Title	Offshore Technology Report 1999 046: Explosion Loading on Topsides Equipment: Part 1 – Treatment of Explosion Loads, Response Analysis and design
Publisher/Author	HSE
Publication Date	2000
Executive Summary	This study addresses the design of topsides equipment to withstand the effects of vapour cloud explosions. Both the loading and response aspects are considered and some recommendations on design practice are given. At present the practice on projects is to perform comprehensive analysis of the structure, but much less attention is paid to the equipment: at best, a rudimentary analysis is performed, at worst, none at all. **Explosion Loading** Prior to this study little was actually known of the loadings on equipment in typical platform layouts, at least not with full equipment congestion included. Three platform types were therefore selected and subjected to a comprehensive loading analysis using a Computational Fluid Dynamics (CFD) code: 1. a small Southern North Sea platform: 2. a large confined and congested process module 3. a large Floating Production, Storage & Offloading platform (FPSO). The loading study was carried out by Christian Michelsen Research AS using the FLACS code. The study provides detailed results for 7 to 8 explosion scenarios for each platform. Though the FLACS code is used, the results are formatted and explained so as to allow the use of other suitable CFD codes for the work. Drag (explosion wind) loads are particularly important for equipment design: There are two methods for determining drag in CFD models: the drag impulse method and Direct Load measurement (DLM) method: the former quantifies only form drag and is suited to quantifying loads on discrete small items, less than 0.3m diameter. Historically, the drag impulse method has also been applied by topsides designers for most or all items larger than 0.3m and grouped equipment items. This practice is assessed by worked example in which both methods are compared. The worked examples included one of the SCI large scale tests. In some areas of the topsides the drag impulse method is found to underestimate loads by a factor of three or more. This is likely to have major implications for existing designs and future design styles. Good agreement was found with the SCI test, where a relatively small equipment item was used for load monitoring. **A hierarchical approach to equipment design** It is recognised that not all the equipment needs to survive explosion and indeed the complexity of the design process means that it may not be possible to ensure that all equipment needs to survive explosion. An outline definition of a criticality rating system and performance standards is therefore included in the study. **Equipment response** The method of converting the load data for use in response analysis is described and worked examples provided to show how this can be done. Response analysis methodologies are explored and described in the study. The methods are based on the techniques already developed for structural response analysis, as defined in the IGN's. These are the Single Degree Of Freedom (SDOF) method and the Multi Degree Of Freedom (MDOF) method.

The SDOF method is dependent upon being able to characterise a complex load pattern as a single time-varying load component. The required degree of simplification of the problem that is inherent to the SDOF method will lead to excessive errors in many situations, to such an extent that the method cannot be used reliably for the design of major equipment. The MDOF method is inherently more accurate as it does not require such simplifications.

The effect of this is that the primary method for the response analysis of safety-critical equipment has to be the MDOF method. Response analysis of topsides structure and equipment is currently performed primarily using the SDOF method and this is reflected in the current revision of the SCI Interim Guidance Notes (IGN's) which gives much more attention to this technique than to MDOF method. This finding may have implications for the forthcoming revision to the IGN's.

A most difficult but important aspect of the study has been to devise a method of condensing the potentially large amount of data and analyses down to a level which can be managed in a project timescale, without significantly prejudicing safety. It has been found that despite its other limitations, the SDOF method has a useful part to play in this aspect of the work.

Equipment design and support details

The loading studies found that the drag and acceleration loads were actually very dynamic and the forces in the equipment supports and piping items would often lead to their rupture capacity being exceeded if they were not made inherently ductile. Some examples of how to achieve this and account for it in the analysis are given.

In practical terms, it occasionally means specifying a higher flange and Wing class for a pipe system than required to meet the stipulated operating conditions (design pressure). In other situations it means using special ductile fixings for equipment skids or revised under-deck secondary steel. Also of great importance is pipe-rack and flare system design: these areas are also addressed with some useful tips on improving safety by thoughtful design. Some examples of improved fixing details are proposed. The loading studies found that forces in gratings (e.g. for escape routes), helidecks and lifeboats are higher than previously thought and fixings were found to be a critical area requiring attention: simple improvements to fixing details are proposed.

The choice of location of escape routes and essential control lines is also an important issue addressed in the study.

Projectile energy and projectile mitigation

Any equipment not designed to resist explosions is at risk of becoming a projectile. Loose temporary items are also a projectile risk. Projectile energy assessment and prevention methods are therefore also described.

Design steps

Figure 1 summarises the activities and elements required for the design of topsides equipment: flow charts are presented in the report to illustrate the advocated design methods.

Calibration against test

The loading and SDOF response methodology is applied to the SCI large scale test module, Test No 13. Loads are developed for the vertical cylindrical obstacle instrumented in those tests, using both the drag impulse and DLM methods and with response determined using the time-domain SDOF method advocated in this report. An extension of the work is carried out with refined grid to test the DLM method for intermediate sized obstacles (0.5m). The work confirmed the following:

- FLACS predicts the drag and differential pressure loadings very well
- The DLM method can be applied economically with reduced control volume size.
- The drag coefficients proposed by Baker are probably inaccurate (too high in this case))
- The load distribution around obstacles (as opposed to the peak pressure differential) needs to be better defined.
- The SDOF method seems to predict response quite well, but the reaction values need to be confirmed by MDOF analysis.

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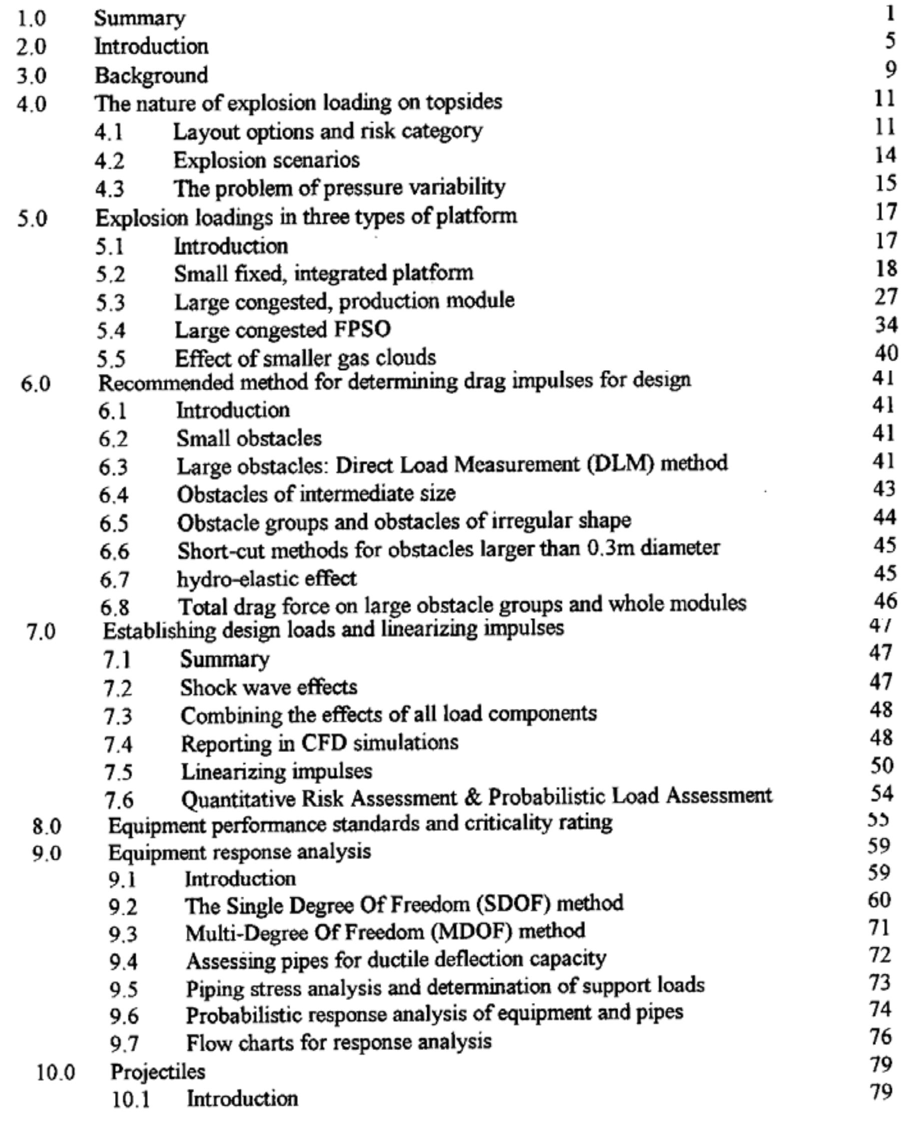

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PART 2: **Determination of explosion loading on offshore equipment using FLACS**
By Christian Michelsen Research A.S

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