ESS procedure for material choice in vicinity of Neutron Spin-Echo (NSE) instruments

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1. PURPOSE

Many of the ESS neutron instruments will both produce and be sensitive to magnetic fields. The purpose of this procedure is to ensure that the instrument halls and the equipment installed there are constructed in such a way that they do not severely impact on the performance of the neutron instruments in terms of their magnetic sensitivity.

Following discussions with all instrument scientists and technical groups at the ESS, only one instrument class was found to have stringent requirements. This is neutron spin echo (NSE). It should perhaps be noted that the impact on the neutron spin-echo instruments is related to their performance, rather than to permanent damage of the instruments - except in the case of very high magnetic fields being generated near the instrument.

Neutron spin echo is a class of instruments that gives unique information about the dynamics within the samples. The technique relies on creating very homogeneous magnetic fields, and is therefore highly sensitive to external magnetic fields. At the same time it produces magnetic fields itself, which can magnetise any nearby objects which are not amagnetic, leading to hysteresis effects for NSE. See section 4.1 for further description of the instrument.

2. PROCEDURE APPLICABILITY

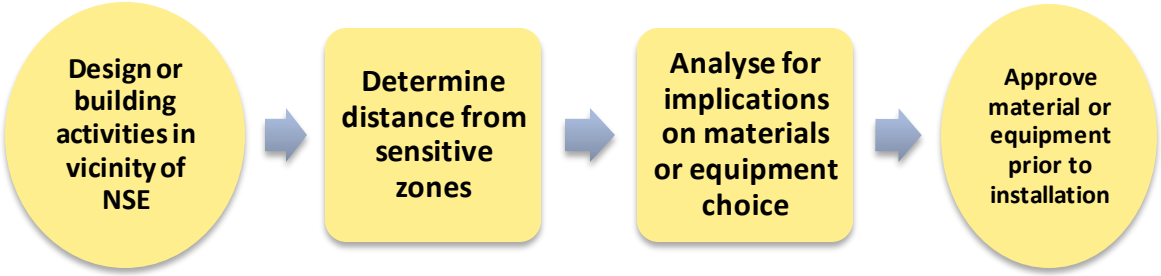
This procedure is applicable to Experimental Hall 2 (North sector of Building D03), where the NSE spectrometers will be located. It has implications for choices of materials within 6 m of the sensitive areas of the NSE spectrometers in all directions (see section 4.2 for further details of this area), therefore including floor, ceiling, pillars. Furthermore, it also applies to any equipment, which produces magnetic fields within the hall, and absolutely within a 20 m radius of the NSE instrument caves in all directions. The current expected location of the first NSE instrument is in Hall 2 (D03), beamport N1 [1].

It is understood that many decisions have already been taken that may not be in compliance with this procedure. It is accepted that no changes will be requested on decisions already made. However, for any future decisions this procedure will be applied. See also section 4.5.

This procedure is written specifically for use when choosing materials and equipment in the experimental hall, which contains the NSE spectrometers. This is Experimental Hall 2 (North sector of Building D03). It needs to be considered both during the design and the implementation (building) of the experimental hall. Clearly some of the requirements will also apply to neighbouring beamlines and their sample environment. There will, however, be additional procedures for ensuring compatibility between beamlines and for sample environment.

3. MATERIALS IN VICINITY OF NSE INSTRUMENTS

3.1. Procedure map



When making choices on materials or equipment to be used in the vicinity of the (future) NSE instruments in the experimental hall, this procedure shall be followed, in order to determine whether the material or equipment can be placed near the sensitive zones of the NSE instruments. If the activity is within this area, it shall be determined if the choice of materials or equipment fulfils the specifications outlined in this procedure. For all work in Experimental Hall 2 (North sector of Building D03) (within a 20 m radius of the sensitve zones) it shall also be determined whether magnetic fields will be produced or affected by the material or equipment and, if this is the case, whether they exceed the limits outlined in this procedure. The outcome will guide the choice of materials or equipment that can be used in the vicinity of the NSE instruments in the experimental hall.

3.2. Procedure details

3.2.1. Input

During the design and construction of the Experimental Hall 2 (North sector of Building D03), and later during maintenance of this hall, as well as the design and construction of neutron instruments within this hall, decisions will need to be made regarding the materials to use and equipment to install. This triggers the need to follow this procedure.

In the first instance, the distance to the sensitive parts of the NSE spectrometers must be determined. For the majority of the experimental hall, the distance to the NSE spectrometers means that no restrictions will result from this procedure. However, in the vicinity of the NSE spectrometers, careful consideration and specification of materials and equipment is necessary to allow the NSE instruments to perform scientifically.

It should be clarified here that this is applicable to both the building itself but also all the instruments and sample environment in this hall.

The procedure requires the person(s) responsible for the design and building to determine the distance to the sensitive zones of the NSE spectrometers. If the planned work is within the sensitive zones of the NSE spectrometers, the persons responsible for the work will be required to provide the necessary information about the materials and/or components they wish to install within these zones to the instrument scientist for neutron spin-echo spectroscopy at the ESS and the NSS lead engineer, to allow them to

determine whether the material is suitable in terms of magnetic permeability and whether magnetic fields are produced or affected. The NSS lead engineer shall provide support to the instrument scientist for this verification, including potentially physically characterizing the material or component.

The person(s) responsible for the design and building should be prepared to accept that, if necessary, the component may need to be (magnetically) shielded.

3.2.2. Determine distance from sensitive zones

The distance, in ALL directions, from the sensitive zones of the NSE instruments will be determined. It therefore includes, but is not limited to, floor, ceiling, support columns, overhead structures, bridges, cranes. It relates to work involving all building materials, also, for example, the reinforcement of concrete or the welding of materials. The outcome of this determines whether there will be restrictions on the choice of materials or equipment used for the building work. If inside the restricted area, refer to point 3.2.3 onwards for guidance in choice of material. If outside of the zones, it must still be determined whether magnetic fields are produced within the zone, refer to point 3.2.5 onwards.	**Responsible:** *CF/SI, Instrument engineer, NSS construction engineer* **Determine distance from sensitive zones**
Activity output/product	Determines which path to follow through the rest of the procedure.

3.2.3. Material choice within 4m of the sensitive zone

If it is determined that the building activity is to be within 4 m of the NSE sensitive zones, there will be restrictions on the choice of ALL materials used. In this zone, there must be NO ferromagnetic materials (such as iron or non-amagnetic steel). This includes weldings, screws, concrete reinforcement, etc. All materials, even small parts, must be amagnetic (defined as having a relative magnetic permeability of <1.01). The persons responsible for the building activity shall provide a list of the materials they intend to use within this zone to the NSE instrument responsible and NSS lead engineer to allow the verification of suitability of the material.	**Responsible:** *CF/SI, Instrument engineer, NSS construction engineer, NSE IS, NSS lead engineer* **Analyse for implications on materials or equipment choice**
Activity output/product	ALL materials used/installed in this zone will be amagnetic.

3.2.4. Material choice within 6 m of the sensitive zone

All sizeable components to be used within 6 m of NSE are to be made of non-magnetic materials. Concrete to be reinforced only with non-magnetic steel or other non-magnetic material.

The sum of external dipole moments due to small (size << r) magnetic parts with dipole moments M at distance r must stay below 1 A/m, i.e. $\sum \mathrm{M_i}\ \mathrm{r_i^{-3}} < 1\ \mathrm{A/m}$. As coarse rule this corresponds to 2 cm^3 magnetised iron at one meter or 250 cm^3 iron at 5m to be applied if the parts 'see' some magnetic field (NSE fringe fields…).

The persons responsible for the building activity shall provide a list of components (inlcuding their size and composition) which they intend to use within this zone to the NSE instrument responsible and NSS lead engineer to allow the verification of suitability of the material.

Responsible:

CF/SI, Instrument engineer, NSS construction engineer, NSE IS, NSS lead engineer

Analyse for implications on materials or equipment choice

Activity output/product	All *sizeable* components will be amagnetic.

3.2.5. Determine whether magnetic fields are produced within 20 m of the sensitive zone

It must be determined whether magnetic fields are produced by any component installed in Experimental Hall 2 (North sector of Building D03), which the NSE instruments will be located in, and absolutely within a 20 m radius of the NSE sensitive zone. If this is the case, it must be determined whether these fields extend into the sensitive zones of the NSE instruments.

The areas of the instrument with a low magnetic field are particularly sensitive to external influence. Here the influence of external fields shall be compensated by large scale current frames installed on the NSE spectrometers, such that after compensation the residual STATIC field (i.e. static on the time scale of months) must be less than 0.1 G.

Additional STATIC fields (i.e. stable over the time scale of months) to the earth field (which is around 0.5 G) must be restricted to 0.5 G (i.e. absolute limit of additional field is 1.0 G before compensation). This also applies to static and low frequency (50 Hz) fields due to current carrying structures, power lines, etc… It also includes causing a variation in the field by, for example, turning on or off magnets or removing large blocks of

Responsible:

CF/SI, Instrument engineer, NSS construction engineer, NSE IS, NSS lead engineer

Analyse for implications on materials or equipment choice

magnetised iron. The persons responsible for the building activity shall provide the necessary information about components they intend to use within this zone to allow the verification of suitability of the component by the instrument scientist and the NSS lead engineer.	
Activity output/product	Restrict additional static magnetic field within the NSE sensitive zone to less than 0.5 G above earth field, stable over months.

3.2.6. Determine magnitude / fluctuation of magnetic fields produced

It must be determined if the magnetic fields produced fluctuate with time. This includes objects where the magnetic fields are turned on or off. Any low gradient FLUCTUATIONS of the magnetic field at any critical parts of the NSE instruments (i.e. the NSE sensitive zone) must be restricted to no more than 0.01 G over a 1 month period. Fluctuations with a frequency above 1000 Hz are no longer a concern. The limit is set significantly lower than that for the static field, since NSE spectroscopy is more sensitive to fluctuating or moving fields. The persons responsible for the building activity shall provide the necessary information about components they intend to use within this zone to allow the verification of suitability of the component by the instrument scientist and the NSS lead engineer.	**Responsible:** *CF/SI, Instrument engineer, NSS construction engineer, NSE IS, NSS lead engineer* **Analyse for implications on materials or equipment choice**
Activity output/product	Restrict low gradient fluctuations in NSE sensitive zone to less than 0.01 G over 1 month.

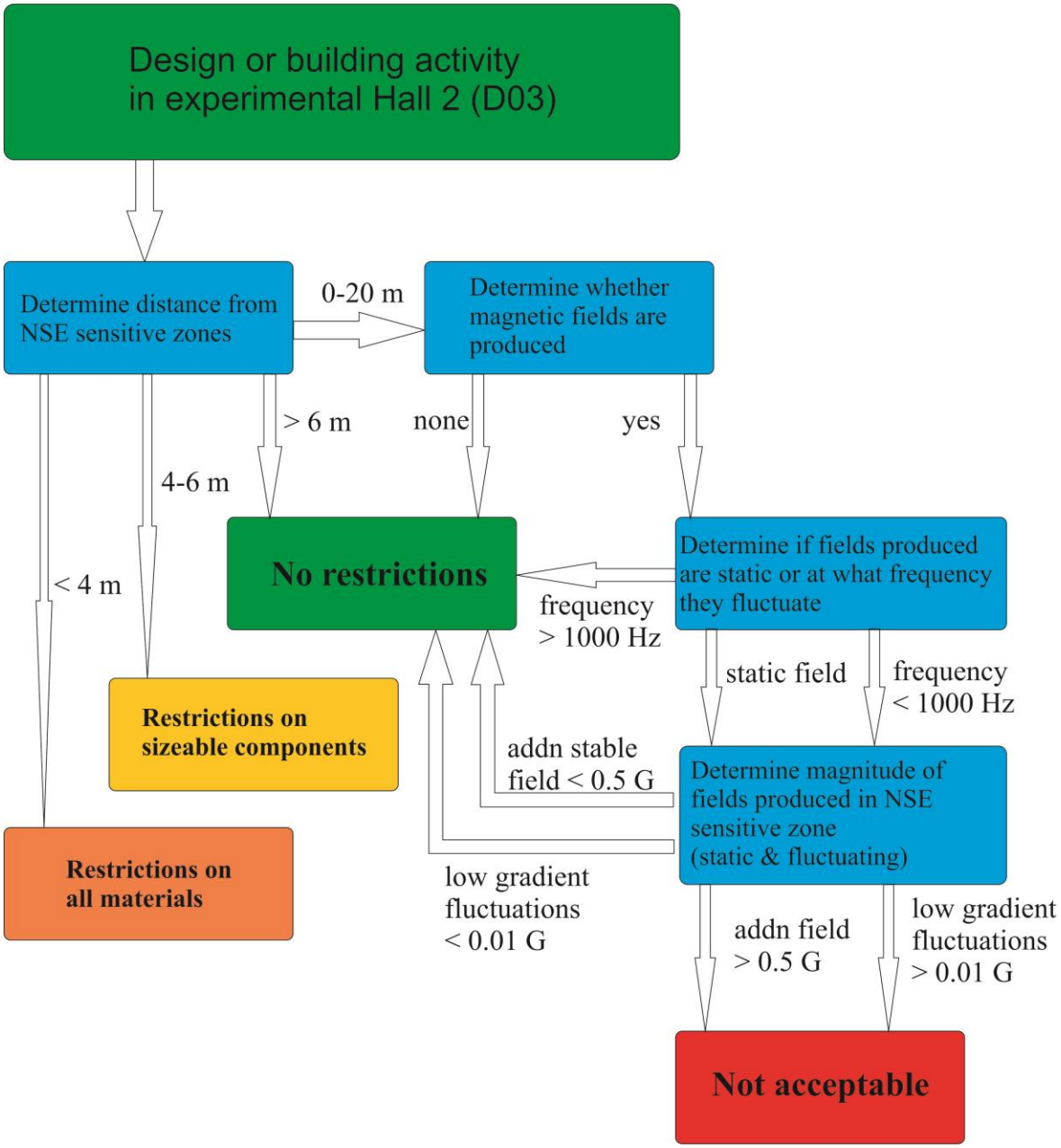
3.2.7. Special consideration for placement of cranes

The crane in the hall should very preferably be made of non-magnetic steel. If this is not possible, then consideration must be given to minimise the time that it spends in the wider vicinity of the NSE instrument during operations. NSE instruments will have to halt measurements when crane influence amounts to more than 0.005 G at any point of the	**Responsible:** *NSS construction engineer, NSE IS*

sensitive zone around them, so critical to minimise the downtime! This is typically when the crane comes within 8 m of the sensitive zone. The crane is treated as a special case, due to its large size and the fact that it is a moving rather than stationary object.	**Analyse for implications on materials or equipment choice**
Activity output/product	When planning cranes and their trajectories, minimise their time near the NSE sensitive zone.

3.2.8. Final choice of material or equipment

Before the final decision is made on use of a material or equipment in the vicinity of the NSE spectrometers, the instrument scientist for neutron spin-echo shall approve the material. In some cases procedures for use may be imposed by the instrument scientist for NSE to complement the choice of material in minimising downtime of the NSE instruments.	**Responsible:** *NSE IS* **Approve material or equipment prior to installation**
Activity output/product	Only suitable materials or equipment will be installed near the sensitive parts of the NSE spectrometers.



This detailed flow chart is intended to help understand the different aspects of the procedure. Specifically it should aid determine whether any restrictions apply to the materials to be used within the experimental hall near any NSE instruments.

3.2.9. Output

Materials used within the 4 m sensitive zone of NSE will be completely amagnetic (i.e. relative magnetic permeability of <1.01), while with the 6 m sensitive zone of NSE the sizeable components will be amagnetic. All additional static external magnetic fields (kept stable over months) within these zones will be kept below 0.5 G (above the earth field), while the fluctuations in the field will be less than 0.01 G. Cranes will be kept and moved to minimise their time within an 8 m radius of the NSE instruments during operations in order to minimise the downtime of the instruments. Other procedures may also apply.

4. COMMENTS

4.1. NSE instrument description

NSE instruments consist of a primary spectrometer, consisting of items such as guides, polarisers, choppers, and a secondary spectrometer, which consists of a number of coils, flippers, analyser, and detector (and sample position). Please note that this use of primary and secondary spectrometer is conventional for NSE, but is different from other types of spectrometers. For conventional spin-echo instruments, the secondary spectrometer is extremely sensitive to any external magnetic interference, since the technique relies on creating very homogeneous magnetic fields itself. In addition there are instrument components which need to be in a very low field environment themselves to function properly. The result is that while the instruments themselves inevitably end up creating stray magnetic fields themselves, which could magnetise any nearby objects which are not amagnetic, these instruments are themselves extremely sensitive to any stray fields from their surroundings. Such instruments have 'compensation' coils in order to compensate for the static magnetic fields that will always exist (such as from the earth magnetic field), but this strategy is only successful with relatively small external magnetic fields. It cannot be used to compensate fields which fluctuate (except at very high frequencies), this includes magnets being ramped up/down. It is therefore imperative that materials in the vicinity of the NSE instruments are chosen carefully, and that any objects which create magnetic fields (static or fluctuating) are placed such that their stray fields are kept within an acceptable level and do not hamper instrument performance.

4.2. NSE instrument layout

Below are sketches to illustrate what is meant by the sensitive zones of the NSE instruments. This is for a generic high-resolution NSE instrument as well as a wide-angle NSE instrument.

The sensitive zones are situated between the first ($\pi/2$) flipper and the last ($\pi/2$) flipper, with the diameter of the main coils. It should be noted that for a high-resolution NSE spectrometer, the second 'arm', located after the sample position, will move between zero degrees and 90 degrees.

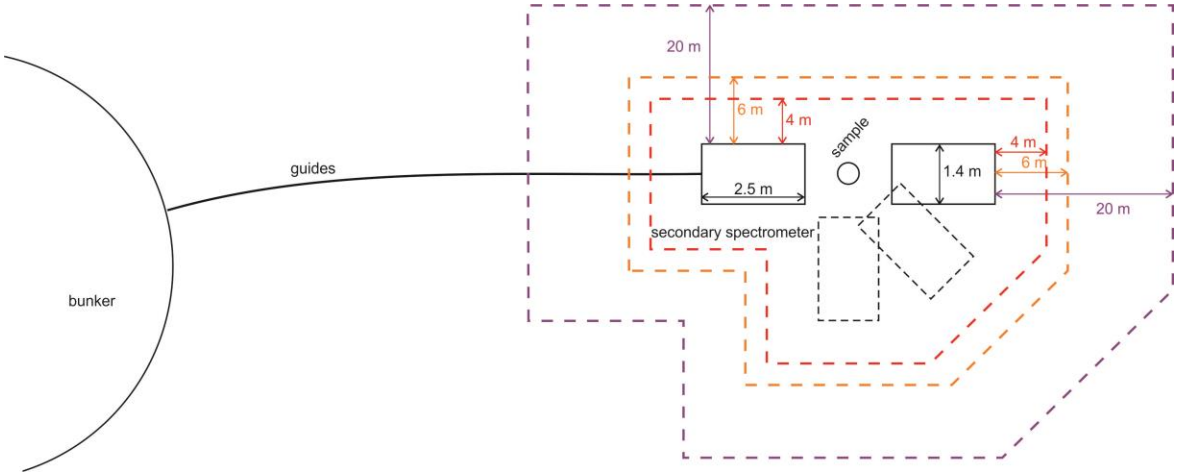


Figure 1: Layout of generic *high-resolution* NSE spectrometer. Red dotted line indicates the 4m boundary around the sensitive zone, while the orange dotted line indicates the 6m boundary around the sensitive zone and the purple dotted line indicates the 20 m boundary around the sensitive zone. The drawing is *not* to scale.

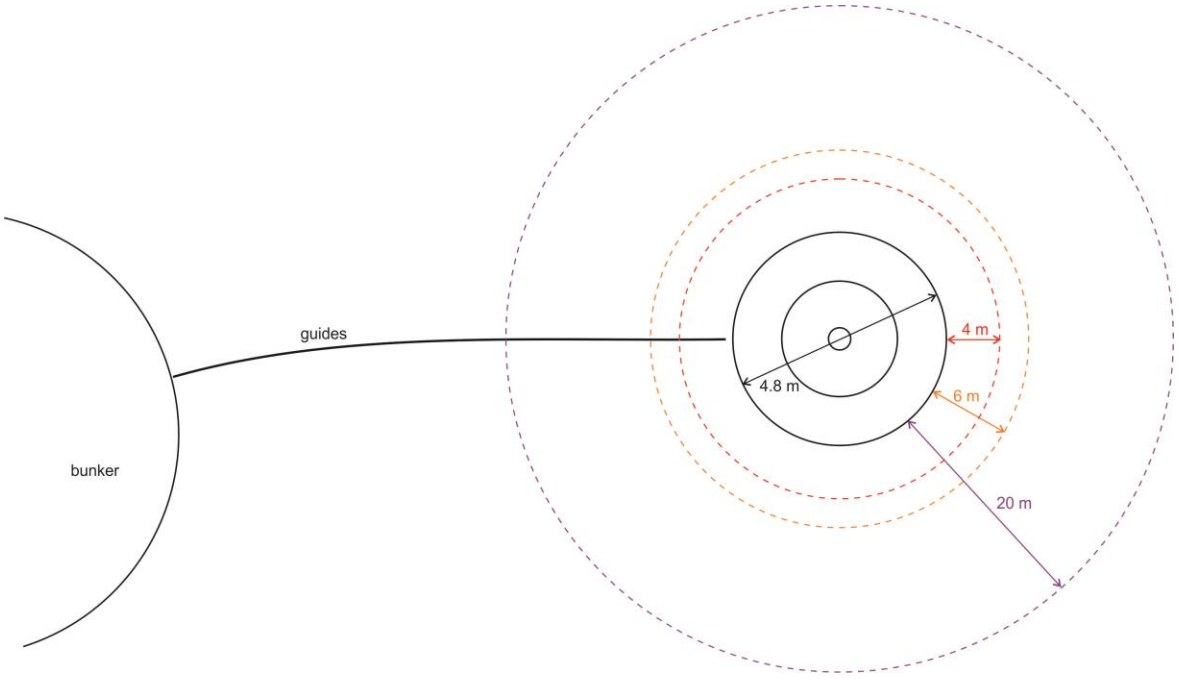


Figure 2: Layout of generic *wide-angle* NSE spectrometer. Red dotted line indicates the 4m boundary around the sensitive zone, while the orange dotted line indicates the 6m boundary around the sensitive zone and the purple dotted line indicates the 20 m boundary around the sensitive zone. The drawing is *not* to scale.

4.3. Relation to other instruments or sample environment

This procedure deals with the restrictions on the materials and equipment used near the NSE spectrometers necessary to allow the ESS to build NSE spectrometers with high performance. This clearly includes not just the building where the NSE instruments are located, but also the (neighbouring) instruments including sample environment. This procedure covers the implications for materials and equipment that can be used near the NSE spectrometers. There will be additional procedures to cover other aspects of ensuring compatibility between the different beamlines and their sample environment during operations.

4.4. Safety aspect to magnetic fields produced

This procedure does not specifically address safety aspects of magnetic fields, but rather serious performance concerns for NSE spectroscopy due to interference from external magnetic fields. There is currently no legal limit in Sweden on the value of exposure to magnetic fields. However, there is a new EU Directive [2] dealing with this topic, stating that the Exposure Limit Value for low frequency < 1Hz is 2T for normal working conditions. The values for magnetic fields discussed in this procedure fall well below this limit, and are therefore not of concern from a safety point of view.

4.5. Design and building activities conducted prior to this procedure

It is understood that many decisions have already been taken that may not be in compliance with this procedure. It should be made clear that there is no expectation that decisions already made prior to this procedure shall be reversed, unless it is still possible in a reasonable manner. However, it is expected that any upgrades of these parts would be done in a manner that would make them compliant with this procedure. Clearly all future design and building activities must follow this procedure.

It should be noted that the consequence of some decisions already being made that place magnetic materials within the sensitive zone of the NSE instruments is that the performance of the NSE instruments is affected, most likely due to hysteresis effects. In the worst case this will reduce the instrument resolution. This will hopefully not be the case, rather the expectation is that it will impact on the way the NSE instrument is operated.

4.6. Queries and disputes

It is strongly encouraged to discuss any questions about what may or may not be a suitable building material with the instrument scientist for neutron spin-echo. Any disputes over the procedure and how it is to be handled or has been handled will, however, be dealt with at a facility level.

5. REFERENCES

These requirements have been identified internally at the ESS and subsequently revised through discussions with working partners and advisors to NSE.

[1] ESS Document 'Neutron Instrument Baseline': ESS-0047786

[2] Directive 2013/35/EU of the European Parliament and of the council of 26 June 2013

6. GLOSSARY

Term	Definition
NSE	Neutron spin echo
IS	Instrument scientist
G	Gauss [equivalent to 10^{-4} T]
CF	Conventional facilities
SI	Site Infrastructure
NSS	Neutron Scattering Systems

DOCUMENT REVISION HISTORY

Revision	Reason for revision	Date
1	New Document	2015-06-30