Radioactive Material Transport Users Committee	
Technical Note Appendix to: RAMTUC(16)GN14 - Rev 1.0	
LOW SPECIFIC ACTIVITY MATERIAL ACTIVITY DISTRIBUTION INTEPRETATION GUIDANCE	December 2016

Appendix: The technical basis

This appendix sets outs the justification for the RAMTUC low specific activity material activity distribution interpretation guidance [1]. It is provided to document and retain the rationale for the interpretation guidance and is not part of the guidance itself.

In order to provide confidence in its suitability, the guidance presented in this document has been developed and informed by the consensus opinion of a range of suitability qualified and experienced UK radioactive materials transport users [2].

1.1. Distributed throughout

The IAEA are developing a technical basis document [3] for the regulations [4]. Existing drafts of the technical basis document provide only a record of the changes to the requirements for LSA material through subsequent editions of the regulations and do not set down the technical justification for the LSA regulations. The IAEA advisory material [5] does provide insight into the technical basis for the average specific activity limits for LSA-II and LSA-III materials. However the information provided on the requirement for activity to be *distributed throughout* is limited to a qualitative recognition that some LSA materials are “*clearly not uniformly distributed*” and that the *distributed throughout* “*provision puts no requirement on how the activity is distributed throughout the material*”. Thus the only quantitative insight into the requirements for compliance with *distributed throughout* is the “simple method” specified in paras 409.11 and 409.12.

In recent years work has been undertaken in Germany to investigate the release behaviour of various LSA-II and LSA-III materials under different mechanical impact conditions and to assess the potential radiation exposures [6]. That work provides confidence that the average specific activity limits for LSA-II and LSA-III material and the material property constraints are suitable and sufficient. It does not address the *distributed throughout* requirement. Subsequent consideration has been given to the consequences of “hot spots” of concentrated radioactivity being present in LSA [7, 8]. Whilst that work would indicate that a safety justification is feasible for LSA incorporating large variations in activity concentration, further work would be needed to develop the arguments to provide a radiological basis for the *distributed throughout* requirement and it is not claimed as part of the arguments presented here.

In the absence of further understanding of the radiological basis or compliance requirements for activity to be *distributed throughout*, this document has adopted the advisory material’s “simple method” as the basis of the guidance provided. That basis has been built upon and adapted to provide more definitive and practical guidance.

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This document adopts the use of notional portions as per the "simple method". The advisory material's number of notional portions is adopted as a minimum number. The user is permitted to increase the number of notional portions. This may be desirable if it provides a more practicable basis for defining notional portions e.g. by aligning the portions to discrete and identifiable volumes within a package. This is justified on the basis that increasing the number of portions would reduce the degree of heterogeneity, thus it would be a more stringent standard and would not be expected to reduce safety. The advisory material specifies the number of notional portions for material greater than 1.0 m^3 and for between 1.0 m^3 and 0.2 m^3. It states that the "simple method" should not be used for volumes less than 0.2 m^3. There is no clear safety detriment to applying the "simple method" to volumes less than 0.2 m^3. In the absence of any other method, the guidance material is interpreted here to mean "need not" rather than "should not" and this document extends the criterion for 1.0 m^3 and 0.2 m^3 to all volumes below 1.0 m^3.

The "simple method" states that if each notional portion is below the average specific activity limit, or if the ratio between most and least active notional portions is less than ten, then the requirement is met. In the latter case, this implies that both the maximum and minimum notional portion specific activities need to be determined and controlled. Logically there is no need to control the minimum specific activity i.e. if very low specific activity material were added to an otherwise compliant package, it could contravene the "simple method" but would not be expected to reduce safety. This document modifies the method to control only the average and maximum specific activities. In this way, application of the requirement is simplified as the user need not accurately ascribe activities to low activity portions, nor is the user prohibited from including lower activity material within a package. It is necessary to specify a limit for the maximum specific activity of a notional portion. A factor of ten (i.e. 10^{-3} A_2/g for LSA-II) is specified in this document as this is the upper limit that could be permitted for a notional portion from interpretation of the IAEA advisory material Para 409.11[1].

This document provides additional guidance to the user on how to specify a notional portion. This document clarifies that depending on the quantity and size of the LSA materials to be transported, a discrete object may need to be notionally subdivided or a number of discrete objects collected into a group in order to define a suitably sized notional portion.

In defining a notional portion for heterogeneous materials the user is required to consider which of the parts of the contents can be counted amongst the LSA material

1 When the number of notional portions is increased, with one portion at the maximum specific activity and the remainder at the minimum, the ratio between the average and maximum tends to ten and thus the maximum permissible specific activity of a portion of material that could be defined as *distributed throughout* is taken as ten times the average.

and can contribute to the mass used for the means of calculating the specific activity. The advisory material distinguishes between external shielding material (i.e. the packaging) which cannot be counted and a "*solid compact binding agent, such as concrete, bitumen, etc*" which may be counted. There are other cases where essentially inactive material may be present and commingled with LSA material. For instance, in the case of a HEPA filter or of personnel protective equipment with absorbed contamination, it would be impracticable to define the regions of the material that contain absorbed radioactivity and those that do not. In such cases the only practical course is to define the entire mass as LSA material. This document considers that inclusion of all the mass present within a notional portion, inclusive of any essentially inactive material that may be present, is consistent with the advisory material requirements.

The advisory material specifies no requirements for assessing or controlling the distribution of activity within a notional portion. Consistent with this and for clarity, this document explicitly states that the activity distribution within a notional portion need not be controlled to a finer level of granularity or assessed further.

In assessing the requirements for activity to be *distributed throughout* the user must consider under what conditions the requirement is to be met i.e. as packaged or as could evolve in routine, normal or accident conditions of transport. No performance requirements on LSA material are set in routine, normal or accident conditions. Consistent with this and for clarity, this document explicitly states that the requirement is to be met by the material as packaged and that the potential for rearrangement of the material under routine, normal or accident conditions of transport need not be assessed.

The advisory material specifies notional portions on the basis of volumes of material. In some cases this may be practical and easy to define e.g. where the material is subdivided into inner containers of equal volume. However there are instances where the use of volume for defining a notional portion is problematic due to the need to account for changes in density e.g. where an inner container is super compacted or where material may settle. In such cases the volume may be variable, but the mass will remain constant. As specific activity is a measure of activity per mass it is considered that defining notional portions in respect of mass is as suitable, if not preferable, to definition in respect of volume. Thus this document permits notional portions to be specified on the basis of equivalent mass.

This document permits the number of notional portions to be increased beyond the specified minimum. A practical approach in applying the requirement may be to identify each discrete object contained within a package as a notional portion it is own right. This could be problematic in that the discrete objects may not be of approximately equivalent volume. Notional portions of unequal volume are a no less stringent heterogeneity standard than the "simple method", so long as no one notional portion exceeds a tenth of the volume for material volumes greater than

1.0 m^3 or a fifth of the volume for material volumes less than or equal to 1.0 m^3. Thus this document permits each discrete object to be defined as a notional portion in its own right, so long as the portion volume limit is not exceeded.

It may be inferred that if all constituents are below the average specific activity limit (i.e. 10^{-4} A_2/g for LSA-II), then the material complies with the *distributed throughout* compliance criterion specified in this document. Alternatively, if the material as a whole has an average specific activity below the average specific activity limit (i.e. 10^{-4} A_2/g for LSA-II) and if the maximum specific activity of any constituent within a portion is less than ten times this limit (i.e. $10^{-3}A_2$/g for LSA-II), then the same must be true. Thus a user, with knowledge of the sources of activity present, may demonstrate that the requirement is met without reference to notional portions. For instance, if the user had knowledge of the specific activity of the source material (e.g. through its irradiation history and activation calculations) and that specific activity complied with the above arguments, there would be no need for the user to consider the activity present in notional portions. This document explicitly identifies that approach for the avoidance of doubt.

1.2. Unshielded dose rate

In addition to limiting the specific activity of LSA material, it is also necessary to limit the *unshielded dose rate* from the quantity of LSA material in a package. This is because the *unshielded dose rate* is a function of the quantity and arrangement of LSA material present and not only a property of the material itself. The limit of 10 mSv/hr at 3 m is specified to be broadly equivalent to the Q system assumptions for Type A package, which limits the dose rate to 100 mSv/hr at 1m from the unshielded contents. As with Type A packages, the IAEA Technical Basis Document [3] notes this requirement is necessary as the "*shielding integrity of the industrial packages cannot be ensured since the most demanding tests imposed are on the IP-3 package type, and these are only for normal conditions of transport*".

The advisory material [5] states that "*Geometrical changes of LSA material or SCO as a result of an accident are not expected to lead to a significant increase of this external radiation level*". It provides guidance to users on how to apply the requirement in the case of "*essentially uniformly distributed*" material. That is to measure the radiation level at the external surface of the package and to undertake calculations to correct for any external shielding that is present. The expectation that geometrical changes will not lead to a significant increase in the external radiation level is true of radioactive material that is essentially uniformly distributed and of many other materials that are distributed to a less uniform extent but that have relatively consistent radiation levels throughout. However it is not universally true of all LSA material. The advisory material does not provide guidance on how to apply the requirement when this expectation is not met.

LSA material may be transported in bulk and thus exhibit a substantial degree of self-shielding. Additionally LSA material may be markedly heterogeneous and have components with both very high and low radiation levels. For instance small quantities of activated high cobalt fraction alloys within miscellaneous low radiation level bulk waste. Good radiation protection practice would impose a requirement to load high dose rate items in the centre of a package to minimise external radiation levels when practicable. In such a case, geometrical changes could be expected to significantly increase the external radiation level through exposing the high radiation level material. Demonstrating compliance through measurement of the radiation level at the edge of such a package would take credit for the self-shielding effect of the LSA material itself. As the shielding effect of the packaging must be excluded due to it not being suitably qualified, it may also be inferred that the mechanically unqualified self-shielding effect of LSA material should also be discounted. Nevertheless, in the case of the advisory material method for essentially uniformly distributed material, a degree of shielding will contribute to a reduction in the calculated *unshielded dose rate*. In a large package with cemented contents, typically only the 30 cm of radioactive material nearest the surface contributes appreciably to the radiation level, as the remainder is effectively shielded. Entirely discounting self-shielding would be onerous, particularly for large packages where the self-shielding effect may be significant. Furthermore self-shielding is an innate property of the radioactive material and may only be entirely lost if the material itself is lost. Thus the specific concern is where geometrical changes could be expected to significantly increase the external radiation level due to there being an enhanced self-shielding effect, through there being shielding of high radiation level materials by low radiation level materials.

This document provides a criterion for assessing compliance by determining the radiation level at a distance of 3 m from the single most onerous planar cross-section through the radioactive material. This criterion is justified as it ensures that credit is not taken for an enhanced self-shielding effect. It provides a practicable and consistent means of allowing for the effect of geometrical changes that could occur in accident conditions of transport on the radiation level. It may be noted that if this criterion were applied to a cuboidal package containing “essentially uniformly distributed” material, that the most onerous planar cross-section would be the edge of the material, and thus the advisory material methodology would remain applicable.

The scenario of exposure to the most onerous planar cross-section is a notional depiction of a conservatively rearranged geometry. It is intended to bound the rearrangement that could credibly be expected to occur during routine, normal or accident conditions transport. This document states that it is not necessary for the user to further assess the potential for rearrangement of the material during transport in respect of the *unshielded dose rate* requirement, as this is considered to be unduly conservative.

Consistent with the IAEA Technical Basis Document and advisory material, this document stipulates that the assessment should disregard external shielding provided by the packaging. In line with the arguments presented above, this document does permit credit to be taken for the self-shielding effects provided by the material itself, from adjacent radioactive material and from any inactive material that is present. This is consistent with the advisory material methodology for "essentially uniformly distributed" which also implicitly allows credit to be taken for self-shielding effects.

This document states that exposure to only one planar cross section need be considered. As stated previously, the scenario of exposure to the most onerous planar cross-section is a notional depiction of a conservatively rearranged geometry. It is considered that exposure to two equidistant most onerous planar cross-sections would be incredible and unduly conservative.

This document states that the single most onerous planar cross-section may be identified through inspection or qualitative judgements. These methods are specified in comparison to detailed measurement or calculation surveys. Use of inspection and qualitative judgement is considered proportionate to the attainable accuracy of the assessment being undertaken. For instance, in many cases the exact disposition of LSA material within a package will be unknown and it will be necessary to apply conservative assumptions in respect of how the material is distributed. In such a case the use of calculation techniques to identify a bounding case would be unnecessarily esoteric.

This document states that it is acceptable to simplify an assessment of compliance through use of either or both of discounting self-shielding effects or through assuming worst-case geometrical changes. These approaches may be appropriate to allow users to undertake simplified assessments where margins are large. For instance by assuming that the entire activity content occupies a notional point source it is possible to demonstrate compliance through reference to isotope radiation level data provided in Table II.2 of the advisory material. Alternatively, the industry survey [2] agreed that an acceptable balance of pragmatic modelling simplifications and conservatism could be achieved by assessing the *unshielded dose-rate* at a distance of 3 m from the edge of the radioactive material in its as packed geometry, disregarding any shielding effect from both the packaging and from any inactive material present. This approach prevents the need for an overly extensive set of modelling calculation scenarios to determine the most onerous cross-section that might otherwise be required for some materials and is comparable with the US DoT guidance on interpretation of *unshielded dose rates* [9]. These simplifications are justified in that they result in the application of a more stringent standard and would not be expected to reduce safety.

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References

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