The UK Nuclear Industry Good Practice Guide To:

**Conservative Exposure Durations for**

**Unmitigated Worker Doses**

**in**

**Design Basis Analysis**



This Nuclear Industry Good Practice Guide was produced by the Safety Case Forum and published on behalf of the Nuclear Industry Safety Directors’ Forum (SDF)

**Issue 2 – March 2020**

**Revision History**

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| --- | --- | --- |
| **Issue Number** | **Revision Date** | **Changes** |
| Issue 1 | January 2014 | Initial Publication |
| Issue 2 | March 2020 | Technical review and update due to time lapse. Incorporation into new SDF Template. |
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It is recognised that – through the experience of using this Guide – there may be comments, questions and suggestions regarding its contents.

In the first instance, any such comments should be sent to the following email address

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Contributions have been provided through the Safety Case Forum by all participating members.

This document was reviewed and approved by the Safety Case Forum
of the Safety Directors’ Forum.

# Foreword

SCF Guides are written for suitably qualified and experienced safety case practitioners, thus the basics of safety cases and safety assessment as they affect a particular Safety Case Forum Guide are not necessarily explained in the Guides.

Authors are expected to use their judgement in applying these Guides, taking account of company-specific, site-specific, building-specific and scenario-specific factors.

# Executive Summary

The worker exposure duration is only one element of demonstrating an overall conservative dose, so worst-case assumptions (that would give an unrealistically high overall dose) would not be proportionate. The exposure duration for unmitigated DBA worker doses should be realistic, conservative and defendable.

For the unmitigated dose, no credit should be taken for evacuation due to any radiometric (or other) alarms that may operate.

The shorter the claimed conservative exposure duration, the more robust the justification needs to be. If the unmitigated dose is close to a DBA threshold, the conservative exposure duration should be justified to be suitably conservative with a very high degree of confidence. In addition, greater complexity in identifying a conservative exposure duration requires greater robustness in the justification.

The conservative exposure duration varies depending on whether the fault is clearly revealed, or not, and on a number of other factors including those outlined below. Some typical durations have been suggested, but each scenario is different, and site-specific, facility-specific and scenario-specific factors need to be taken into account.

If the fault is unrevealed, the task duration may be the conservative exposure duration if the unrevealed fault is terminated by completion of the task. Otherwise, the standard working period may be used as the conservative exposure duration.

If the fault is revealed, consideration should be given to the time periods to:

* sense that there is something wrong;
* decide that evacuation is the best course of action; and
* effect the evacuation.

Where there is reasonable doubt that the fault will be clearly revealed, the advice for unrevealed faults should be followed.

## Safety Directors’ Forum

In a sector where safety, security and the protection of the environment is, and must always be the number one priority, the SDF plays a crucial role in bringing together senior level nuclear executives to:

* Promote learning;
* Agree strategy on key issues facing the industry;
* Provide a network within the industry (including with Government and regulators) and external to the industry;
* Provide an industry input to new developments in the industry; and,
* To ensure that the industry stays on its path of continuous improvement.

It also looks to identify key strategic challenges facing the industry in the fields of environment, health, safety, quality safeguards and security (EHSQS&S) and resolve them, often through working with the UK regulators and Government, both of whom the SDF meets twice yearly. The SDF members represent every part of the fuel cycle from fuel manufacture, through generation to reprocessing and waste treatment, including research, design, new build, decommissioning, care and maintenance and waste disposal. The Forum also has members who represent the Ministry of Defence (MoD) nuclear operations, as well as “smaller licensees” such as universities and pharmaceutical companies. With over 25 members from every site licence company in the UK, every MoD authorised site, and organisations which are planning to become site licensees, the SDF represents a vast pool of knowledge and experience which has made it a key consultee for Government and regulators on new legislation and regulation.

The Forum has a strong focus on improvement across the industry. It has in place a number of subject-specific sub-groups looking in detail at issues such as radiological protection, human performance, learning from experience and the implementation of the new regulatory framework for security. Such sub-groups have developed a number of Good Practice Guides which have been adopted by the industry.

## Safety Case Forum

This Guide has been produced by the Safety Case Forum, which is in turn a sub-group of the SDF.

The Safety Case Forum was established in June 2012 and brings together a wide range of representatives of nuclear operators, from all the Licensees and Authorisees across the UK, including:

* Civil, commercial and defence activities;
* Design, operation and decommissioning of nuclear facilities;
* Research facilities.

The purpose of the Safety Case Forum is to provide guidance that is useful to, and will benefit the widest possible range of UK nuclear operators.

Such guidance is not mandatory, nor does it seek to identify minimum standards. It aims to provide a tool kit of methods and processes that nuclear operators can use if appropriate to their sites and facilities.

These guides are intended to improve the standardisation of approach to the delivery of fit-for-purpose safety cases, while improving quality and reducing the cost of production. They are designed to cater for all stages of a facility’s life cycle and for all processes within that life cycle.

This includes any interim, continuous and periodic safety reviews, allowing for the safe and efficient operation of nuclear facilities.

When using the information contained within these guides, the role of the Intelligent Customer shall always remain with the individual nuclear operator, which shall retain responsibility for justifying the arguments in their respective Safety Cases. The ONR and the Defence Nuclear Safety Regulator are consultative members of the Safety Case Forum.

The following companies and organisations are participating members of the Safety Case Forum:

   

  

  

  

   

  

  

Safety Case Forum Guides are available on the Nuclear Institute Website;

<http://www.nuclearinst.com/SDF-safety-cases>

**Disclaimer**

This UK Nuclear Industry Guide has been prepared on behalf of the Safety Directors’ Forum by a Technical Working Group. Statements and technical information contained in this Guide are believed to be accurate at the time of writing. However, it may not be accurate, complete, up to date or applicable to the circumstances of any particular case. This Guide is not a standard, specification or regulation, nor a Code of Practice and should not be read as such. We shall not be liable for any direct, indirect, special, punitive or consequential damages or loss whether in statute, contract, negligence or otherwise, arising out of or in connection with the use of information within this UK Nuclear Industry Guide.

This guide is produced by the Nuclear Industry. It is not prescriptive but offers guidance and in some cases a toolbox of methods and techniques that can be used to demonstrate compliance with regulatory requirements and approaches.

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# Introduction

1. Design Basis Analysis (DBA) also known as Design Basis Accident Analysis (DBAA) is a fundamental technique used to robustly demonstrate the fault tolerance of nuclear facilities and operations.
2. DBA incorporates a conservative (pessimistic) approach, requiring the identification of an initiating event frequency and a conservative unmitigated radiation dose, in order to determine the safety measures needed to prevent or mitigate that dose.
3. In overall ALARP terms, consideration needs to be given to any elimination, prevention or protection that is higher up the safety hierarchy than evacuation (which is an operational mitigation system and therefore at the bottom of the hierarchy) even if the unmitigated dose doesn’t exceed any DBA threshold.
4. Within DBA, potential doses to workers in postulated accident scenarios are estimated. The unmitigated dose is the dose received when safety measures, e.g. evacuation in response to area gamma monitors, are assumed to have failed; no credit should be taken for evacuation due to any radiometric alarms operating for the unmitigated dose. Such evacuation should be treated as a safety measure that if successful gives a lower mitigated dose, but it does not have any effect on the size of the unmitigated dose.
5. The worker exposure duration is the period of time for which the worker is exposed to an external dose rate and/or for which the worker is breathing in airborne contamination. The exposure can usually be deemed to have finished:
	* + In the case of airborne contamination, when a worker leaves a room.
		+ In the case of external dose rate, when a worker is sufficiently far away or behind sufficient shielding (such that dose uptake falls below a consequence threshold).
6. The unmitigated dose is estimated, based on a number of elements. For an inhalation dose to a worker, all the following elements are usually relevant, the:
	* + Inventory;
		+ Physical and chemical form of the material;
		+ Release Fraction in the postulated accident;
		+ Release chemical reactions and other removal mechanisms;
		+ Settling of particles of different sizes;
		+ Distance of the worker from the release point;
		+ Model assumed for expansion of the ‘cloud’ of airborne activity;
		+ Decontamination Factors for passive, permanently available barriers;
		+ Breathing rate of the worker;
		+ Worker exposure duration;
		+ Model assumed for converting activity inhaled into dose to a worker;
		+ Lung Class of the material.
7. For an external dose, the list would be shorter. The key point, whether for internal or external dose, is that this Guide only addresses one element (the worker exposure duration) none of the other elements are within the scope of this guide.
8. DBA requires that the estimated worker dose is demonstrably conservative overall. In most estimates of inhalation dose, many of the above elements will contain a degree of conservatism, giving an overall dose that is conservative.
9. It is not necessary (or desirable) to make worst case assumptions for every single element, as that approach would multiply each of the worst cases, giving an unrealistically high overall dose. Thus, the aim for a worker exposure duration is to identify ***a period of time which contains a suitable degree of conservatism***, thus contributing to an overall demonstrably conservative dose.
10. If the analyst underestimates the unmitigated consequences, the whole process of DBA can be circumvented, i.e. the safety case will have insufficient extent and depth, leading potentially to safety measures of inadequate quality, or perhaps none at all.
11. This Guide does not attempt to provide guidance on workers who are unable to leave an area, for example because they are trapped in rubble, or because they have been made unconscious as part of an accident. Specialist advice, including Human Factors advice, should be sought in these circumstances.
12. The estimated worker exposure duration for an unmitigated dose for DBA purposes is called ‘the conservative exposure duration’ in this Guide.
13. The conservative exposure duration in any postulated accident scenario needs to be considered on an individual basis. However, **this Guide provides guidance on key aspects to be considered, and suggests some time periods as examples**. The quoted durations should not simply be used without considering the individual aspects of the postulated scenario.
14. In this Guide, it is assumed that nuclear workers are suitably qualified and experienced for the task they are doing, and are therefore familiar with the key concepts of radiation and contamination.
15. This Guide focuses on accidents and workers inside rooms/buildings (though some limited advice is given on workers outside exposed to a revealed accident). Workers nearby are also included.
16. Releases inside a building affecting workers outside the building are not included. Similarly, workers in adjacent buildings are not included - dose rates and/or airborne concentrations affecting these workers should, in most cases, be significantly smaller.
17. This Guide addresses unrevealed faults before clearly revealed faults, but no hierarchy is implied. If a fault is clearly revealed (as defined in Section 4), then Section 3 is irrelevant.

# Key Principles

1. The worker exposure duration is only one element of demonstrating an overall conservative dose, so worst-case assumptions (that would give an unrealistically high overall dose) would not be proportionate. The exposure duration for unmitigated DBA worker doses should be realistic, conservative and defendable.
2. For the ***unmitigated*** dose, no credit should be taken for evacuation due to any radiometric (or other) alarms that may operate.
3. The shorter the claimed conservative exposure duration, the more robust the justification needs to be. If the unmitigated dose is close to a DBA threshold, the conservative exposure duration should be justified to be suitably conservative with a very high degree of confidence. In addition, greater complexity in identifying a conservative exposure duration requires greater robustness in the justification.
4. The conservative exposure duration varies depending on whether the fault is clearly revealed, or not, and on a number of other factors including those outlined below. Some typical durations have been suggested, but each scenario is different, and site-specific, facility-specific and scenario-specific factors need to be taken into account.
5. Where there is reasonable doubt that the fault will be clearly revealed, the advice for unrevealed faults should be followed.

# Unrevealed Faults – Key Considerations for Conservative Exposure Durations

1. Although no credit should be taken for radiological alarms when assessing unmitigated DBA doses, an unrevealed fault would not, in-practice, remain unrevealed forever.
2. The advice that follows mostly assumes that the worker is present where the accident occurs. If not, see the advice below on **unrelated accidents**. Furthermore, most of the advice that follows is for a contamination event, – see advice on **external dose rate** events.
3. If the unrevealed fault may be terminated by the completion of the task, see the advice below on using **task duration**. If not, the proposed concept for conservative exposure duration for unrevealed faults is a **standard working period** in the area where the worker would be exposed. This is typically less than half a shift (‘shift’ is taken to apply to ‘working day’ for day workers) given that workers can be relied-on to take a meal break roughly in the middle of their shift, and usually have to pass through changerooms etc. in order to eat, or to take a natural break. This would give typical exposure durations of approximately 3 to 4 hours (see Paragraph 13), but there are a number of caveats below.
4. If the fault can only occur while a worker is in an area requiring access beyond a further barrier, i.e. C3 area (or higher contamination classification), the conservative exposure duration is reduced due to the time needed for dressing and undressing in the sub- changeroom. This would give exposure durations of approximately 2 to 3 hours (see Paragraph 13), but there are a number of caveats below. There may be other considerations that reduce the conservative exposure duration, such as walking time from the changeroom to the work area in the facility.
5. The reasoning behind this concept is that workers will have had to pass through changerooms, carrying out monitoring on themselves as they pass into the clean (C1/C0) area. Even without any contamination being found, on return to the work area, workers are more wary of conditions on the facility, being more aware of their surroundings when returning fresh from a break. In many accident scenarios, plant-based parameters such as flow or pressure may be out of range; these would be investigated by control room operators on return to the work area, and investigation of these parameters would lead to discovery of the unrevealed accident. While it is possible that an unrevealed fault could remain unrevealed for longer than half a shift, this is considered too conservative for this one element of DBA. Contamination monitoring in changerooms becomes part of the safety argument, but it may not need to be formally designated as a safety measure, since Local Rules made under the Ionising Radiations Regulations 2017 (Ref. 1) will inevitably require it.
6. There should be no significant difference to worker exposure durations if lone working is allowed, for example the need for a work break still applies. However, lone working is more of an issue for clearly revealed faults – see Section 4.

## Task Duration

1. The task duration is an alternative concept from the standard working period. It might be applicable for limiting some conservative exposure durations:
	* + The unrevealed fault may be resolved by the completion of the task, for example, once a skip is in a transport flask, the dose rate is likely to be low (in safety case terms) even if the skip contains much more highly active material than expected. In this case, the task duration may well be the conservative exposure duration, but consideration should be given to the possibility that the task is not completed within the expected times.
		+ If the unrevealed fault won’t be resolved by completion of the task, and if this is less than the ‘standard working period’ concept above, it is certainly possible that the workers may stay in the same area (being exposed) because they have other tasks to do in the same area. If this can’t be predicted in advance, task duration is not considered to be appropriate in this case.

## External Dose Scenarios

1. For external dose scenarios that are unrevealed, there may be fewer arguments to support the ‘standard working period’ concept, as some of the reasoning above only applies to airborne contamination scenarios, so more case-by-case assessment may be necessary. But there are still ways of limiting conservative exposure durations:
	* + There may be a system for recording external dose that operates daily or even at the end of each working period. This system would have to be of a sufficiently high standard that it could be effectively ‘guaranteed’ just as the contamination monitoring in Paragraph 27 is essentially ‘guaranteed’. If credit is taken for an external dose recording system, then the requirement for operation of this system (from a safety case perspective) should be clearly communicated to Facility Managers.
		+ External radiation surveys may be frequent enough to be useful. There would have to be confidence that the survey would identify a problem (maybe not for localised dose rates) and it should be made clear to Facility Managers what arrangements are needed from a safety case perspective.
		+ Use of task duration may be appropriate – see previous paragraph.
2. If the job routinely involves a Health Physics (radiation protection) operative present during a task, it might be thought that the conservative exposure duration could be limited to a few minutes, but obtaining the services of a Health Physics (radiation protection) operative is in itself a safety measure, so the conservative exposure duration for unrevealed faults should be applied (see above). Similarly, the wearing of alarmed dosimeters is a safety measure, and no credit should be taken for these when assessing unmitigated dose.

## Unrelated Accidents

1. In the case of unrelated accidents, for example a high external dose rate appears in an area in which workers may be present, but the accident is not related to what the workers are doing, then shorter conservative exposure durations may apply than those given above. In these cases, the affected area may have a low occupancy and more specifically may have a low maximum period that a worker may spend in that area, e.g. to change a filter paper on an air monitor. In this case, the low ‘maximum period of occupancy’ becomes the conservative exposure duration, as long as the accident is terminated before workers return to the area.

# Clearly Revealed Faults – Key Considerations for Conservative Exposure Durations

1. ‘Evacuation’ in this section is ‘guaranteed evacuation’ that is bound to happen due to the clearly revealed nature of the fault, giving an unmitigated dose. It should be distinguished from evacuation as a result of radiometric alarms etc., which (if successful) is a safety measure giving a mitigated dose.
2. Section 1 requires consideration of any elimination, prevention or protection that is higher up the safety hierarchy than evacuation (which is an operational mitigation system and therefore at the bottom of the hierarchy) even if the unmitigated dose doesn’t exceed any DBA threshold. Thus, even guaranteed evacuation as a dose reduction measure, should be considered after or alongside the search for other measures.
3. Where guaranteed evacuation is claimed to support unmitigated doses, it must be recognised that it may take the fault out of a DBA region, compared to conservative exposure durations for unrevealed faults (see Section 3). Therefore, where guaranteed evacuation thus changes the DBA region, the level of confidence in the guaranteed evacuation (including a demonstration that the fault is clearly revealed) must be demonstrably equivalent to the level of confidence required in the substantiation of a typical DBA safety measure; this may require a significant depth of analysis that addresses all credible potential reasons why evacuation might not happen in the duration claimed.
4. A clearly revealed fault in this case means a fault that is obvious to operators by means other than radiometric alarms. Examples include: a container is dropped onto the floor and there is a visible break of containment; there is obvious release of material; fumes are detected; or a fire breaks out. In some cases, a release of radioactive material might always be accompanied by a clear visible indication or other means of human detection. The senses of sight and hearing are the most likely ones to enable a fault to be clearly revealed. In such cases, conservative exposure durations that take credit for guaranteed evacuation can be justified.
5. Where there is a reasonable doubt that the fault will be clearly revealed, the advice for unrevealed faults should be followed. It is worth remembering that what is obvious in ideal conditions may be less obvious to those in a noisy environment, wearing PPE, etc. In addition, in the early stages of an incident, there may be confusion as to what the accident actually is.
6. Consideration should be given to any counter-indications that could mean the worker does not evacuate despite apparently obvious evidence of the fault. For example, if there is a clear danger of airborne activity due to some loss of containment, but there is no alarm from the airborne activity monitor (or no alarm yet) this could cast doubt in the mind of the worker, and could delay evacuation believing that ‘no alarm’ equated to ‘no release’.
7. It is always possible that a worker may wish to retrieve a situation, or warn other workers, thereby increasing their exposure time. Adequate training should ensure evacuation in response to most accident situations. A judgement needs to be made on this, and Human Factors guidance sought in case of any doubt. For example, where workers consider their own lives to be in danger, it can be confidently expected that evacuation will take place.
8. It has been standard practice within the UK civil nuclear reactor sector to design the reactor such that no human intervention should be necessary for approximately 30 minutes following the start of a requirement for protective action. Given that workers in a revealed fault scenario, on plant, are much more likely to take the simple protective action of evacuating to protect themselves than control room operators are to take potentially more complex protective action, it is considered that the worst case exposure duration for a clearly revealed fault is 30 minutes (see Paragraph 13). In some cases, this exposure duration may be overly-conservative. A worker exposure duration of less than 30 minutes for a clearly revealed fault should be justified, either specifically or generically for a particular type of scenario.
9. This justification may need to take account of how obvious the fault is, and may need to consider generic Human Factors issues such as training, local environment, and other workplace, organisation and people issues.
10. There are some fault scenarios for which 30 minutes would clearly be too long to be realistic. For example, a fire is highly likely to cause evacuation in a short time, though consideration should be given to whether workers might attempt to extinguish the fire.
11. Whatever the scenario, short conservative exposure durations need to consider the following time periods:
	* + Time period to sense that there is something wrong, noting that the workers may not be looking in the ‘right’ direction all the time, though a ‘flash’ or a ‘bang’ would draw their attention.
		+ Time period to decide that evacuation is the best course of action.
		+ Time period to effect the evacuation (see Paragraph 5).
12. In most cases, assessment of the above time periods would conservatively add up to around 5 minutes, but see Paragraph 13. However, there may be situations in which the worker is facing extreme danger and/or extremely obvious danger, when shorter conservative exposure durations may be appropriate. Examples include:
	* + If a worker in an air-fed suit notices that the suit is deflating, the potential loss of breathing air may well be enough to strongly encourage evacuation conservatively within about a minute (see Paragraph 13) while using the breathing tube, though this would depend on evacuation distances, etc.
		+ If a worker opens a door to enter a room, and observes an extremely obvious hazard inside such as a fire, the conservative exposure duration should be significantly less than 5 minutes (see Paragraph 13), noting that the action required to mitigate or prevent dose in this case is shutting the door, not evacuation, and this task can be completed more quickly than evacuation.
13. A conservative exposure duration of less than 1 minute (see Paragraph 13) should not normally be used for any scenarios, unless there is a robust justification that has involved relevant specialist disciplines, including Human Factors.
14. If there is lone working, a lone worker could be more likely to carry on with a task despite a revealed fault, and longer exposure durations may be appropriate. Thus, if there is a significant possibility that a facility might allow lone working, it should either be assessed for lone working (taking specific Human Factors advice), or if not, it should be made clear to facility managers that lone working is not allowed under the current safety case (or that no intrusive operations take place when lone working is allowed).
15. If there is historical evidence of exposure durations, this can be used directly for expected exposure durations, but the question still remains as to the conservative exposure duration to be used in the safety case, and the advice in the above paragraphs still applies, though it can be supplemented by historical evidence.
16. A fault that is clearly revealed to the workers involved may be totally unrevealed to other workers nearby, e.g. if they are behind a partition wall. Workers evacuating from a dangerous location can be relied on to inform their supervisor. If there are nearby rooms/areas that also need to be evacuated, evacuation should be effected within about 30 minutes (but see Paragraph 13). It is possible that these nearby workers would have a higher unmitigated dose, due to a longer exposure duration than the workers directly involved, and because they may be less well-protected than the workers directly involved.
17. In order to support evacuation of nearby workers, it should be made clear to facility managers what arrangements are needed.
18. For a revealed accident outside a facility affecting a worker outside, the advice on conservative exposure durations is basically the same as for workers inside buildings. However, consideration needs to be given to other people outside, who may be further away but are unaware of an airborne release or a higher external dose rate, for whom the advice on unrevealed faults would apply.

# Glossary

| **Term** | **Definition** |
| --- | --- |
| ALARP | As Low As Reasonably Practicable |
| ONR | The Office for Nuclear Regulation |
| LC | Licence Condition |
| AC | Authorisation Condition |

# References

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|  | **Title** |
| 1.
 | The Ionising Radiation Regulations 2017 (as amended).UK Statutory Instrument No: 1075 of 2017. |