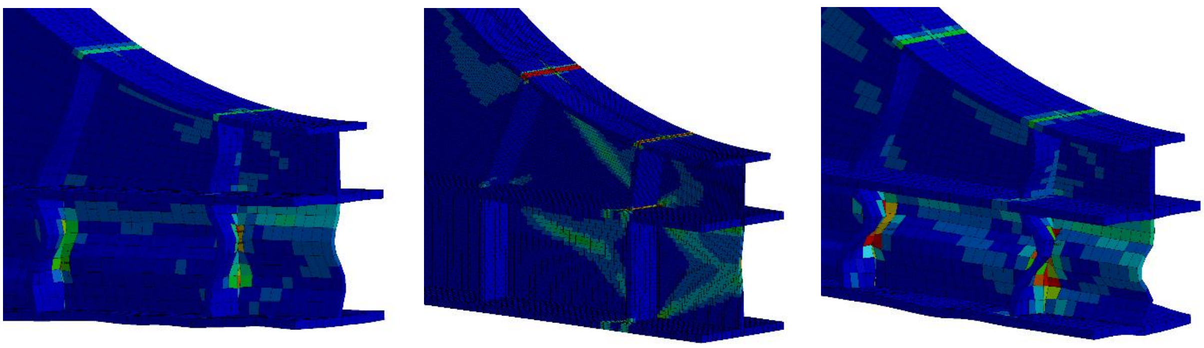

**Figure 2:** buckling sensitivity for different calculation cases, left hand side: calculation of applicant (source Orano NCS), center: refined mesh, right hand side: increased impact velocity

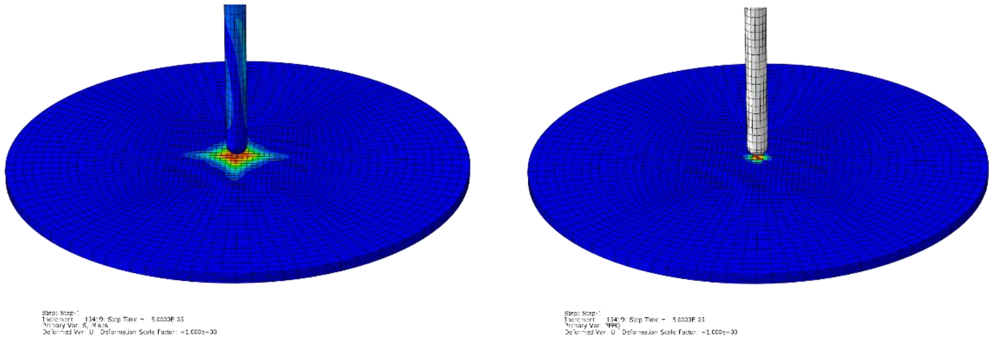

**Figure 3:** Calculation of the penetration test aiming on the center of a welded lid of the steam converter, left hand side: von-Mises stresses, right hand side: equivalent plastic strains.

The penetration test is another mechanical test which has to be assessed for SCO-III. Unlike the free drop test, this test is not demanded for a transport under special arrangement. A steel bar with a mass of 6 kg is dropped onto the surface of the transport object from a height of 1 m. The steam generator is a thick-walled steel object. Therefore, there are sufficient margins for the penetration test. The welded lids for the openings are much thinner. The impact of the penetration test can be assessed by analytical calculations. In this case, BAM has performed dynamic calculations for the welded lids with Simulia/Abaqus (see Figure 3). It can be noticed that the von Mises stresses are very locally limited (Figure 3, left hand side). Plastic deformations only occur in the impact area of the bar (Figure 3, right hand side). As a result, the penetration test does not lead to significant deformations of the welded lid. According to SSR-6 Paragraph 520 (e) (3), the penetration test is preceded by the water spray test. Due to the convex form of the steam converters, there are no accumulations of water to be expected. So, there is no impact of the water spray test on the penetration test for the transport object presented.

The 20 % criterion for the free drop test and for the penetration test according to [1] Paragraphs 520 (e) (iii) and (iv) is not assessed by BAM. The responsibility lies with the BASE based on the mechanical assessment of BAM.

## CONCLUSION

There has been an increasing demand in many countries for transportation of large radioactive objects. Many large objects previously had to be transported under special arrangement. However, as experience with this type of transport has grown and is becoming more routine, specific regulatory requirements were required to allow the movement of large radioactive objects without the need for special arrangement. A set of standard provisions for transport of large objects as SCO-III have been developed and included in the 2018 edition of the international SSR-6 regulations [1]. Accompanying advisory material in a new version of SSG-26 is expected to be published soon [2].

BAM was involved in the assessment of the two steam converters of the NPP Lingen, Germany as SCO-III objects. These were the first experiences of BAM with an approval process for a shipment as SCO-III according to the new SSR-6 [1] which became effective in Germany with the release of the ADR 2021 [4].

## REFERENCES

[1] International Atomic Energy Agency (IAEA) Safety Standard, “Regulations for the Safe Transport of Radioactive Material, Specific Safety Requirements”, 2018 Edition, No. SSR-6, Vienna, Austria, 2018.

[2] International Atomic Energy Agency (IAEA) Specific Safety Guide, “Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2018 Edition)”, No. SSG-26, Vienna, Austria, to be published soon.

[3] International Atomic Energy Agency (IAEA) Specific Safety Guide, "Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2012 Edition)", No. SSG-26, Vienna, Austria, 2014.

[4] ADR 2021, Agreement for the Transport of the Dangerous Goods by Road Übereinkommen vom 30. September 1957 über die internationale Beförderung gefährlicher Güter auf der Straße (ADR) (BGBl. 1969 II S. 1489), Anlagen A und B in der Fassung der Bekanntmachung vom 16. November 2021 (BGBl. 2021 II S. 1184).