Title	FABIG Technical Note 4: Explosion Resistant Design of Offshore Structures
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Scope	**Introduction** Where gas explosions represent a credible risk, platform topsides have to be designed to withstand explosion loading. There are two aspects to consider: firstly loading on the structure and secondly loading and effect on equipment. This technical note deals principally with the first aspect but is also relevant to the second because the performance of the structure, e.g. deflection and acceleration, affects the equipment mounted on it. It is also relevant to the evaluation of the strength and deformation capacity of the equipment items themselves, e.g. pipes and vessels. This Technical Note covers both design of new platforms and reassessment of existing structures and is designed to supplement Sections 3.5 and 5.4.4 of the Interim Guidance Notes (IGN's). Several methodologies are presented: from simple hand methods to complex non-linear finite element analysis (NLFEA) for determining ultimate strength. In practice a mixture of methods will be used on a given installation. For new designs the emphasis will be on the simpler methods but for structural reassessment it will often be necessary to quantify strength reserve and for this more complex methods of analysis may be required. Section 2 of this Technical Note is dedicated to the issue of designing for inherent blast resistance at both concept and detail design stage. This is one of the most important steps in the design process as certain design styles are more inherently blast resistant than others. Section 2 contains a brief review of alternative structural styles and is included to provide topsides design engineers with a starting point for preparing conceptual structural designs, as an alternative to starting with the design style of the previous platform which might have had very different explosion pressures. Further guidance on approach to inherent resistance is also provided in Section 9. Before the structural response analysis can be started it is necessary to establish performance standards. These are required to judge whether the response is acceptable or not. The role of performance standards for topsides design in general is given in Section 3 of Technical Note 3 "Use of Ultimate Strength Techniques for Fire Resistant Design of Offshore Structures". These high level performance standards have to be translated into low level performance standards that are directly usable by structural engineers in computer models and code checks. In the context of explosion resistant design, low level performance standards are used as follows: • To define the behaviour of materials and structural members under dynamic loading and their characteristic failure modes, • To assess the performance of the structure during explosions, e.g. deflection, acceleration and shape change: this provides data for the assessment of equipment response to explosion, • To assess the condition of the structure at the end of the explosion event in relation to subsequent fire endurance: the condition after explosion must be consistent with the start condition assumed for the fire response analysis (IGN's Section 5.4.4).

Section 4 defines input loading requirements for explosion response analysis. It is important to make a judgement at the start of the structural design process of what the design pressures might be. Studies have shown that congestion due to equipment and secondary structure is a key factor in dictating the explosion pressure levels in a particular layout/venting arrangement. In practice, the level of congestion is not defined at the time that the main structural design is carried out. It is consequently necessary to commence and progress structural design on the basis of a range of possible design pressures and extend this flexibility as far into the procurement phase as is practicable. Pointers on how to treat these difficulties in new projects are given in Section 4.

Section 5 covers response of materials to dynamic loading and gives guidance on how to establish probable material yield strengths to use in place of code specified minima.

Section 6 is a guideline on the use of the two basic alternative methods of analysis (single and multi-degree of freedom) and the application of nonlinear finite element analysis (NLFEA) to them.

In Section 3.5 of the IGN's mention is made of the need to assess the rebound condition in SDOF analysis. This requires Rebound Dynamic Load Factors: these have therefore been developed and are included in Appendix A of this Technical Note.

Having established the general dynamic response of structures to the design explosion events it is necessary to assess the resistance of members to ensure that they do not break or buckle under the imposed loadings and deformations. Structural codes of practice form the basis of these checks e.g. Ref 1. However, as most do not cover excessive yielding or membrane action, a series of supplementary checks is required. Section 7 gives guidance in this area and draws on testing work carried out in Japan for the design of earthquake resistant structures.

The effects of boundary strain on membrane stresses in plating and the effect of membrane tension on the compression loading of boundary members is of particular importance in blast-resistant design; Section 7.5 provides methods for calculating these effects.

Section 8 gives a methodology for establishing the adequacy of the structure at the end of the postulated explosion events and addresses two aspects:

- The interface between the explosion and fire response analyses.
- The state of the structure in relation to the equipment and the escalation risk (interface with the equipment response analysis).

Section 9 gives practical guidance on the design of various types of structural components (blast walls, decks, members, joints). It gives advice on potentially critical features of these basic components. Special attention is given to blast walls and structural joints.

Section 10 gives guidance on reassessing structures for increased loading. It is generally possible to carry out limited modifications to structures to increase strength. Modules are usually initially designed for the same pressure over the whole module hence it is sometimes found that an increase in design blast pressure affects only part of the module. In such instances the extent of structural modifications required to upgrade the blast strength of a module are small. It is also recognised that with most platforms there is usually a feature or joint detail

	that severely limits the blast resistance. Appendix A is a supplement to Section 6 and contains charts of Dynamic Load Factors and Rebound Dynamic Load Factors. Also included are some charts to supplement Tables 3.9 to 3.11 of the IGN's to facilitate the calculation of support shear loads. Appendix B gives charts of membrane tension versus design pressure and boundary strain for 8 mm deck plate with 1000 mm clear span (1100 mm stringer spacing). Appendix C gives example calculations. The technical note, as a whole, is specifically geared to identifying the weak points, assessing them and rectifying the problem, i.e. it is a comprehensive guide to structural mitigation. The theme running throughout the Technical Note is the role of inherent safe design and how this philosophy can be applied to maximise blast resistance of topsides structures.
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