

APPLYING EMF EXPOSURE LIMITS TO CABLES AND CABLE TUNNELS

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PURPOSE AND SCOPE

This Technical Guidance Note sets out the position in National Grid regarding the exposure limits for electric and magnetic fields (EMFs) that underground cables should comply with, and some of the issues involved in achieving that compliance. The issues affect both the design and the operation of cable systems, and apply both to cables installed in tunnels and to direct-buried and trough cables near the surface and cable bridges.

The need to comply with exposure limits stems from the National Grid Corporate Public Position Statement on EMFs which states: "In all our operations, as a minimum we comply with EMF regulations, guidelines or practices in force in the countries and different jurisdictions in which we operate." Separate considerations apply for exposures to workers and to the general public.

PART 1 –PROCEDURAL

1 INTRODUCTION

Compliance issues arise:

- In the design of cable systems, principally those in tunnels, which produce occupational EMF exposure when operating to ensure the design allows the relevant occupational exposure limits to be complied with.
- In the design of cable systems, principally direct buried or in troughs, which produce EMF exposure to the general public when operating, to ensure the design allows the relevant public exposure limits to be complied with.
- When setting staff or contractors to work on or near cables, to ensure the work practices comply with the EMF occupational exposure limits.

Cables do not produce external electric fields so the only compliance issues that need to be considered are with magnetic fields.

The requirements for limiting magnetic-field exposures of the general public and in the workplace are different. Section 2 deals with occupational exposures. Section 3, dealing with public exposure, is under development and will be included in a later issue of this TGN(E).

More information relating to the subjects covered in this TGN(E) can be found at www.emfs.info.

The purpose of this document is to set out the principles that underlie the design of cable systems and tunnels, and that underlie operational procedures. The design and operational procedures themselves are not given here.

2 OCCUPATIONAL EXPOSURES

2.1 Occupational Exposure Limits

The relevant limits for occupational exposures are those of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) 1998. These do not have statutory force but compliance with them is Government policy and is expected by the Health and Safety Executive (HSE).

The basic restrictions that underlie the ICNIRP 1998 guidance have a considerable degree of conservatism incorporated in them. They are set with a safety factor of 10 relative to the point at which fields might interact with the nervous system of a worker in such a way as to have any effect. Such an effect, in turn, might affect their safety only when other unspecified hazards are present. The levels of field necessary to cause harmful health effects are in fact (considerably) larger than are found in the working environment.

The HSE therefore expects compliance with the ICNIRP 1998 limits in a pragmatic way. That is, it is sufficient to take reasonable steps to ensure that staff normally will not exceed the limits, though it is not necessary to ensure compliance under every circumstance however unlikely they are to occur, such as during fault current conditions which are "inherent in the design of the system".

The ICNIRP limits are expressed in terms of the induced current density in the central nervous system, which comprises principally the brain and retina (both in the head) but also the spinal cord. For practical purposes this limit converts to a magnetic field of 1800 μT for situations where the field is uniform over the volume of the body or where only the head or torso are exposed. For other parts of the body (limbs and abdomen) no limit is provided or necessary. Appendix A describes how the value of 1800 μT is derived.

Where the field is non-uniform, such as is produced close to the individual cables, the permitted field may be slightly higher and could be calculated on a case-by-case basis if necessary.

Normally it is sufficient and relatively easy to demonstrate that the magnetic field exposure from a transmission cable, even at its pre-fault continuous current rating, is below 1800 μT in relevant areas. As long as the head and trunk remain below 1800 μT it is acceptable for the limbs to experience the higher fields that exist close to the cables.

The situation regarding EMF limits is expected to change in the future. The ICNIRP guidelines are being update and the revised version has now been published. At some future date, the ICNIRP guidelines are likely to acquire legal force via an EU Directive¹ which

¹ The implementation date of the current Directive (2004/40/EC), which was originally 2008, has been delayed until April 2012 by a second directive 2008/46/EC while a further new directive is formulated. This new directive will not come into force before 2012.

requires the HSE to put regulations in place. These are not likely to come into force until 2014 or 2015, and until then our procedures continue to follow the ICNIRP 1998 guidance. It is expected that the directive will recognise the low level of the hazard and that the requirements will be proportionate to this.

Additional precautions may be required for workers with active implantable medical devices such as pacemakers and defibrillators, or for workers who are pregnant, and who need to work in the vicinity of transmission cables. These are not covered in this TGN and should be dealt with on a case-by-case basis through the Occupational Health Team in consultation with the ENI Environmental Engineering Team Manager (within Electricity Networks Investment of Transmission Asset Management).

2.2 Applying Occupational Limits to Cable Tunnels

General principles associated with applying EMF exposure limits to cable systems are discussed first, and then these are applied to designing cable tunnels and to operational procedures.

2.2.1 General Principles

To deal with EMF issues correctly, it is important to understand that the nature of the EMF exposure limits means that the severity of the hazard is not comparable with the system derived hazards that are covered by the National Grid Safety Rules. While the ICNIRP guidance should be complied with where possible, exceeding the exposure limits will have only minor, passing consequences, if any consequences at all, and this limits the lengths that it is appropriate to go to in order to prevent non-compliance. It is expected that this will be recognised explicitly in future regulations arising from the revision of the EMF directive.

The basic approach is to ensure that exposure to the head and trunk is less than 1800 μT for all activities in a cable tunnel, as planned. However it is not necessary for the procedures and design features to be so rigorous, and hence costly, as to guarantee compliance under every conceivable but unlikely eventuality. Inadvertent exposure in excess of the ICNIRP basic restriction is acceptable (see section 2.1). It is not necessary, for example, to put in place barriers or procedures that make it impossible for 1800 μT to be exceeded under all circumstances, such as when emergency current ratings are applied at short notice or when stumbling and coming into contact with a cable.

For cables in cable tunnels, staff need to be able to move around freely in the central region of the tunnel and therefore the magnetic field needs to be lower than 1800 μT throughout that central 0.6m wide region.

There will be occasions when staff need to move off the central region of the tunnel to work closer to the cables. The field will be highest on the surfaces of the cables, but whether or not 1800 μT is exceeded there depends on the particular circumstances, primarily on the current in the cable and on the diameter of the cable. In situations where the field at the surface of the cable can exceed 1800 μT it is necessary to aim for compliance with 1800 μT for the head (brain and retina) and the torso (spinal cord). For the limbs and abdomen there is no specific limit so, for example, it is acceptable for the hands, arms and legs to be touching the outer surface of the cables.

In the unlikely event of a fault on a circuit that passes through a cable tunnel at a time when personnel are in the tunnel, it is possible that the current in one or more of the phases will increase to such an extent the magnetic field exposure limit will be exceeded for the duration of the fault. Such events fall in the category of "inherent in the design of the system" and, as discussed above, it is not necessary to ensure compliance under such conditions.

Principles to be applied when designing new cable tunnels and in the development of procedures for working in tunnels are presented in the next two sections respectively.

This document is not intended to provide detailed design rules or operational procedures. These need to be assessed on a case-by-case basis by the Company's EMF specialists, through the ENI Environmental Engineering Team.

Appendix B contains an illustration of the application of these principles for a particular cable tunnel design.

2.2.2 Design Features

It will be necessary to ensure that the width of the region where the field is lower than the 1800 μT limit along the length of the cable, including joint bays, is wide enough for access to the whole length of the tunnel when continuous rated current is flowing. It is not necessary to design for short-term ratings as they are dealt with through operational procedures.

As previously stated it is not required to prevent inadvertent exposure to magnetic fields greater than 1800 μT , and so it would not normally be necessary to build physical barriers to prevent access to places where the fields are higher than this level. This should be satisfactorily preventable using suitable operating procedures (see Section 2.2.3).

If there is to be a tunnel vehicle, consideration will need to be given to enabling personnel to get past the tunnel vehicle without exceeding 1800 μT in the head or trunk.

Advice can be obtained from the Company's EMF specialists, through the ENI Environmental Engineering Team.

2.2.3 Operational Procedures

As stated previously it is not necessary for operational procedures to be devised to make it impossible for the exposure limit to be exceeded for short periods of time. Rather, procedures should be based on training and information for workers about what the exposure levels are in different places and about what they must do to avoid exceeding the exposure limit.

PPE to reduce magnetic field exposures does not exist.

The magnetic field in the "central region" of all cable tunnels will be less than 1800 μT for the continuous rating of the cable. This should be true for all new cable tunnels following the advice in Section 2.2.2. All existing cable tunnels will have a central region where the field is below 1800 μT . The width of the central region is different in each case and would need to be confirmed on a case by case basis. For example, for a particular tunnel, the closer together the three phase conductors of each circuit are to each other and the lower their current rating, the wider the central region will be.

Access within the central region is therefore permissible without further restriction.

Work may need to take place closer to a cable. For limbs and abdomen there is no specific limit and so (from an EMF perspective) it is acceptable for workers to touch the outer surface of the insulated cable, whatever the geometry or current.

For head and torso the field level near the cable needs to be considered. An approximation of the distance from the centre of a single cable carrying a current, I , at which the magnetic field is 1800 μT is given by

$$r = \frac{0.2 I}{1800} \quad m$$

Thus for example when the current is 1000 A the field is 1800 μT at a distance of 11.1 cm from the centre of the cable, and at a smaller distance from the surface of the cable. This is an approximation because of the contribution to the field from the other nearby cables. Software is available to calculate this distance for specific situations.

The maximum magnetic field on the surface of the cable is likely to exceed 1800 μT for the continuous current rating of the cable. However for the maximum expected current in the cable for the duration of the period when access is required, it is possible that the current on the surface of the cable will be less than 1800 μT in which case no constraint would be needed on EMF grounds.

A procedure could specify the closest distance of approach to the cables of the head and torso that the worker is required to observe.

The minimum distance for head and torso could be selected on the basis of either the continuous current rating of the cable or alternatively, on the highest normal load current that is expected during the period of time for which access to the tunnel is planned. The latter would allow for closer working when it is known that the current will be lower than the continuous rating.

Where short term ratings are being applied during the work these should be used in the calculation of minimum distances to be observed, but higher short term ratings (either emergency ratings or cyclical ratings) that are not due to be used during the duration of the work do not need to be considered.

Alternatively the operational procedure could specify that the current will not exceed a specified maximum value such that a distance limit is not required.

In either case, it may be that, while work is in progress, the current rises above the value of current for which the assessment was carried out, (for example due to unexpected switching, or a fault). If this happens, workers should move towards the central region of the tunnel far enough from the cable to ensure that the exposure limit is complied with regardless of the short term rating.

In support of the application of operating procedures it would be useful for information to be provided for each installation in a common format as follows:

- The current at which the field is less than 1800 μT everywhere (I_A)
- The continuous current rating of the cable (I_B)
- The highest short term current rating that has been specified for the cable (I_C)
- The width of the central region where the magnetic field is less than 1800 μT for currents between I_A and I_C , including I_B
- The maximum distance of the 1800 μT contour from cable surface for currents between I_A and I_C , including I_B

Advice, including calculations for specific geometries and loadings, can be obtained from the Company's EMF specialists, through ENI Environmental Engineering Team.