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Inherent Safety

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HAZARD MANAGEMENT IN

STRUCTURAL INTEGRITY - VOL 4: INHERENT SAFETY

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SUMMARY

This report presents findings related to the topic of inherent safety which arose during research conducted for the Health and Safety Executive (HSE) in order to review how the offshore industry applies measures to manage structural integrity hazards. The complete study is described in 'Hazard Management in Structural Integrity' HSE Research Project ref. P3599-1 [Ref 1].

This report summarises views of inherent safety presented in regulations and by the regulator, and by representatives of the offshore industry. A summary of the different definitions that are available is provided, demonstrating that there is no one definition accepted by either regulator or industry. In particular, two conflicting definitions emerge. One is related to the design process, and refers to anything that may be done during design in order to make an installation less vulnerable to hazards. The effect may be to reduce the likelihood of a hazard occurring, to reduce its consequence if it does occur, or to reduce the risk associated with the hazard in some other manner. Within this definition, inherence should imply that the vulnerability to hazards does not increase significantly over time (eg it is not dependent on repairs or maintenance). The second definition is not tied to the design process, and can involve steps taken at any stage of design, build, operation or modification. However, it is more restricted in a different sense, in that it refers only to steps taken to prevent a hazard from being realised. Between these two extremes are a variety of hybrid definitions, where inherence is linked to both design and prevention, or is left unrestricted to mean almost anything to do with reducing risks.

The work described in this report was carried out between February and June 1998. This was prior to the revocation of SI/289 and the certification regime. Elsewhere in the report, therefore, the term 'certification body' is used.

This report is one of five reports produced by the study, the others being:

- OTO 98/148 'Hazard Management in Structural Integrity' [Ref 1]
- OTO 98/149 'Hazard Management in Structural Integrity: Summary Report' [Ref 2]
- OTO 98/150 'Hazard Management in Structural Integrity: Hazard Management Measures' [Ref 3]
- OTO 98/152 'Hazard Management in Structural Integrity: Performance Standards' [Ref 4].

INHERENT SAFETY

1. INTRODUCTION

This report presents findings related to the topic of 'inherent safety' identified during research conducted for the Health and Safety Executive (HSE) in order to review how the offshore industry apply measures to manage structural integrity hazards. The complete study is described in 'Hazard Management in Structural Integrity' [Ref 1] and summarised in 'Hazard Management in Structural Integrity: Summary Report' [Ref 2]. Additional reports on the project cover hazard management measures 'Hazard Management in Structural Integrity: Hazard Management Measures' [Ref 3] and performance standards. 'Hazard Management in Structural Integrity: Performance Standards' [Ref 4].

Since Piper Alpha and the Cullen Report, there has been a move away from prescriptive regulation to a 'goal setting' environment within the offshore industry. Generally, this is believed by regulator and operator alike to have improved safety. The overall goal in the context of structural integrity is to ensure that the integrity of an installation is as high as reasonably practicable, such that the level of risk to personnel is as low as reasonably practicable [Ref 5].

The nature of 'goal setting' allows a diverse range of solutions to the problem of designing a system for extracting oil and gas which is both safe and economic. In the Safety Case the duty holder may present to the regulator a range of different solutions in order to meet this goal. These measures can include prevention and mitigation measures, and measures to protect people from the consequences of an accident. However, there is little in the way of guidance as to how different measures can best be applied. There is a broad understanding that elimination and minimisation measures are more readily accomplished at design than during operation, but no more focused guidance. In particular, the guidance to the Safety Case Regulations [Ref 5] advocate 'inherent safety'. The operator of a fixed installation is required to submit:

> '*...a design safety case which describes how the design will provide for inherent safety...*'.

However the regulations do not provide a definition of what is meant by 'inherent safety'. This report sets out to provide a clearer understanding of what is understood by the term 'inherent safety', and the implications of that understanding within the UK Offshore industry in relation to issues of structural integrity.

2. INHERENT SAFETY IN THE REGULATIONS

Whilst the Safety Case Regulations [Ref 5] provide no clear definition of 'inherent safety', they do provide examples of how it should be applied, 'among other matters', as follows:

- substituting less hazardous for more hazardous processes;
- avoiding undue complexity in the design...;
- allowance for human factors... ...or control systems which reduce the risk of human error;
- minimising risks from hydrocarbons by keeping inventories as low as possible, by minimising the number of risers, and by minimising risks from risers by their design, location, and fire protection and by the fitting of valves;
- the selection of construction materials; and
- the design of vessels and pipelines to minimise the effect of sources of deterioration, to reduce stress concentration, and to facilitate inspection after construction and during operation..

The guidance for the Design and Construction Regulations (DCR) [Ref 6, paragraph 32] suggest a hierarchy of measures with inherently safe design as the first preference, giving as reasons:

- first, the costs associated with reducing risk levels are lowest at the design stage;
- second, eliminating or reducing hazards at source, through design, will be more robust and effective than control or mitigation.

The emphasis in the DCR is on consideration of hazards at the design stage, with examples given (regulation 5) including ensuring that the layout and configuration of the installation will not prejudice its integrity, and that suitable materials are used in the construction.

Reference is also made to inherent safety in 'Protection of Fire and Explosion and Emergency Response of offshore installations' (PFEER) [Ref 7}. In the guidance for regulation 4 (paragraph 34) the term 'protecting persons from fire and explosion' is defined as covering:

> *all the measures which may be needed to safeguard people from fires and explosions, ie inherent safety by design, preventive, detection, control and mitigation measures.*

This appears to differ from the information in DCR - DCR implies that inherent safety is a design issue, whereas this quote from PFEER implies inherent safety can be achieved at stages other than design, and includes control and mitigation measures. This ambiguity in the regulations and the guidance on the regulations is reflected by the large differences in interpretation in the industry.

3. UKOOA VIEWS OF INHERENT SAFETY

The industry body UK Offshore Operators Association (UKOOA) [Ref 8] offer a definition for inherent safety which at the start supports the DCR approach that inherence is linked to design, but towards the end includes construction and operation:

> *an approach to design in which hazards are 'designed out' at source. The primary means of prevention are the use of appropriate standards for design and operation, the optimisation of the layout for safety and the quality standards applied to design, construction and operation.*

Note also that this definition appears to equate inherent safety with prevention (otherwise the second sentence is a non-sequitur). A further comment in [Ref 8] is that:

> *the principles of inherent safety should be applied early in the design so as to eliminate or reduce hazards so far as is reasonably practicable.*

If interpreted to mean *early* in design compared to *later* in design, this statement could support the 'inherence is about design' argument; however, if it implies *in* design, compared to *after* design, then the alternative view is supported.

4. VIEWS ON INHERENT SAFETY DEVELOPED WITHIN THE HSE

The HSE commissioned an earlier study of inherent safety, which has been published as an Offshore Technology report [Ref 9]. The first definition given in this report is that inherent safety is an approach to hazard management:

> *that tries to avoid or eliminate hazards, or reduce their magnitude, severity or likelihood or occurrence, by careful attention to the fundamental design and layout.*

A more extreme definition is given later in this report, which is that:

> *an inherently safe plant or activity is one that cannot under any circumstances cause harm to people or the environment.*

Since this state is unachievable, further definitions are presented, including:

> *those aspects of the fundamental design which can be used to prevent, control or mitigate hazards.*

The definition is however confused by the statement in the Appendix to Ref 9 that:

> *such measures... make use of existing equipment and systems.*

The 'inherence is about design' view is supported in a paper by an HSE inspector [Ref 10], where inherent safety is defined as:

> *one of the fundamental principles of good design .. to eliminate hazards or minimise their consequences before resorting to control measures.*

However, Blackmore [Ref 10] introduces the concept of differing degrees of 'inherent safety' and, in particular, the idea of 'poor inherent safety'. In other sources, inherent safety is good, lack of inherent safety is bad, such that 'poor inherent safety' appears to be a contradiction. Blackmore presents no examples of poor inherent safety compared to good inherent safety, and hence the selection of appropriate inherent measures is not informed.

5. OTHER INDUSTRY VIEWS OF INHERENT SAFETY

In papers written by members of the offshore industry, inherent safety is listed as the preferred choice in a hierarchy of measures [Ref 11] and [Ref 12]. However, neither source provides a definition of inherence, and in [Ref 11] inherent safety is grouped together with prevention in the remaining discussion (as it was in the UKOOA reference cited earlier [Ref 8]).

Elsewhere the term 'inherent safety' is used - but not defined. For example, Tilsen [Ref 14] uses the idea of an 'inherently safer' design, stating that 'an inherently safe design is unachievable'. The author defines the concept of an 'inherently safer' as one in which 'potential hazards are minimised from the outset'. Similarly, Dalzell [Ref 15] makes reference to 'inherently safer features' without any definition of what is meant by this term.

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6. COMPARISON OF DEFINITIONS OF INHERENT SAFETY

One of the problems with the definitions presented is that they mix aspects of intention or aim with the means to achieve them. Table 6.1 summarises some definitions of inherent safety, with definitions divided into aim and means.

Table 6.1 Aims and means given for 'Inherent Safety'

Source	Aims	Means
SCR ([Ref 5] page 29, para 5, guidance to schedule 1)	None given	Substitution of less hazardous for more hazardous processes; avoid undue complexity in design; allowance for human factors; minimise risks from hydrocarbon inventories; selection of construction materials; design of vessels and pipelines.
DCR ([Ref 6] pg 8)	Risk reduction at the design stage	Ensuring that the layout and configuration of the installation will not prejudice its integrity, and that suitable materials are used in the construction
PFEER ([Ref 7] page 7)	To safeguard people from fires and explosions	By design, preventive, detection, control and mitigation measures.
UKOOA [Ref 8], pg 31-32]	Hazards are 'designed out' at source.. prevention	Primary means .. are the use of appropriate standards for design and operation, the optimisation of the layout for safety and the quality standards applied to design, construction and operation
HSE in OTH [Ref 9]	Those aspects of the fundamental design which can be used to prevent, control or mitigate hazards	Such measures.. make use of existing equipment and systems
HSE, Blackmore [Ref 10]	To eliminate hazards or minimise their consequences before resorting to control measures	Eg, design the pressure envelope to withstand the maximum possible pressure (so there is no need for safety valves) and minimise inventories of hydrocarbons held on platform.
HSE, Al-Hassan [Ref 13]	Eliminate or reduce hazards at source where reasonably practicable	Design jacket to protect risers from ship collision; minimise inventories of key equipment; specify corrosion resistant material. 'May still be ways to make the installation inherently safer onwards during construction, commissioning, operation and throughout the lifecycle.'
BRES [Ref 11] (page 1.1.3)	None given	IS and prevention achieved by: layout optimisation and quality of the design.
Britannia [Ref 12]	None given	Installation design

Source	Aims	Means
Granherne [Ref 14]	Inherently 'safer' not 'safe': Potential hazards are prevented or minimised from the outset; prevent rather than control and mitigate; ALARP risk criteria is met	Minimise process facilities, inventory and leak points. Optimise location of facilities. Selection of equipment and material.
BP [Ref 15]	None given	Substitution, intensification, attenuation, simplification. Concept, layout and detail: eg, simpler processing, fewer joints, less dependence on instrumented systems
INSIDE project [Ref 16]	None given	Intensification, substitution, attenuation, limitation, simplification. Eg reduction of inventory
IChemE [Ref 17]	To eliminate hazards at the design stage instead of adding on safety features at full scale manufacture	Simplify, moderate, minimise, substitute, make changes early.
Ref 9, pg i	Avoid or eliminate hazards, or reduce their magnitude, severity or likelihood or occurrence	By careful attention to the fundamental design and layout.. intensification and simplification .. inventory reduction
Ref 9, pg 1	Avoiding or limiting the hazard at source	Reducing inventories and simplification
Ref 9, pg 3-5	Hazard elimination, prevention and reduction … 'cannot under any circumstances cause harm to people or the environment.' Hazard avoidance, prevention, control and mitigation.	Uses materials that are harmless; small inventories; conditions render materials harmless. Less equipment and fewer opportunities for human error. Self-limiting processes.
Ref 9, pg 15	Minimise hazards at source where reasonably practicable (rather than stopping at an arbitrary level of design safety judged to be adequate).	Careful setting of safety goals, standards and philosophies
Ref 9, pg 16 / 17	The building of structures that cannot collapse. Risk avoidance	By not having an offshore structure at all Artificial island instead of a structure on the sea floor
Ref 9, pg 18	Reduce or eliminate the need for divers	Design for inspection (eg FMD, ROV)
Ref 9, pg 20	To produce a design which is less sensitive to assumptions made	Eg design for 100 or 1000 year wave instead of 50 year wave.
Ref 9, appendix 1, pg 44-45	To avoid hazards, or to reduce hazards to such trivial levels that the plant and process pose no threat of harm to people, property or the environment, on or off-site, and as a result there is no need for additional engineered or procedural safeguards.	Minimisation of hazardous inventory by reducing the size of a vessel; designing the plant to take maximum well pressure; redesign the process so some stages are avoided; optimising the layout in a module to reduce the severity of an explosion, minimising the number of potential leak sites.

Differences worth noting between the understanding of inherent safety shown by different sources include:

- Some limit inherent safety to the design stage (eg DCR), others allow for inherent safety measures throughout the lifecycle (especially [Ref 13]).
- Some exclude control and mitigation (eg [Ref 14]), others include it as part of inherent safety [Ref 6, 9].
- Some definitions imply an absolute: a structure which 'cannot collapse' or 'cannot under any circumstances cause harm' [Ref 9], but most imply a relative 'risk reduction' or 'minimise hazards' (also [Ref 9]) ie 'inherently safer' rather than inherently safe.
- In some cases inherent safety appears to include only elimination of a hazard [Ref 17], in others it can include reduction [Ref 6].

It can be concluded therefore that opinions on 'inherent safety' vary. In some cases, the term 'inherent safety' seems over used, being used merely as a synonym for 'safer'. For example, in Reference 9 'designing for easier inspection' should be considered as a measure which makes an installation safer, not inherently safer, as there are many ways in which the safety can be 'lost'.

7. CONCLUSIONS ON INHERENT SAFETY DEFINITIONS

Two alternative definitions appear to emerge of inherent safety:

- One is that it is related to the design process - any thing which is done during design to make an installation less vulnerable to hazards, whether natural or 'man-made', including environmental conditions and incidents brought about by human error. The effect may be to reduce the likelihood of a hazard occurring, to reduce its consequence if it does occur, or in some other manner to reduce the risk associated with the hazard. Inherence should imply that the vulnerability to hazards does not increase significantly over time (eg it is not dependent on repairs or maintenance).
- The second definition is not tied to the design process, and can involve steps taken at any stage of design, build, operation or modification. However, it is more restricted in a different sense, in that it refers only to steps taken to prevent a hazard from being realised - reducing the consequences of an incident once it has occurred is 'safer' but not 'inherently safer'.

Between these two extremes are a variety of hybrid definitions (as illustrated in Table 6.1), where inherence is linked to both design and prevention. In other cases the definitions are unrestricted, meaning almost anything to do with reducing risks.

An investigation into the attitudes of people working within the offshore industry towards the use of hazard management measures in structural integrity [Ref 1] revealed that the the concept of 'inherence' is associated with expense and an increase in time from concept to production. It was clear from this work that a convincing case for the cost benefits of inherence have not yet been presented to the industry and further work may need to be undertaken to establish whether it has real benefit.

The investigation further demonstrated the confusion that exists within industry in terms of what is meant by the term 'inherent' [Ref 1]. Little agreement existed in terms of the classification of a number of hazard management measures in terms of 'inherence'. Results suggest that what is more important is where in the lifecycle a hazard is tackled - the earlier a hazard can be removed or reduced or prevented the better.

8. REFERENCES

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