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Review of the Jack-Ups: Safety in Transit (JSIT) technical working group

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Review of the Jack-Ups: Safety in Transit (JSIT) technical working group

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This report is a summary review of the activities of the Health and Safety Executive's 'Jack-ups: Safety in Transit' (JSIT) Technical Working Group. This Group consisted of representatives from the HSE itself, the Marine Safety Agency, NMD, certification bodies, oil companies, drilling contractors, jack-up owners, designers and constructors. This Group met at intervals between early 1991 and late 1995 to review safety standards and codes, and to identify any research needs relating to jack-ups undergoing 'wet' tows. There had previously been a number of major incidents and losses of jack-ups after they had encountered a severe storm during a wet tow.

A number of pieces of technical work were undertaken, either directly or indirectly as a result of the Group's activities. These included: a review of past jack-up losses, stability standards and seakeeping (with follow-up studies); studies on the application of quantitative risk assessment to jack-up tows, detection of water ingress, fatigue analysis guidance, assessments of the reliability of moorings during close proximity operations and close-proximity manoeuvring, and the effects of applying the 'Site-Specific Assessment' Recommended Practice to existing units; other studies relating to the Recommended Practice, watertight integrity of bulkheads and doors, and risk studies on towing operations. The HSE subsequently supported a programme of model tests to investigate the dynamic behaviour and stability of a jack-up during a wet tow in severe weather.

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EXECUTIVE SUMMARY

This report is a summary review of the activities of the Health and Safety Executive's 'Jack-ups: Safety in Transit' (JSIT) Technical Working Group. This Group consisted of representatives from the HSE itself, the Marine Safety Agency, NMD, certification bodies, oil companies, drilling contractors, jack-up owners, designers and constructors. This Group met at intervals between early 1991 and late 1995 to review safety standards and codes, and to identify any research needs relating to jack-ups undergoing 'wet' tows. There had previously been a number of major incidents and losses of jack-ups after they had encountered a severe storm during a wet tow.

A number of pieces of technical work were undertaken, either directly or indirectly as a result of the Group's activities. These included: a review of past jack-up losses, stability standards and seakeeping (with follow-up studies); studies on the application of quantitative risk assessment to jack-up tows, detection of water ingress, fatigue analysis guidance, assessments of the reliability of moorings during close proximity operations and close-proximity manoeuvring, and the effects of applying the 'Site-Specific Assessment' Recommended Practice to existing units; other studies relating to the Recommended Practice, watertight integrity of bulkheads and doors, and risk studies on towing operations. The HSE subsequently supported a programme of model tests to investigate the dynamic behaviour and stability of a jack-up during a wet tow in severe weather.

Key results and conclusions from these studies were:

- An initial review study of jack-up losses identified a typical sequence of events involving damage and multiple-compartment flooding in a severe storm.

- This study also found that current intact stability criteria had been successful to the extent that no losses seemed to have occurred while rigs were in the intact condition. A follow-up study supported the continued use of existing intact stability standards, concluding that it would be premature to consider use of dynamic stability criteria until basic sea-keeping analysis issues have been resolved.

- Model tests on a large jack-up unit in waves found that existing intact stability standards provided an adequate margin of safety against capsize in a severe storm, but raised concerns about the adequacy of the 1.0 area ratio criterion in the damaged condition.

- The complex technical issues surrounding the successive flooding of compartments after damage, and the roles played by deck-edge immersion, water on deck and wave-induced roll motions were seen to be worthwhile area for further research.

- A study of alternative methods for estimating green water loads on deck structures was inconclusive, and it was not possible to make recommendations about the use of any one design procedure or set of coefficients.

- A quantitative risk assessment study identified the major risks associated with a wet tow, and detailed risk management measures that might be applied to reduce the risk of a major accident. The largest individual factor contributing to fatalities and major damage potential was bad weather.

- A study on water ingress found that there was a large variation in the void space configuration of jack-ups, and also a significant variation in current practice for flooding detection and tank volume measurement. The effects of tank flooding on stability should be assessed on a case-by-case basis.

- A review of possible methods for flooding detection found an extensive range of available equipment.

- Initial guidelines were developed for estimating fatigue of jack-ups under tow.

- A review of the effects of applying the 'Site Specific Assessment' Recommended Practice to North Sea jack-up rigs found a marked difference in their capacity to withstand environmental forces, compared with Operations Manual/ design limits, for all but the most recent designs.

No known jack-up losses have occurred over the period since the JSIT Group first met. This is probably due largely to improvements in operating practice, less reliance on long wet ocean tows, greater awareness of the risks and better training standards throughout the industry. Existing intact stability standards and criteria seem to be satisfactory, although recent work has raised concerns about the adequacy of damaged stability standards for jack-up units.

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Review of the Jack-ups: Safety in Transit (JSIT) Technical Working Group

1. INTRODUCTION

BMT Fluid Mechanics Limited (BMT) was commissioned to prepare a review report on the activities of the Health and Safety Executive's (HSE) 'Jack-ups: Safety in Transit' (JSIT) Technical Working Group. The JSIT Group [1] was instigated by the HSE and NMD and included representatives from the HSE and NMD, the Marine Safety Agency, certification bodies, oil companies, drilling contractors, jack-up owners, designers and constructors. The JSIT Group met at intervals between early 1991 and late 1995 to review safety standards and codes, and to identify any research needs relating to jack-ups undergoing 'wet' tows. There had previously been a number of major incidents and losses of jack-ups after they had encountered a severe storm during a wet tow.

The JSIT Group issued a total of 56 numbered documents, and set up a number of sub-groups to review specific topic areas. Work subsequently commissioned by the HSE is described in various published and unpublished HSE reports. One major outcome was the publication of a BMT report [1] [2] reviewing the circumstances in which jack-ups had been lost, existing intact and damaged stability criteria, and the availability of relevant seakeeping model test data and numerical models. BMT's Phase 1 report made a number of recommendations for further work. A subsequent Phase 2 programme of work resulted in a number of further published and unpublished reports. It also led eventually to a programme of model tests performed in 1999 on a jack-up in severe storm conditions, to investigate the adequacy of existing intact and damaged stability criteria [2].

1.1 OBJECTIVES

The main objectives of this study were as follows:

- To prepare a review report on the activities of the JSIT Technical Working Group, which summarises the aims, objectives, key events and tasks undertaken in relation to JSIT, and resulting key documents, reports and publications.
- To summarise them in a form suitable for circulation to the jack-up community as a whole.
- To summarise them in a form which acts as a 'route map' for others trying to discover information about the Group and work undertaken in consequence.
- To identify key conclusions arising out of JSIT's activities and subsequent project work.

1.2 TERMS OF REFERENCE

This work was undertaken under HSE agreement number D3938 dated 12 February 2001, and was based on BMT Fluid Mechanics proposal reference Q/94774 dated 9 March 2000.

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1 Members of the JSIT Group are listed in Appendix A.

2 References in this report are denoted by square brackets, [], and are listed in Section 7 on page 21. Curly brackets, {}, denote JSIT document numbers, a list of which may be found in Appendix C.

2. REPORT CONTENTS

This report contains the following items:

- ***Chapter 3:*** a summary of the history of the JSIT Group;
- ***Chapter 4:*** a summary of key research results and reports which arose directly or indirectly out of JSIT activities;
- ***Chapter 5:*** a summary of key conclusions from these research studies;
- ***Appendix A:*** a list of organisations participating in JSIT;
- ***Appendix B:*** a list of all meeting dates, and key extracts from meeting minutes;
- ***Appendix C:*** JSIT numbered documents;
- ***Appendix D:*** a review of documents from JSIT activities;
- ***Appendix E:*** executive summaries or abstracts from key reports.

As part of this study, BMT reviewed documents and files contained in the HSE's project archives. The archived documents relating to JSIT consisted of two project files, 56 numbered JSIT documents, and about 20 published and unpublished reports, together with various unclassified documents. BMT did not prepare an exhaustive list of all these documents, or carry out a detailed technical review of all items, but aimed instead to identify key documents, list them, and summarise their main contents and findings.

3. SUMMARY OF JSIT HISTORY

The 'Jack-ups: Safety in Transit' (JSIT) Technical Working Group first met at Lloyd's Register of Shipping (LR) on 25th April 1991, following a number of jack-up losses, such as the 1990 *West Gamma* accident [3, 4]. The last meeting was held on 29th September 1995 at the Health and Safety Executive (HSE). A further seven meetings of the Group took place in the intervening period.

The history of jack-up losses, [5], suggested that jack-ups are at their most vulnerable during a wet tow. The JSIT Group was asked to consider a range of issues identified in a 'Statement of Study Requirements' [6], which related to a review of safety standards and codes. These issues included the following:

- reduction in stability due to flooding, or harsh environmental conditions;
- watertight integrity - wave impact loading to be established, as wave impact loads may cause most damage;
- movement of cargo on deck due to wave impact and green water;
- structural damage to the leg and leg support structures, due to inertia loads when rolling and pitching with the barge during wet tow;
- towline failure, leading to loss of control of heading;
- criteria for moving on and off location.

The Health and Safety Executive concluded that the guidelines produced from any research focusing on the above safety items should be produced in the form of a safety notice. Originally issued as Safety Notice 16/90 [29], there were deemed to be issues concerning design and construction, which were in need of further development.

The HSE was approached by NMD, and due to a number of agreements concerning the safety issues of a jack-up under-tow, it was agreed that OSD and NMD should work together to find solutions to these issues.

The JSIT Group subsequently agreed that the following issues were within its remit, suggesting that working groups should set up where appropriate:

- stability;
- watertight integrity and leg design;
- towing guidelines and procedures;
- towing operations and equipment;
- risks.

Various programmes of work came out of the Group's meetings. These activities were mainly funded by the HSE or NMD, although certain activities involving JSIT members were undertaken by the IADC and others. The JSIT Group was made aware of related activities (eg SNAME), by means of presentations at its meetings.

The following pieces of technical work were undertaken, either directly or indirectly as a result of the Group's activities:

3.1 STABILITY

1. Jack-up Stability in Transit, Phase I: Review of Casualties, Stability Standards and Seakeeping;
2. Jack-up Stability in Transit, Phase II:

- Task 1: Assessment of Intact Stability Criteria;
- Task 2: Assessment of Dynamic Effects on Stability;
- Task 3: Assessment of Water Impact Loads[3];
- Task 4: Assessment of Model Test Results;

3. Jack-up Stability in Transit, Phase II Final Summary Report.

3.2 WATERTIGHT INTEGRITY

4. Bilge and Ballast/Preload Systems;
5. Detection of Water Ingress into Jack-up Units Whilst in the Floating Condition;
6. Wave Impact;
7. Watertight Integrity of Internal Bulkheads and Doors on CFEM Design Type T2005C Jack-up Unit.

3.3 LEG DESIGN

8. Guidance Notes: Fatigue of Jack-Ups During Tow;
9. Site Specific Assessment of Mobile Jack-up Units (related work);
10. Investigation into the Effect of RP on North Sea Jack-up Rigs;
11. Foundation Fixity Study for Jack-up Units.

3.4 TOWING GUIDELINES AND PROCEDURES

12. Criteria for Jack-ups Manoeuvring in Close Proximity to Jacket Platforms;
13. Guidelines for Moving Jack-Ups;
14. NMD Towing Operations Manual.

3.5 TOWING

15. TOWCAP Development;
16. Risk Analysis of Jack-up Towing.

3.6 RISKS

17. Quantified Risk Assessment of Jack-Up Operations Afloat: Definition of a Rig Move on the UK Continental Shelf;
18. Quantified Risk Assessment Study.

3.7 BEYOND JSIT

The HSE subsequently supported a programme of model tests to investigate the dynamic behaviour and stability of a jack-up during a wet tow in severe weather. These tests were performed to investigate the adequacy of existing intact and damaged stability criteria. Whilst the reports from these tests are not strictly JSIT documents, they were on-going results from work started by the JSIT Group, and details are therefore included in this report.

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[3] Whilst this is not a stability issue but rather a hull integrity issue it is included here because it was undertaken as one of the tasks in the BMT's stability study.

During the time of the JSIT committee, a new regulatory regime came into being with the introduction of the Offshore Installations (Safety Case) Regulations 1992 [7]. A key feature of this new regime is the requirement for the owner or operator of every offshore installation operating in UK waters to prepare a ‘safety case’, and submit it to OSD for formal acceptance.

3.8 JSIT HISTORY HIGHLIGHTS

Key results and conclusions from the above studies are summarised in Section 4 and Appendix E.

Other issues considered by the JSIT Group included the following:

- circumstances surrounding the loss of the *West Gamma* in 1990;
- the adequacy of existing intact stability criteria, including the 1.4 area ratio, whether existing criteria are over-stringent for very large jack-ups, and the ‘free-twist’ versus ‘free-trim’ approaches to assessing stability;
- the adequacy of existing damaged stability criteria, the number of compartments to be assumed flooded, and the wind speed to be assumed in the analysis, in the light of flooding levels and wind speeds reported in past incidents;
- methods for calculating water impact loading on deck items and sea-fastening loads, and difficulties with existing load estimation procedures, in the light of calculations which demonstrated that containers on deck could not withstand water impact loading;
- the need for purpose-built means of securing permanent and semi-permanent items on deck, and the need for a code of practice, in the light of evidence that deck cargo had broken free and had been a significant factor in several recent losses;
- the need for bolted covers instead of hatches, and security of closing devices;
- the need to minimise the carriage of cargo on deck during a wet tow;
- the need to minimise the number of personnel on board during a wet tow, and for this issue to be addressed in a code of practice;
- towing procedures, tow-line monitoring and load prediction, and the need for regular checks on the tow wire and connections;
- the need for pump-out facilities, pumping capacity, and the adequacy of a proposed three-hour pump-out requirement;
- the importance of adequate weather forecasting, the need for better dialogue between providers and users of forecasts, and the need to consider the time taken to secure legs when planning a rig move.

4. KEY RESEARCH RESULTS AND REPORTS

This section of the report provides brief descriptions of work that came out of the JSIT Group's activities. The work was mainly carried out on behalf of the HSE, but includes some items that were undertaken as joint industry projects and were sponsored by the industry. (A list of work sponsored by the HSE can be found in Appendix E.)

This section of the report also includes descriptions of related works that, whilst not strictly about jack-ups in transit, involves the safety of jack-up operations in general, and so were considered by the Group. Appendix D includes a list of JSIT documents arranged according to subject.

Fuller descriptions, in the form of summaries extracted from the reports or guidance documents (where available), may be found in Appendix E.

HSE reports in the OTO series may be downloaded from the HSE website using the link http://www.hse.gov.uk/research/index.htm.

4.1 STABILITY

4.1.1 Stability in Transit, Phase I

This project [1], undertaken by BMT on behalf of the HSE, represented the first phase of a research programme into jack-up safety in transit. Essentially a review of existing documents, rather than a new technical investigation, this study aimed to identify key outstanding issues. Views of individuals and organisations with direct experience of jack-up tows were also sought.

The study reviewed:

- past jack-up capsize incidents,
- current HSE and other criteria concerning stability, watertight integrity and leg bending moments, applying to jack-ups during a wet tow,
- the suitability of numerical and physical models in this context.

The review of jack-up losses identified a typical sequence of events involving damage and multiple-compartment flooding in a severe storm. Most of the fundamental causes of loss were of an operational nature, and therefore outside the scope of the present review study. Present concerns were to ensure that standards for stability and watertight integrity were adequate.

Current intact stability criteria had been successful to the extent that no losses seemed to have occurred while rigs were in the intact condition. Fundamental problems were loss of watertight integrity and multiple compartment flooding, and the damaged stability criteria were seen to be an area of concern.

Concern was also expressed about the lack of direct experimental validation of numerical models, and the scarcity of appropriate model test data. Existing numerical models were seen as useful for qualitative and investigative studies in moderate sea states, but should not be regarded as fully established design tools, and should be used with caution.

A number of unexplained issues were identified, and recommendations were made for future phases of work.

4.1.2 Stability in Transit, Phase II

BMT then undertook a second phase of research into jack-up safety in transit, on behalf of the HSE, covering the following tasks. BMT's final summary report [8] outlined the main results and conclusions from these investigations.

Assessment of Intact Stability Criteria

The aim of this study [9] was to investigate the feasibility of carrying out a numerical study to assess the intact stability criteria of the HSE and other authorities, and the benefits of involving the certifying authorities in the process. A sensitivity study was proposed on four selected jack-up units, in which the stability requirements would be varied in a systematic manner, and the effects on the maximum allowable *KG* value would be assessed. Recommendations were made about future work.

Assessment of Dynamic Effects on Stability

Conventional stability criteria do not have a clear and rational physical basis. In this study [10], BMT reviewed a number of techniques which aim to put stability criteria on a more rational footing, and in particular aim to take explicit account of the dynamic effects of wave and wind gust loading.

Systematic calculations were performed on four jack-up units, based on a modified version of the Sarchin and Goldberg procedure, to investigate the feasibility of representing dynamic wave effects explicitly in the analysis. The main difficulties were found to be in selecting an appropriate design sea state, and in estimating realistic values of roll damping and maximum roll response in heavy seas.

The results from this investigation supported the continued use of existing conventional intact stability standards, and concluded that it would be premature to consider the use of dynamic stability criteria until basic sea-keeping analysis issues have been resolved.

The complex technical issues surrounding the successive flooding of compartments after damage, and the roles played by deck-edge immersion, water on deck and wave-induced roll motions were seen to be worthwhile area for further research, which might eventually lead to improved stability criteria.

Assessment of Model Test Results

BMT's earlier review [1] highlighted the lack of experimental validation of numerical models for predicting jack-up seakeeping behaviour, especially behaviour in severe sea states involving water on deck and flooding. It was therefore proposed that a correlation study should be undertaken in order to validate existing numerical techniques, as far as was practical using existing model test and full-scale data, and to define precisely where the deficiencies in present techniques, data and knowledge lie.

BMT's follow-up study [11] identified a number of existing experimental data sets which might be suitable for validating numerical models of jack-up seakeeping during a wet tow. BMT recommended that numerical calculations should be undertaken, as part of a follow-up study, for comparison with these experimental data sets. The need for further systematic model testing or full-scale measurements should then be assessed.

4.1.3 Jack-up Stability Model Tests

Model tests [2, 12] were performed to investigate limiting conditions for stability of a jack-up during a wet tow in severe North Sea storm conditions. The model was tested in the intact condition, and also with various peripheral damage and internal flooding conditions.

The objectives were to investigate whether traditional stability criteria, such as those contained in the Health and Safety Executive's Fourth Edition guidance, provide a satisfactory measure of the unit's stability in these conditions, and to estimate the margin of stability. The model's margin of stability was judged in terms of the height by which its centre of gravity could be raised before capsize occurred.

The model was based on an actual large jack-up design, but the compartments were deliberately enlarged so that flooding of a single compartment would cause the model to change from just meeting traditional intact stability criteria to just meeting traditional damaged criteria. Peripheral damaged compartments were allowed to flood freely when damaged. A large internal centre compartment, not free-flooding, was provided so that when flooded to $^{2}/_{3}$ capacity it just met the criteria. Tests were also performed with this internal compartment pressed full.

The majority of the tests were performed in severe storm conditions represented by a 70-knot wind and 12m sea states in the intact condition, and a 50-knot wind and 9m sea states in the damaged condition. The wind speeds were chosen to be consistent with traditional stability criteria, and the wave heights were representative of severe North Sea storms and consistent with the chosen wind speeds.

Initial hydrostatics calculations showed that the 30^o second intercept angle criterion was governing when the model was intact. The intact model remained stable in the chosen test conditions when set up to comply with this criterion.

The 1.0 area ratio criterion was governing in the damaged condition. This criterion did not provide an adequate measure of the model's stability when damaged, and did not provide an adequate margin of stability to prevent capsize in storm waves. It was difficult to see any consistent relationship between the point at which the physical model became dynamically unstable and conventional stability parameters. No single parameter emerged from this study as being a completely satisfactory measure of the model's stability.

For this particular unit and test conditions, therefore, existing intact stability standards provided an adequate margin of safety against capsize in a severe storm. The test results raised concerns, however, about the adequacy of damaged stability standards for jack-up units.

4.2 WATERTIGHT INTEGRITY

4.2.1 Bilge and Ballast/Preload System

The NMD/DNV jointly produced a proposal for changing the NMD regulations and the HSE guidance on bilge and ballast systems. It was noted that there were several factors which were specific to jack-ups.

In addition to the existing regulations for jack-ups to improve safety, they proposed that:

1. A piping system shall be permanently connected to all compartments that are assumed to be flooded in the damage stability calculation for each unit.
2. The piping system shall have the capacity to empty any one compartment, covered by 1, in 3 hours. Any pump connected to the emergency power system may be used. Complete stripping of the compartment is not to be included in the 3 hours.
3. The means for the operation of the bilge systems should be located (grouped) in as few locations as practical (at least two), and be easily accessible and operate after flooding of any one of the tanks or compartments covered by 1.
4. The lay-out and operational instructions for the bilge and drainage systems should be displayed at a suitably located graphic panel close to the location of operation of the system.

4.2.2 Detection of Water Ingress into Jack-up Units Whilst in the Floating Condition

NDE undertook a further study [13] into the possibilities for detecting water ingress into a jack-up unit whilst in the afloat condition.

The study found that there was a large variation in the void space configuration of jack-ups and also a significant variation in current practice for flooding detection and tank volume measurement. The effects of tank flooding on stability should therefore be assessed on a case-by-case basis in order to determine the extent of flooding detection system required.

A review of possible methods of flooding detection found an extensive range of equipment available for water detection. Water level switches and level monitors were both considered effective, and different devices were seen as appropriate for different tank configurations. Retro-fitting was seen as posing a number of problems.

4.2.3 Stability in Transit, Phase II: Assessment of Water Impact Loads

This work was undertaken as Task 3 in the Stability in Transit, Phase II study. Current guidelines for jack-up operations discourage the carriage of deck cargo in unprotected locations during a wet tow. Procedures for estimating green water impact loads are nonetheless needed for unavoidable deck structures and equipment. BMT's earlier review [1] found considerable evidence of deck items breaking loose and causing damage in past severe storms, but identified no existing established and validated procedure for estimating green water impact loads.

Representative calculations were performed [14] using a standard IACS design procedure, originally intended for designing end bulkheads of ships' deck-houses. These results were compared with estimates of wave slam and drag forces, calculated using standard force calculation procedures and coefficients. These sample values were also compared with typical maximum inertial and gravitational forces.

The results from this study were inconclusive, and it was not possible to make recommendations about the use of any one design procedure or set of coefficients.

Systematic model tests on a jack-up in boarding seas were recommended, to help validate load prediction methods, and to improve understanding of the physical processes.

4.2.4 Watertight Integrity of Internal Bulkheads and Doors on T2005C Jack-up Unit

This study [15] was undertaken by Lloyd's Register on behalf of the HSE.

The design appraisal was undertaken according to Lloyd's Register Rules as defined in Part 3, Chapter 3.7 of the "Rules and Regulations for the Classification of Mobile Offshore Units".

4.3 LEG DESIGN

4.3.1 Guidance Notes: Fatigue of Jack-Ups During Tow

In the design of a jack-up rig, the towing case is usually one of the critical fatigue cases for the leg design. The results, however, are very sensitive to the assumptions made and there are many uncertainties in this area.

Lloyd's Register (LR) was commissioned by HSE to provide an initial guideline [16] giving an approach to fatigue analysis of jack-ups under tow. It is hoped that this initial guideline might form a basis for industry review and comment, and would enable some progress to be made to further the safety enhancement of jack-ups under tow.

4.3.2 Site Specific Assessment of Mobile Jack-up Units

A guideline and recommended practice [17] for the "Site Specific Assessment of Mobile Jack-up Units", SNAME Technical & Research Bulletin 5-5A, was drafted by the working group of the joint industry sponsored project 'Jack-Up Site Assessment Procedures - Establishment of an International Technical Guideline'.

The guideline and recommended practice are bound together on one document. The guideline describes a general approach to site assessment that should be applied. The recommended practice describes one example of a methodology that can be followed to achieve the intent of the guideline.

4.3.3 Investigation into the Effect of RP on North Sea Jack-up Rigs

NDE was commissioned to carry out a Phase 1 study [18] to investigate the effects of applying the Recommended Practice (RP) for the "Site Specific Assessment of Mobile Jack-up Units" [17] to jack-ups operating in the UK sector of the North Sea.

The objective of the study was to produce a report including the following items:

1. (Approximate) quantification of qualitative results presented at the May OC-7 meeting, with an explanation of the methodology used.
2. To augment the above with information on other rig types that has been assessed to the RP by Noble Denton.
3. To list other North Sea rig types and qualitatively identify rig types that may or will be affected by analysis to the RP (this might include rigs in 1 or 2 at alternative water depths).
4. Review the jack-up fleet operating in the North Sea and provide an indication of the number of units that are close to their limits.
5. Provide a historical perspective on the results obtained in the above, including comment on the calibration of the RP safety factors and any bias due to:
    - the 'typical' rigs selected, and
    - the basis used for targeting the reliability levels, with discussion of the expected impact of alternative methods.

This review found that the capacity to withstand environmental forces according to the RP assessment was at variance with Operations Manual/ design limits for all but the most recent designs. A comparison of site-specific environmental data with Operations Manual conditions for units actually operating in the North Sea indicated that only a limited number of units were operating at sites close to the Operations Manual limits. A greater number of units may be operating at sites which are close to, or exceed, their estimated capability according to the RP.

The work leading to the partial safety factors in the RP was also summarised.

4.3.4 Foundation Fixity Study for Jack-up Units

SINTEF had been commissioned by the SNAME OC-7 panel to review the document "Site Specific Assessment of Mobile Jack-up Units", SNAME Technical & Research Bulletin 5-5A, which defines a Recommended Practice (RP) document for jack-up units.

The work has been conducted as a desk study [19], based on a large number of earlier research documents. These included PhD theses, research reports and published papers, covering the range from theory and model development, via model tests to field case studies.

The main focus of the study was on seabed fixity. The then current RP provided only small benefits when foundation fixity was taken into account. The objective of the study was to investigate whether the potential benefits of foundation fixity were taken into account in the new RP.

4.4 TOWING GUIDELINES AND PROCEDURES

4.4.1 Criteria for Jack-ups Manoeuvring in Close Proximity to Jacket Platforms

Global Maritime had earlier initiated a JIP to investigate the problems associated with jack-up rig leg impacts on touchdown, and also presented an Offshore Technology Conference paper 'Motions and Impact Responses of Jack-ups Moving onto Location' (JSIT {35}).

Global Maritime undertook this study [20, 21], carried out as follow-up work, on behalf of the HSE. In this study, risks associated with jack-ups moving onto location next to a fixed installation were investigated. Detailed finite element analyses were carried out, modelling impacts between the spud-can of a Marathon LeTourneau 116-C and a typical jacket.

4.4.2 Guidelines for Safe Movement of Self-Elevating Offshore Installations (Jack-Ups)

The IADC was considering the safe movement of jack-ups (JSIT{4}) and this was taken up by the UKOOA in association with the North Sea Chapter of IADC and BROA who developed guidelines

[22]. The guidelines concentrated on the operational aspects of moving jack-ups making recommendations upon responsibilities, planning, towing arrangements, weather criteria, navigation, communications, preparations seafastenings, and procedures under tow, arrival and placement.

4.4.3 Guidelines on the Contents of Operations Manuals

NMD had identified a need to minimise the contents of operations manual to include only that which was necessary for daily operations. They produced a proposal for comment about the contents of operations manuals (JSIT {18}, JSIT {37}) with the intention of updating NMD Guidelines No. 19.

4.5 TOWING

4.5.1 TOWCAP Development

Towing operations were investigated by NMD, who commissioned MARINTEK to study the dynamic loads in the mooring lines, taking into account both the towing vessel and jack-up, and the characteristics of the mooring lines and towing winch. The *TOWCAP* software was written to give a means of estimating the maximum tension loads, which might occur [24].

4.5.2 Risk Analysis of Jack-up Towing

SikteC had been commissioned by NMD to carry out this risk analysis project. The project performed a data simulation programme for tows and found values of risk of break of tow line during varying weather conditions. An objective of the project was to also evaluate whether there is a significant risk difference between using one advanced or two ordinary tugs during transfer and was to find out whether standby vessels were necessary during towing operations. The study was based on the use of the MARINTEK *TOWCAP* software.

Phase 2 [25] of this project contained further development of the models created in Phase 1 [26], and was intended to be more specific to different vessels, equipment, tows, locations and procedures.

4.6 RISKS

4.6.1 Quantified Risk Assessment of Jack-Up Operations Afloat

Phase I of this study [27], by Noble Denton Europe Ltd. (NDE), detailed the definition of a unit and an example location move for the North Sea. These were based on an actual unit, and on a rig move that occurred in 1992. Various key stages and events were identified, to act as a framework for NDE's follow-up study.

NDE then undertook a Quantified Risk Assessment [28] of jack-up rig moves in the North Sea in order to determine the risks to a jack-up and personnel involved in a rig move.

The study identified the major risks, detailing risk management measures that may be applied to reduce the risk of a major accident. The largest individual factor contributing to fatalities and major damage potential was bad weather. It was estimated that a reduction in fatality potential of about 30% could be achieved through using enhanced weather forecasting techniques, in order to avoid jack-ups being under tow during bad weather.

4.6.2 Risk Analysis of Jack-up Towing

See Section 4.5.2.

4.7 REGULATIONS AND HSE SAFETY NOTICES

The following relevant Safety Notices have been issued by the Department of Energy or HSE, either in draft or final form [29]. The first two Safety Notices were issued shortly before the JSIT Group was formed, and the last was a direct result of concerns arising out of the model tests discussed in Section 4.1.3:

- PED4 16/90: ‘Movement and Towage of Self-Elevating Offshore Installations’;
- PED4 **/90: ‘Positioning of Self-Elevating Installations Alongside Fixed Platforms’;
- SN 2/2001: ‘Self-Elevating (Jack-up) Installations Floating Damage Stability Survivability Criterion’.

Current regulations as of 1995 can be found in JSIT{52}.

5. CONCLUSIONS

It is difficult to summarise conclusions from the wide-ranging activities of the JSIT Group as a whole, and the following conclusions are extracted from the specific research studies described in Chapter 4:

Stability

- An initial review study of jack-up losses identified a typical sequence of events involving damage and multiple-compartment flooding in a severe storm. Most of the fundamental causes of loss were of an operational nature, and outside the scope of the review study.

- Current intact stability criteria had been successful to the extent that no losses seemed to have occurred while rigs were in the intact condition. Fundamental problems were loss of watertight integrity and multiple compartment flooding, and the damaged stability criteria were seen to be an area of concern.

- Concern was also expressed about the lack of direct experimental validation of numerical models, and the scarcity of appropriate model test data. Existing numerical models were seen as useful for qualitative and investigative studies in moderate sea states, but should not be regarded as fully established design tools, and should be used with caution.

- An investigation into the feasibility of representing dynamic wave effects explicitly in the analysis found that the main difficulties were in selecting an appropriate design sea state, and in estimating realistic values of roll damping and maximum roll response in heavy seas. This investigation supported the continued use of existing conventional intact stability standards, and concluded that it would be premature to consider the use of dynamic stability criteria until basic sea-keeping analysis issues have been resolved.

- A study on water ingress found that there was a large variation in the void space configuration of jack-ups and also a significant variation in current practice for flooding detection and tank volume measurement. The effects of tank flooding on stability should therefore be assessed on a case-by-case basis in order to determine the extent of flooding detection system required.

- Model tests on a large jack-up unit in waves found that existing intact stability standards provided an adequate margin of safety against capsize in a severe storm. The 1.0 area ratio criterion did not provide an adequate measure of the model's stability when damaged, however, and did not provide an adequate margin of stability to prevent capsize in storm waves. The test results therefore raised concerns about the adequacy of damaged stability standards for jack-up units.

Watertight Integrity

- The complex technical issues surrounding the successive flooding of compartments after damage, and the roles played by deck-edge immersion, water on deck and wave-induced roll motions were seen to be worthwhile area for further research, which might eventually lead to improved stability criteria.

- A study of alternative methods for estimating green water loads on deck structures was inconclusive, and it was not possible to make recommendations about the use of any one design procedure or set of coefficients.

- A review of possible methods for flooding detection found an extensive range of available equipment. Water level switches and level monitors were both considered effective, and different devices were seen as appropriate for different tank configurations. Retro-fitting was seen as posing a number of problems.

Leg Design

- Initial guidelines were developed for estimating fatigue of jack-ups under tow, for industry review and comment.
- A review of the effects of applying the 'Site Specific Assessment' Recommended Practice to North Sea jack-up rigs found a marked difference in their capacity to withstand environmental forces, compared with Operations Manual/ design limits, for all but the most recent designs.

Towing Guidance and Procedures

- Guidelines for moving jack-ups were developed. Whilst they were not mandatory, they were generally regarded as good practice in the Industry, and although different standards may be adopted in a particular situation, it was expected that equivalent levels of safety would be maintained.

Towing

- The dynamic loads in the towing lines were studied, taking into account the towing vessel and the jack-up. Maximum tension loads were estimated using the TOWCAP software developed as part of the study.
- Draft guidelines were developed on the basis of risk assessment methodology.

Risks

- A quantitative risk assessment study identified the major risks associated with a wet tow, and detailed risk management measures that might be applied to reduce the risk of a major accident. The largest individual factor contributing to fatalities and major damage potential was bad weather. It was estimated that a reduction in fatality potential of about 30% could be achieved through using enhanced weather forecasting techniques, in order to avoid jack-ups being under tow during bad weather.

No known jack-up losses have occurred over the period since the JSIT Group first met. This is probably due largely to improvements in operating practice, less reliance on long wet ocean tows, greater awareness of the risks and better training standards throughout the industry. Existing intact stability standards and criteria seem to be satisfactory, although recent work has raised concerns about the adequacy of damaged stability standards for jack-up units.

6. ABBREVIATIONS

ABS	American Bureau of Shipping
BMT	BMT Offshore Limited/ BMT Fluid Mechanics Limited
BROA	British Rig Operators Association
CA	Certifying Authority
DEn	UK Department of Energy
DnV	Det Norske Veritas
HSE	Health and Safety Executive
IACS	International Association of Classification Societies
IADC	International Association of Drilling Contractors
IMO	International Maritime Organisation
JIP	Joint Industry Project
JSIT	Jack-Ups: Safety in Transit
LR	Lloyd's Register of Shipping
MLT	Marathon Le Tourneau
MODU	Mobile Offshore Drilling Unit
NDE	Noble Denton Europe Ltd.
NMD	Norwegian Maritime Directorate
NSOA	Norwegian Shipowners' Association
OCB	Offshore Certification Bureau
OSD	Offshore Safety Division (of the HSE)
OTC	Offshore Technology Conference
PED	Petroleum Engineering Division (of the Department of Energy)
RP	Recommended Practice
SN	Safety Notice
SNAME	Society of Naval Architects and Marine Engineers
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
UKOOA	United Kingdom Offshore Operators Association
USCG	United States Coast Guard

7. REFERENCES

[1] BMT Offshore Limited, *Stability Criteria for Jack-ups in Transit. Phase 1: Review of Casualties, Seakeeping Data and Numerical Methods*, Report to the Health and Safety Executive, project no. 45459, revised final report, 18th July 1994.

[2] BMT Fluid Mechanics Limited, *Investigations into the Stability of an Intact and Damaged Jack-up during a Wet Tow: Model Test Interpretation and Assessment*, report 44217r22, HSE ref. OTO 2000 059.

[3] *Report on Jack-Up Installation [re West Gamma Accident] - Submitted to NMD*, 15th January 1991.

[4] Captain Asbjorn Rislaa, *Foundering of West Gamma, Sequence of Events and Observations*, 27th August 1990.

[5] World Offshore Accident Databank, [WOAD] for 1970-90 - Statistical Report.

[6] Health and Safety Executive, *Statement of Study Requirements*, 7th February 1992.

[7] *The Offshore Installations (Safety Case) Regulations,* Statutory Instrument no. 2885, HMSO, London, 1992.

[8] BMT Fluid Mechanics Limited, *Stability of Jack-Ups in Transit Phase II: Final Summary Report*, report 44058r63, HSE ref. OTO 98049, 4th August 1998.

[9] BMT Fluid Mechanics Limited, *Stability of Jack-Ups in Transit, Phase II: Task 1: Assessment of Current Intact Stability Criteria*, report 44058r52, HSE ref. OTN 95173, 7th September 1995.

[10] BMT Fluid Mechanics Limited, *Stability of Jack-Ups in Transit, Phase II: Task 2: Assessment of Dynamic Effects on Stability*, report 44058r25, HSE ref. OTN 95174, 2nd September 1997.

[11] BMT Fluid Mechanics Limited, *Stability of Jack-Ups in Transit, Phase II: Task 4: Assessment of Model Test Results*, report 44058r42, HSE ref. OTN 95175, 13th September 1995.

[12] BMT Fluid Mechanics Limited *Investigations into the Stability of an Intact and Damaged Jack-Up during a Wet Tow: Model Testing*, report 44217r12, 24th November 1999

[13] Noble Denton Europe Ltd., *Detection of Water Ingress into Jack-Up Units whilst in the Floating Condition*, HSE ref. OTO 95008, September 1995.

[14] BMT Fluid Mechanics Limited, *Stability of Jack-Ups in Transit, Phase II: Task 3: The Assessment of Water Impact Loads*, report 44058r33, HSE ref. OTO 95022, 4th January 1996.

[15] Lloyd's Register of Shipping, *Watertight Integrity of Internal Bulkheads and Doors on CFEM Design Type T2005C Jack-Up Unit*, HSE ref. OTN 95100, January 1995.

[16] Lloyd's Register of Shipping, *Guidance Notes: Fatigue of Jack-Ups During Tow*, G. Tseng/LR, 22nd October 1992.

[17] Society of Naval Architects and Marine Engineers, *Site Specific Assessment of Mobile Jack-Up Units*, Technical and Research Bulletin 5-5A, Panel OC-7, 1994.

[18] Noble Denton Europe Ltd., *Investigation into the Effect of the RP on North Sea Jack-Up Rigs,* ref. L17290/NDE/MJRH, 12th June 1995.

[19] SINTEF, *Foundation Can Fixity Study for Jack-Up Units* ref. STF22 F96660, 30th August 1996.

[20] Global Maritime Limited, *Risks Associated with Operational Criteria for Jack-Ups Location Moves*, proposal ref. GM-P672-0691, 16th July 1991.

[21] Global Maritime Limited, *Criteria for Jack-ups Manoeuvring in Close Proximity to Jacket Platforms*, GM-1306-0594-1818, May 1994.

[22] Guidelines for Safe Movement of Self-Elevating Offshore Installations (Jack-Ups), UKOOA, Issue No 1, April 1995.

[23] MARINTEK A/S, *TOWCAP - General Description*, 11th December 1991.

[24] Dynamics of Offshore Towing Line Systems, S Moxnes, IJ Fylling, Paper 10 Offshore 93, February 1993.

[25] NMD/ SikteC A/S, *Proposed Guidelines For Approval of Towing, Draft Report Phase II*, March 1993.

[26] NMD/ SikteC A/S, *Risk Analysis of Jack-Up Towing Phase I, Final Report*, Trondheim, July 1992.

[27] Noble Denton Europe Ltd., *Quantified Risk Assessment of Jack-up Operations Afloat, Phase I Definition of a rig move on the UK Continental Shelf*, Report No. L17403/NDE/SJP, 20th March 1995.

[28] Noble Denton Europe Ltd., *Quantified Risk Assessment of Jack-up Operations Afloat*, HSE ref. OTO 98045, August 1998.

[29] Department of Energy, *Safety Notice PED4 16/90, Movement and Towage of Self-Elevating Offshore Installations*, 1990.

[30] Overhead projections - List of suggestions by ABS, DnV and LR on calculations of loads due to wave impact.

[31] Marine Structure Consultants (MSC) bv, *Fatigue Analysis - CJ62-S120*, September 1990.

[32] Hitachi Zosen, *Fatigue Analysis of Rack Plates Under Towing Condition*, March 1985.

APPENDIX A: JSIT PARTICIPANTS

Government Departments

HSE, OSD	Health and Safety Executive, Offshore Safety Division.
NMD	Norwegian Maritime Directorate.

Certifying Authorities

ABS	American Bureau of Shipping.
DnV	Det Norske Veritas
LR	Lloyd's Register of Shipping.
OCB	Offshore Certification Bureau.

Industry

UKOOA	United Kingdom Offshore Operators Association
IADC	International Association of Drilling Contractors
BROA	British Rig Operators Association
NSOA	Norwegian Shipowners' Association
Diamond M Odeco	
Houlder Offshore Engineering	
Friede & Goldman	
Santa Fe International Corp	
Marathon Oil UK Ltd.	
Marathon LeTourneau.	
Texaco UK	
MATSU	Marine Technology Support Unit

JSIT Research Contractors

BMT Offshore Limited / BMT Fluid Mechanics Limited
Global Maritime
Noble Denton Europe Ltd.

Other Research Contractors

MARINTEK	
SikteC A/S	later Dovre SafeTec
MSC	Marine Structure Consultants bv

APPENDIX B: JSIT MEETINGS

The JSIT Group met in 9 formal meetings over a period of approximately 4 years. Summaries of the meetings taken from the minutes are given below.

B.1 Meeting - 25th April 1991

Referred documents: {2}, {3}, {4}, {5}.
Venue: Lloyd's Register of Shipping, Fenchurch Street, London.

After failures of *West Gamma*, and *Rowan Gorilla I*, Safety Notice 16/90 was issued. Further study from OSD and NMD, for design and construction issues was deemed to be appropriate. M. Havig referred to JSIT document {2}, 'Report on Jack-Up Installation' and explained the events leading to the sinking of *West Gamma*. Other documents discussed consist of JSIT {3}, 'Foundering of *West Gamma*', JSIT {4}, 'General Ocean Tow Recommendation for Jack-Up Drilling Units', and JSIT {5}, 'World Offshore Accident Databank [WOAD] for 1970-90'.

Other main issues which were discussed included:

Intact and Damaged Stability Criteria

The present intact criteria are not entirely satisfactory, relying on the 1.4 area ratio, but the point was made that no jack-ups had capsized in the intact condition (<1.5m penetration). This was not considered to be the major threat. Damaged criteria were geared mainly to minor collision, but structural damage could also occur due to leg reaction loads, and movement of cargo or wave loads caused by failure of watertight or weathertight closing appliances.

OSD's most recent guidance recommended consideration of the flooding of internal compartments. The design of seafastenings was considered very important, and it was noted that there was a lack of codified industry-accepted good practice.

Watertight and Weathertight Integrity

Wave loads were considered to be the cause of the most serious damage. Methods of access to pre-load tanks and the security of closing devices were to be reviewed, as well as the physical protection for ventilator ducts (recommended in SN 16/90 [29]).

Hull Strength

Legs and leg support structure are susceptible to fatigue damage.

Securing and Reduction of Deck Loads

In the first instance the amount of deck load should be reduced. There should be purpose-built means of securing semi-permanent and permanent items, which are accepted in advance by the CAs.

Possibility of Using Skeleton Crew whilst in Tow

A minimum of 30 to 40 people are required for normal operations on location. But this number could be reduced to only 9 persons during a wet tow, with jacking personnel flown out to the rig when required.

General Towing Procedures

Regular checks of the condition of towing wire and connections are required. Quicker leg clamping systems are also required.

B.2 Meeting - 4th September 1991

Referred documents: JSIT {4}, {6}, {7}, {14}.
Venue: HSE, Offshore Safety Division, Ferguson House, 15 Marylebone Road, London.
Letter from Marathon expressing interest to join the Committee, JSIT {14}.

Leg Design

A fatigue analysis can pin-point areas which might be reasonably vulnerable to fatigue damage. LR proposed to prepare a guideline document [16] that can be incorporated into the HSE Guidance Notes. Legs are normally designed to withstand a roll angle of 15 or 20 degrees, with a 100-knot wind speed. There is a need to note exceedances, which can occur in short-period waves. There is also a need for guidance on relating weather forecasts to rig motions, in order to comply with design criteria. The only guidance seen is in an IADC report, JSIT {4}.

Securing of Deck Loads

IADC and BROA are to develop a code of practice concerning the securing of deck loads. Water on deck appeared to be the main cause of the problem. To avoid forces from water on deck, containers could be sited in protective locations on deck or raised above the deck. Drilling equipment also needs to be properly secured.

Manning

The number of personnel on board depends on repair work being carried out, and excludes drillers. It was proposed that the industry be asked to develop a code of practice on minimum numbers on board.

Dynamic Tow-Line Analysis Developments

NMD provided the following papers for circulation by HSE: JSIT {6} '*TOWCAP* general description', and JSIT {7} '*TOWCAP* - Simulation of Towing Gear Dynamics'. This software was deemed to be useful for providing assistance in ascertaining the correct number of tugs required, motion of both units, and towing equipment. As of the 4th September 1991, HSE had no specific requirements for towing.

Stability

The present stability criteria were not considered satisfactory for large jack-ups.

Watertight Integrity

The legs should be designed for the worst storms worldwide, and the designers should state any design limitations.

Bilge and Ballast Systems

The need for a pump-out facility was stressed, and the 3-hour requirement was questioned.

B.3 Meeting - 12th December 1991

Referred documents: nil.
Venue: HSE, Offshore Safety Division, Ferguson House, 15 Marylebone Road, London.

Watertightness and Weathertightness

Jack-ups are considered to be a type B vessel under the Load Line Act, with freeboard increased for intact or damaged stability requirements. They can have considerable amounts of water on deck in transit, so deck structures should be watertight, not weathertight. Loose deck cargo has been known to open the dogs on hatch covers and damage ventilators, hence bolted covers instead of hatches were considered desirable.

Leg Strength

Weather forecast needs to be considered by the operator before moving, so that the unit keeps within its structural limitations. The time for securing legs (of the order of 6 hours) must be considered. Such information should be in the Operations Manual, along with chord loads, elevated load, spud can penetration, together with a list of limitations.

Bilge and Ballast Systems

It was thought that jack-ups should not have the same requirements as semi-submersibles, as in the MODU code. Pumping capacity was thought to be adequate on most jack-ups if the pipe work was suitably modified.

B.4 Meeting - 13th December 1991

Referred documents: JSIT {8}, JSIT {9}, JSIT {10}, JSIT {11}, JSIT {12}, JSIT {13}.
Venue: HSE, Offshore Safety Division, Ferguson House, 15 Marylebone Road, London.

Stability Consideration

The draft Statement of Requirements was reviewed, JSIT {8}, and the general opinion was that it was still too narrowly focused on stability aspects. The scope should be widened to gain a proper understanding of the behaviour of jack-ups, as a pre-requisite for updating the wave impact, loading, strength, watertight integrity and stability criteria.

Watertight Integrity

The CAs' meetings had taken place on the 4th September and the 12th December, and the following is a brief summary:

Watertightness and Weathertightness:

> The IACS committee on jack-ups would review criteria for watertightness and weathertightness.

Leg Strength:

> As an interim measure, the NMD and HSE would jointly prepare a list of environmentally related operating limit information to be included in the Operations Manual.

Leg and Hull Strength

HSE wrote to the Chairman of the JIP on 'Jack-Up Site Assessment Criteria' concerning leg strength assessment and associated operating criteria. The Chairman had approached other unit designers who would prepare a collective response.

A project launched by Global Maritime was described, which was looking at limitations associated with leg transit loads, and spud can bottom impact.

HSE tabled a proposal for a report, which LR had offered to prepare on fatigue considerations for jack-ups under tow, JSIT {9}. It was noted that ABS required a structural survey after a tow, and that fatigue damage was usually confined to areas around the upper guides where the maximum stresses occurred.

Towing Operations and Equipment

Present work by NMD involves developing a pilot software package, and the commercial software package was to be available in 6 months. The paper JSIT {10}, '*TOWCAP* - General Description, MARINTEK', and JSIT {11}, 'Risk Analysis of Jack-up Towing' were tabled. It was also noted that a proposed code of practice, JSIT {12}, on jack-up towing operations was to be developed by a joint operator/owner working group.

Manning during Tow

It was confirmed that manning levels would be addressed in the jack-up towing code of practice.

Securing of Deck Loads

Consideration of the securing of deck cargo was being given in the jack-up towing code of practice. Problems had been identified in applying current standards to strength and securing arrangements for containers.

Bilge and Ballast Systems

A joint NMD/DnV paper containing proposals for new builds was tabled by NMD, JSIT {13}.

Weather Forecasting

NDE was trying to encourage better dialogue between providers and users of weather forecasts, so that the forecasting service would be better tailored to operating circumstances.

B.5 Meeting - 8th July 1992

Informal meeting between NMD and HSE/OSD.
Referred documents: nil
Venue: HSE, Offshore Safety Division, Ferguson House, 15 Marylebone Road, London.

Development of TOWCAP

The pilot development of *TOWCAP* was complete. Modifications to *TOWCAP* were due by the end of 1992 and would involve:

- Development commercially available version of program.
- Include instrumentation requirements of extreme tension predictions.
- Winch rendering characteristics - testing and documentation.
- Full scale verification.

NMD proposals on bilge systems, and guidance on the definitions of operating limits for inclusion in operating manuals, had been prepared for evaluation and comment. It was stated that the UKOOA would be given the opportunity to consider the operating limit document for development into industry guidelines.

B.6 Meeting - 22nd October 1992

Referred documents: JSIT{15}, {16}, {17}, {18}, {19}, {20}, {21}, {22}, {23}, {24}, {25}, {26}, {27}, {29}.
Venue: HSE, Offshore Safety Division, Ferguson House, 15 Marylebone Road, London.

Seaworthiness and Stability of Jack-Ups in Transit

The scope for the Statement of Requirements for research and development had been widened as a result of the previous meeting. This document had been re-circulated as JSIT {15}.

BMT had been awarded the contract for Phase 1, with an option for Phase 2 (to be defined after Phase 1). BMT began their presentation by saying that the project had identified 20 capsizings during wet tows, involving 17 fatalities. The study by BMT will require access to private information on some of these accidents in order to evaluate details.

Other comments and details:

- There was considered to be no need to investigate intact stability, because it was not a contributor in any known losses.
- It was pointed out that the range criteria were considered unrealistic for very large jack-ups.
- The high *GM* required to meet the criteria results in a 'stiff' motion response, with possible adverse effects on leg stresses.
- Towing operations data were to be obtained from discussions with operators.

***Jack-ups Leg Structure - Guidance on Fatigue* - JSIT {17}**

Lloyd's Register (LR) led the discussion. HSE intends to develop guidance on the basis of this LR proposal, subject to comments made by the working group.

Criteria for Going On and Off Location - Leg and Spudcan Bottom Impact Considerations

Global Maritime made a presentation on work sponsored by Arco and Total. HSE intended to become a co-sponsor, and was interested in extending the work to jack-ups in close proximity to fixed installations. The objectives of the project included developing rational criteria for the safe limitations for establishing a jack-up on bottom. Interactions between the spudcan and seabed were investigated, modelling the soil/structure interaction by non-linear springs, and taking into account specific soil conditions. Results were presented illustrating behaviour in different water depths and soil conditions.

Towing Operation and Towing Equipment

Since the last meeting, the following documents had been sent to committee members:

1. JSIT {21} TOWCAP Documentation Pilot Version
2. JSIT {22} Risk Analysis of Jack-up Towing. Final Report
3. JSIT {23} Project Proposal - TOWCAP further developments.
4. JSIT {24} Risikoanalyse - Slep av Offshore Innretninger (Risk Analysis of Jack-up Towing, phase 2, scope of work).

The additional paper was added:

5. JSIT {25} Preliminary Data Sheets - Towline Tension Analysis

The risk analysis work was on going. NDE were to make an independent check of the statistical data used by SikteC, and the model was to be developed further.

***Bilge Systems* - JSIT {19}**

NMD's presentation of this document brought the following comments from Committee members:

- An 'any compartment' requirement on MLT designs would be hard to meet.
- High capacity pumps should be restricted to pre-load tanks.

- Members had reservations about emptying the tank in 3 hours.
- The wording of the second proposal might imply a need for two or three pump rooms, each housing two pumps

Towing Operation: Interim Guidance on Information Required in the Operations Manual Regarding Safe Operating Limits **- JSIT {18}**

It was noted that an overlap existed between this document and JSIT{16} and it should be made clear what were operations guidelines and what were operations manuals.

Towing Operation: Industry Guidelines **- JSIT {16}**

This document was considered fit to go out for discussion. It was agreed that other national authorities, such as Norway, could use the guidelines.

Watertight Integrity: Criteria for Watertight and Weathertight Closing Appliance etc. on Jack-ups **- JSIT {26}**

ABS had developed this document as a first step, and it had been difficult to get the impact pressure factor right. Helicopter decks must be located with sufficient clearance above the waves, because it is unrealistic to build such structures to withstand the large impact forces involved.

The Safety Issues of Jack-Ups in Transit

Marathon LeTourneau gave a personal account of involvement in recent casualty investigation proceedings. Conclusions can be misleading due to fundamental aspects being overlooked. Interpretations of the casualty reports do not necessarily give a proper insight into the causes of the incidents. Insight can be obtained through discussion with those involved in the incident, witness testimony, or source evidence. JSIT {29} summarises these personal observations.

B.7 Meeting - 30th March 1993

Referred documents: JSIT {20}, {22}, {31}, {32}, {33}, {34}, {35}, {36}, {37}, {38}, {39}, {40}.
Venue: HSE, Offshore Safety Division, Ferguson House, 15 Marylebone Road, London.

Guidance Notes on Fatigue of Jack-ups Legs during Tow **JSIT {20}.**

Review of comments by LR.

Stability Criteria for Jack-ups in Transit: Phase 1: **JSIT {32},** ***Casualties, Seakeeping Data and Numerical Methods;*** **Overheads, JSIT {34}**

The key issues were considered to be:

1. Wave damage to the unit structure leading to penetration of watertight boundaries.
2. Damage to the unit structure caused by shifting of deck cargo.
3. Structural damage in the vicinity of jack-up leg reaction structures.

The conclusions were in agreement with those of the enquiry into the *West Gamma* accident. It is important to remove all deck loads. BMT recommended further phases of the investigation.

Criteria for Going On and Off Location - Leg and Spudcan Bottom Impact Considerations

HSE's Statement of Requirements for this part of the Global Maritime study was issued during the meeting, JSIT {33}.

Global Maritime distributed their OTC paper: 'Motions and Impact Responses of Jack-ups Moving on to Location', JSIT {35}.

Towing Operations and Towing Equipment Presentation

The work carried out since the end of the Phase 1 report (JSIT {22}) was reviewed. The main conclusions were as follows:

1. Safe towage requires information on extreme towing line loads.
2. A tension meter without memory is not sufficient.
3. Simulation programs are useful for parametric studies.
4. Advanced equipment may increase safety, but skilled personnel are still important.
5. Skill comes through experience and tension monitoring and simulations will increase the learning effect.

***Towing Operations: Interim Guidance on Information Required in the Operations Manual Regarding Safe Operating Limits* - JSIT {31}**

A draft report, which considered the risks of towing jack-ups, had been completed.

***Bilge Systems [Pre-load Tank De-Watering]* - JSIT {36}**

Some of the committee felt that the 3-hour requirement was too rigid, and there was a need for a simple system on vessels with as few control positions as possible.

***Towing Operations: Interim Guidance on Information Required on the Operations Manual Regarding Safe Operating Limits* - JSIT {37}**

The tabled document was divided into five parts, and contained design limitations which the crew on board should work to.

***Towing Operations - Latest Guidelines: Working Draft 3* - JSIT {40}**

Following further comments, a new draft would be produced. There was now an intention to internationalise the document. Concern was expressed that deck cargo and manning levels were not sufficiently specific.

***Watertight Integrity. Criteria for Watertight and Weathertight Closing Appliances etc. on Jack-ups* - JSIT {38} and JSIT {39}**

ABS had demonstrated that containers could not be expected to withstand the enormous forces generated by waves on deck, reinforcing the recommendations in SN 16/90 on removal of deck cargo.

Existing scantlings for vents and hatch coamings were shown to be satisfactory.

B.8 Meeting - 24th September 1993

Referred documents: JSIT{32}.
Venue: HSE, Offshore Safety Division, Ferguson House, 15 Marylebone Road, London.

Review of BMT Response to the JSIT Committee Comments on the Draft Final Report

BMT responded to comments on their draft report (JSIT {32}). The following points were made in the subsequent discussion:

1. It is not always easy to distinguish between liftboat and jack-up related incidents in the accident records. Liftboat accident statistics were not truly representative of jack-up units.

2. The main cause of flooding has been through movement of deck cargo. Deck cargo is acceptable during transit only if adequately designed to withstand the possible loads, or in a protected location.
3. It is not clear how conservative is the 1.4 area ratio factor used in the intact stability criteria.
4. Sea-fastening loads. If HSE intends to instruct drillers not to carry unnecessary deck cargo, then this would no longer be an issue. Earlier work carried out by IACS suggested that it would be impossible for a standard container on deck, during transit, to withstand an impact by green water.
5. Definitions used in rules. It was agreed that although the free-trim approach is a more complicated technique than the free-twist approach, it depicts the actual vessel response with greater accuracy. HSE would accept the free-trim method.
6. New damage stability criteria. Any proposed changes to the damage stability criteria would need considerable input from the industry.
7. Phase II objectives. New damage stability criteria should be last in the proposed list of priorities. The main need here was to identify suitable damage criteria for both wind speed and multiple compartment flooding. There was discussion on whether a 50 or 100-knot wind speed is appropriate for the damaged state.
8. QRA. This item was removed from study at this stage, and HSE was to inform the main JSIT Committee of how it intended to proceed.
9. Sea fastening loads. This item was deemed to be of value, and should remain in the study.
10. Definitions used in the rules. The industry was aware of the free-trim versus free-twist debate, and this item was dropped from study.

B.9 Meeting - 29th September 1995

Referred documents: JSIT {35}, JSIT {51}, JSIT {52}, JSIT {53}, JSIT {54}, JSIT {55}, JSIT {56}.
Venue: HSE, Offshore Safety Division, Ferguson House, 15 Marylebone Road, London.

Review of Work Items

Document JSIT {51} was distributed to Group members.

Stability Criteria: The Phase I report had now been released. A presentation was made on the status of Phase II, using overheads found in JSIT {53}. The work programme consists of 4 main tasks: assessment of current intact stability criteria, assessment of dynamic effects on stability, assessment of water impact and assessment of model test results. Four rigs were proposed as a basis for calculations: large, medium and small 3-leg units, and a 4-leg unit.

Fatigue Guidance: The future of the document was undecided due to new Design and Construction regulations.

Criteria for Going On and Off Location: Phase I was confidential to participants, and Phase II will be issued as an OTB report. Conclusions from Phase II were presented as an OTC paper, JSIT {35}. Global Maritime are to make a presentation to UKOOA based on a 116C unit.

Towing Operations: Contact had been made with NMD and that a correspondence group headed by Norway was taking this work forward. A report is due in October. IADC were also members of the group and the HSE were in the process of making contact with the group.

Bilge System: No activity was reported at present.

Towing Operations: UKOOA was to circulate JSIT {56}. The issue of removing containers during transit was discussed.

Recent Legislation Developments in UK in Relation to Mobiles in Transit

A presentation was made on the summary contained in JSIT {52}, covering the following regulations:

1. Application outside Great Britain Order [AOGBO].
2. Safety Case Regulations [SC].
3. Management and Administration Regulations [MAR].
4. Prevention of Fire and Explosion and Emergency Response Regulations [PFEER].
5. Design and Construction Regulations [DCR].

Presentation on the Stability Study

BMT's Phase I report had been issued, and Phase II was presented (overheads used in the presentation are available in JSIT {53}.

Task 3, Assessment of water impact confirmed that an earlier piece of work that containers should not be carried on open decks. The IACS procedure for deckhouse loading had proved satisfactory although its physical basis is obscure.

NDA Presentation on the QRA Study

Draft document JSIT {54} was the first of four phases covering: the definition of a rig move, hazard registration, carrying out a risk assessment, and mitigating factors. The unit to be considered was an F&G L780 Mod. V. Some 20 events in a rig move planning were then to be considered. A risk steering group was to be formed, to which NDE would submit a list of risks.

Study on Methods of Flood Detection

Notes on this NDE study, JSIT {55}, were distributed with the minutes of the meeting.

APPENDIX C: JSIT NUMBERED DOCUMENTS

{1} Stability Criteria for Jack-Ups - Statement of Study Requirement, DEn OSD4d PEA 68/93/16 April 1991.

{2} Report on Jack-Up Installation [re *West Gamma* accident] - Submitted to NMD, 15th January 1991.

{3} Foundering of *West Gamma*, Sequence of Events and Observations, Captain Asbjorn Rislaa, 27th August 1990.

{4} General Ocean Tow Recommendation for Jack-Up Drilling Units - International Association of Drilling Contractors.

{5} World Offshore Accident Databank, [WOAD] for 1970-90 - Statistical Report.

{6} TOWCAP - General Description, Software Documentation: Preliminary Document, MARINTEK A/S, 22nd August 1991.

{7} TOWCAP - Simulation of Towing Gear Dynamics, Results from two test runs, MARINTEK.

{8} Stability Criteria For Jack-Ups - Study Requirements, HSE OSD4/703/255/141 Revised version JSIT {2}, 2nd December 1991.

{9} Fatigue of Jack-Ups Under Tow - Proposed Guidance and Background Document.

{10} TOWCAP - General Description, MARINTEK A/S, 11th December 1991.

{11} Risk Analysis of Jack Up Towing, SikteC A/S Data Research, 10th December 1991.

{12} UKOOA Report Contents List, 9th December 1991.

{13} NMD/DnV Paper: Bilge and Ballast Systems.

{14} FAX: - Marathon Letter, 24th April 1991.

{15} Stability Criteria for Jack-Ups - Study Requirements. Revised, 2nd February 1992.

{16} UKOOA/IADC/BROA, Guidelines for Safe Movement of Self-Elevating Offshore Installations.

{17} Guidance Notes: Fatigue of Jack-Ups During Tow HSE Project 2898, G Tseng/LR.

{18} FAX: - Proposal on Content of Operation Manuals for Jack-Ups, KM Havig, 4th September 1992.

{19} Proposal for Bilge and Preload System in Connection with HSE/NMD Working Group on Jack-Ups - Safety in Transit, NMD/DnV.

{20} Guidance Notes: Fatigue of Jack-Ups During Tow - Revised version of JSIT {17}, G Tseng/LR, 22nd October 1992.

{21} TOWCAP: - Pilot Version Software Documentation, MARINTEK Sintef Group, 19th February 1992.

{22} Risk Analysis of Jack-Up Towing Phase I, SikteC A/S Trondheim, Final Report, NMD, July 1992.

{23} Project Proposal - TOWCAP PC Software Further Development, MARINTEK, 2nd July 1992.

{24} Risk Analysis of Jack-Up Towing. Phase II. SikteC, 7th August 1992.

{25} Preliminary Data Sheets: Towline Tension Analysis 'M/S Supply', TOWCAP Output, 21st October 1992.

{26} Proposal - Formula for Wave Impact Pressure, R Bowie/ABS.

{27} FAX: Friede and Goldman Ltd, Report on Status of Activities, 19th October 1992.

{28} Overhead Projection Slips, Conclusions from the Rowan Gorilla I Incident.

{29} Safety of Jack-ups in Transit - Marathon LeTourneau Position.

{30} FAX: Updated version of JSIT {19}, 24th November 1992.

{31} Proposed Guidelines For Approval of Towing, NMD/SikteC, Draft Report Phase II, March 1993.

{32} Stability Criteria for Jack-Ups in Transit - Phase I: Review of Casualties, Seakeeping Data, and Numerical Methods, BMT Offshore Limited, Final Draft Report, 1st March 1993.

{33} Risks Associated with Operational Criteria for Jack-Ups Location Moves, Global Maritime, Proposal GM-P672-0691, 16th July 1991.

{34} Overhead Projection Slips for Presentation by BMT Relating to JSIT {32}.

{35} Motions and Impact Responses of Jack-Ups Moving Onto Location. B Miller, P Frieze, P Lai, T Lewis & I Smith, OTC 7301, 1993.

{36} FAX Updated Bilge and Preload System JSIT {19}, NMD, 17th March 1993.

{37} FAX Limiting design parameters to be worked out and included in operational manual for Self Elevating Offshore Units, NMD, 17th March 1993.

{38} Jack-Ups Safety in Transit, Working Group [on wave impact], R Bowie.
{39} Overheads for JSIT {38} presentation, R Bowie, IACS/ABS.
{40} UKOOA/IADC/BROA Guidelines for Safe Movement of Self Elevating Offshore Installations, 30th March 1993.
{41} Safety During Tow - Dynamic Towing Line Tension Analysis, NMD, 19th March 1993.
{42} BMT Paper for Jack-up Conference, 26th July 1993.
{43} BMT Stability Report: Comments from OCB, 16th April 1993.
{44} BMT Stability Report: Comments from ABS Europe, 21st June 1993.
{45} BMT Stability Report: Comments from LR, 12th July 1993.
{46} BMT Stability Report: Comments from Friede and Goldman, 23rd August 1993.
{47} BMT Stability Report: Comments from DnV, 2nd September 1993.
{48} BMT Stability Report: Comments from NMD, 18th June 1993.
{49} BMT Stability Report: Comments from Offshore Safety Division, September 1993.
{50} The Safety of Jack-Ups in Transit, Draft Paper for JU Conference, AR McIntosh, KM Havig, ADMoyse.
{51} HSE Status Report on Projects, ADMoyse, 28th September 1995.
{52} Summary of H&S Regulations applicable to mobile installations in transit in UK controlled waters, R McIntosh, 2nd October 1995.
{53} Overheads for 29th October presentation on 'Stability and Sea-Keeping of Jack-Ups in Transit'. BMT Fluid Mechanics Limited.
{54} QRA of Jack-Up Operations Afloat. Phase I Definition of a rig move on the UK Continental Shelf, Noble Denton Europe Limited, Report No. L17403/NDE/SJP, 20th March 1995.
{55} Detection of Water Ingress into Jack-Up Units whilst in the Floating Condition, Noble Denton, September 1995, Ref: OTO-95008.
{56} Guidelines for Safe Movement of Self-Elevating Offshore Installations (Jack Ups), UKOOA, April 1995.

Completion Reports: [2] and [28].

APPENDIX D: DOCUMENTATION REVIEW

Further detail of the JSIT history is given in extracts from the meeting minutes within Appendix B.

D.1 JSIT DOCUMENTS BY SUBJECT

D.1.1 JSIT - Stability

1. JSIT {1} Stability Criteria for Jack-Ups - Statement of Study Requirement, April 1991.
2. JSIT {8} Stability Criteria For Jack-Ups - Study Requirements, 2nd December 1991.
3. JSIT {14} Letter from Marathon .
4. JSIT {15} Stability Criteria for Jack-Ups - Study Requirements. Revised, 2nd February 1992.
5. JSIT {29} Safety of Jack-ups in Transit - Marathon LeTourneau Position.
6. JSIT {32} Stability Criteria for Jack-Ups in Transit - Phase I: Review of Casualties, Seakeeping Data and Numerical Methods, BMT Offshore Limited, Final Draft Report, 1st March 1993.
7. JSIT {34} Overhead Projection Slips for Presentation Relating to JSIT {32}.
8. JSIT {42} BMT Paper for Jack-up Conference, 26th July 1993.
9. JSIT {44} containing comments on BMT Jack-Up Stability Report, Phase 1.
10. JSIT {43} to {49}, containing comments on BMT's Jack-Up Stability Report, Phase 1.
11. JSIT {50} The Safety of Jack-Ups in Transit, Draft Paper for JU Conference, AR McIntosh, KM Havig, AD Moyse.
12. JSIT {51} Status Report on Projects, ADM, 28th September 1995.
13. JSIT {53} Overheads for 29th October presentation on 'Stability and Sea-Keeping of Jack-Ups in Transit. BMT Fluid Mechanics Limited.
14. See also [2].

D.1.2 JSIT – Bilge and Ballast/Preload Systems

1. JSIT {13} NMD/DnV Paper: Bilge and Ballast Systems.
2. JSIT {19} Proposal in Connection with HSE/NMD Working Group on Jack-Ups - Safety in Transit, NMD/DnV.
3. JSIT {30} FAX: Updated version of JSIT {19}, 24th November 1992.
4. JSIT {36} FAX Updated JSIT {19}, NMD, 17th March 1993.
5. JSIT {55} Detection of Water Ingress into Jack-Up Units whilst in the Floating Condition, Noble Denton, September 1995, Ref: OTO-95008.

D.1.3 JSIT – Watertight Integrity

1. JSIT {26} Proposal - Formula for Wave Impact Pressure, R Bowie/ABS.
2. JSIT {38} Jack-Ups Safety in Transit HSE Working Group [on wave impact], B Bowie.
3. JSIT {39} Overheads for JSIT {38} presentation, R Bowie, IACS/ABS.

D.1.4 JSIT – Leg Design

1. JSIT {9} Fatigue of Jack-Ups Under Tow - Proposed Guidance and Background Document.
2. JSIT {17} Guidance Notes: Fatigue of Jack-Ups During Tow, HSE P2898. G Tseng/LR.
3. JSIT {20} Guidance Notes: Fatigue of Jack-Ups During Tow - Revised version of JSIT {17}. Tseng/LR, 22nd October 1992.

D.1.5 JSIT – Operational Limits for Legs

1. JSIT {27} FAX: Friede and Goldman Ltd, Report on Status of Activities, 19th October 1992.

D.1.6 JSIT - UKOOA Towing Guidelines

2. JSIT {4} General Ocean Tow Recommendation for Jack-Up Drilling Units, International Association of Drilling Contractors.
3. JSIT {12} UKOOA Report Contents List, 9th December 1991.
4. JSIT {16} Guidelines for Safe Movement of Self-Elevating Offshore Installations.
5. JSIT {35} Motions and Impact Responses of Jack-Ups Moving Onto Location. B Miller, P Frieze, P Lai, T Lewis & I Smith, OTC 7301, 1993.
6. JSIT {40} Guidelines for Safe Movement of Self-Elevating Offshore Installations, 30th March 1993.
7. JSIT {56} Guidelines for Safe Movement of Self-Elevating Offshore Installations (Jack Ups), UKOOA, April 1995.

D.1.7 JSIT - NMD Towing Operations

1. JSIT {18} FAX, Proposal on Content of Operation Manuals for Jack-ups, KM Havig, 4th September 1992.
2. JSIT {31} Proposed Guidelines For Approval of Towing. Draft Report Phase II, NMD/SikteC, March 1993.
3. JSIT {37} FAX, Limiting design parameters to be worked out and included in operational manual for Self Elevating Offshore Units, NMD, 17th March 1993.

D.1.8 JSIT – MARINTEK - TOWCAP

1. JSIT 6} TOWCAP - General Description, Software Documentation: Preliminary Document, MARINTEK A/S, 22nd August 1991.
2. JSIT {7} TOWCAP - Simulation of Towing Gear Dynamics – MARINTEK, Results from two test runs.
3. JSIT {10} TOWCAP - General Description - MARINTEK A/S, 11th December 1991.
4. JSIT {11} Risk Analysis of Jack Up Towing - SikteC A/S Data Research, 10th December 1991.
5. JSIT {21} TOWCAP: - Pilot Version Software Documentation, MARINTEK Sintef Group, 19th February 1992.
6. JSIT {22} Risk Analysis of Jack-Up Towing Phase I. Final Report, SikteC A/S Trondheim, NMD, July 1992.
7. JSIT {23} Project Proposal - TOWCAP PC Software Further Development, MARINTEK, 2nd July 1992.
8. JSIT {24} Risk Analysis of Jack-Up Towing, Phase II, SikteC, 7th August 1992.
9. JSIT {25} Preliminary Data Sheets: Towline Tension Analysis 'M/S Supply', TOWCAP Output, 21st October 1992.
10. JSIT {41} Safety During Tow - Dynamic Towing Line Tension Analysis, NMD, 19th March 1993.

D.1.9 JSIT Casualties and Accidents

1. JSIT {2} Report on Jack-Up Installation [re *West Gamma* accident] - Submitted to NMD, 15th January 1991.
2. JSIT {3} Foundering of *West Gamma*, Sequence of Events and Observations, Captain Asbjorn Rislaa, 27th August 1990.
3. JSIT {5} World Offshore Accident Databank, [WOAD] for 1970-90 - Statistical Report.
4. JSIT {14} Letter from Marathon.
5. JSIT {28} Overhead Projection Slips. Conclusions from the Rowan Gorilla I Incident.
6. JSIT {29} Safety of Jack-ups in Transit - Marathon LeTourneau Position.

D.1.10 JSIT – Risk Assessments

(see also D.1.8 Nos 4, 6, and 8 for Risk Assessment for Towing Operations)

1. JSIT {33} Risks Associated with Operational Criteria for Jack-Ups Location Moves, Global Maritime, Proposal GM-P672-0691, 16th July 1991.
2. JSIT {54} QRA of Jack-Up Operations Afloat. Phase I Definition of a rig move on the UK Continental Shelf, Noble Denton Europe Limited, Report No. L17403/NDE/SJP,.20th March 1995.
3. See also [28].

D.1.11 JSIT - Regulations

1. JSIT {52} Summary of H&S Regulations applicable to mobile installations in transit in UK controlled waters. R McIntosh 2nd October 1995.

D.1.12 Other Related but Unnumbered Documents Found in Review

- Overheads for presentation on, Stability Criteria for Jack-ups in Transit, Phase I, BMT Offshore Limited, P45459.
- Suggestions to earlier draft of Stability and Seakeeping Review for Jack-Ups in Transit, BMT Offshore Limited, OTC Paper, Chapter 10.
- 'HSE Jurisdiction on Offshore Installations in Transit', Final note of meeting of 26/4/95. Circulated 7/8/95.
- Suggestions on information and procedures to be included in the operating manual for Jack-up units. 08/09/92.
- Review of Resolution A.714 (17) and Code of Safe Practice for Cargo Stowage and Securing. Maritime Safety Committee. 9/9/1992.
- Marine Accident Report: Capsizing and Sinking of the Mobile Offshore Drilling Unit Rowan Gorilla I, - National Transportation Safety Board, 12th September 1989.
- Risk Reduction in Towing Fixed Offshore Structures, RL Jack, Capt. Noble-Smith and Capt. J Huntington.
- History, Theory, and Extension of Current Jack-Up Quasi-Dynamic Stability Criteria, R Bush, RV Ahilan, Noble Denton Consultancy Services.
- Stability Calculations for Jack-Ups and Semi-Submersibles, J van Santen, MSC.
- TOWCAP - General Description:- MARINTEK A/S, 22nd August 1991.
- Two designers calculations on jack-ups relevant to fatigue study.
- Proposal No. Q/94048 - Phase 2 of a Research Programme into Stability Criteria For Jack-Ups in Transit, BMT Offshore Limited, 24th January 1994.
- Stability Criteria For Jack-ups in Transit, Notes on Tender Presentations by BMT / WS Atkins / OCB / Noble Denton, 16th Sept. 1992.
- TOWCAP: - Pilot Version Software Documentation, MARINTEK Sintef Group, 19th February 1992.
- Dynamics of Offshore Towing Line Systems, S Moxnes, I J Fylling, Paper 10, Offshore 93, February 1993.1

D.2 WORK ARISING FROM JSIT

Stability

The work to be undertaken on stability was arranged into the following tasks:

1. Review and analyse casualty statistics from previous experiences.
2. Review results of previously run model tests and numerical simulations, and assess the responses of floating jack-ups.
3. Determine whether numerical models can be used to simulate jack-up behaviour, either free floating, or under tow.

4. Use model tests, or calculations, to determine what conditions influence seaworthiness, deck wetness, wave loading, and stability, either freely floating or under tow.
5. Investigate methods for calculating wave loads on the jack-up structures, and cargo.
6. Review current stability, watertight integrity, structural strength, and wave loading safety criteria. Derive new criteria if necessary.
7. Test any new criteria with calculations and model tests.
8. Investigate the consequences of applying the criteria to other designs of jack-up.

BMT undertook the work, and the final report on tasks 1 to 3 [1] was completed and issued in 1994.

BMT later also produced the following three reports covering the remaining tasks:

Assessment of Current Intact Stability Criteria [9]

- To investigate whether the existing HSE intact stability and leg bending moment rules are redundant or inconsistent.
- To investigate whether the existing area ratio and stability range rules are likely to cause excessive structural problems for large jack-ups, as a result of the rig becoming excessively stiff in roll.
- To quantify the differences between various stability criteria currently operated by different bodies, in order to determine their practical significance.

Assessment of Dynamic Effects on Stability [10]

- To review past attempts at developing methods which include explicit dynamic terms in the stability analysis.
- To investigate whether such methods are likely to offer a more practical, more reliable or more uniform approach to assessing stability than current static methods.
- If considered appropriate, to develop and validate such methods further.
- To investigate whether safety factors in the static approach are adequate to allow for the dynamic response of jack-ups in a seaway.

Correlation between Numerical Predictions and Model Test or Full Scale Data [11]

- To identify scenarios in which failures in operational procedures or watertight integrity may lead to damage and flooding.
- To consider the need for new damage stability criteria, which address the most likely circumstances of damage, experienced by jack-ups, and how these criteria might be formulated.
- To perform calculations associated with possible new criteria on three typical modern jack-up designs to determine what design changes would be required (if any) in order for them to meet the new criteria.
- To produce a discussion document that can be widely distributed within the industry describing any proposed new criteria and their likely impact on design.

Bilge and Ballast/Preloading

NMD and HSE jointly produced a proposal regarding bilge systems for jack-ups. They proposed that in addition to the existing regulations for bilge systems for jack-ups there should be additional measures to improve safety.

Flooding Control

Noble Denton undertook an investigation into the possibilities for detecting water ingress into a jack-up whilst afloat [13]. The scope of work was as follows:

- Identify the equipment presently available for flooding detection which may be suitable for use in a jack-up.
- Determine the effectiveness of the equipment in the rapid detection of flooding, and for providing information to the crew for them to effectively carry out damage control.
- Review the problems associated with retro-fitting the flooding detection equipment to common types of jack-up units operating in the UK Sector.

Water Impact Loading

Watertight integrity was considered by a working group led by ABS. Scantlings of water tight closing appliances are adequate to resist wave impact loads, but this is not the case for deck mounted containers. With the wave impact formulae derived from the ABS, DnV and LR suggestions [30], it was established that the resulting wave impact force, subject to not unrealistic wave characteristics, on a container, is much higher than the capacity of currently available container securing systems. This evidence supports the advice in Safety Notice 16/90 [29] concerning the elimination of containers on deck.

Water impact loads were also considered by BMT as Task 3 of the Phase 2 Stability Study:

Assessment of Water Impact Loads [14]

- To establish the basis of the two calculation methods identified.
- To compare these methods with each other and set the forces calculated in the context of the other (inertial) forces acting.
- To arrive at conclusions regarding the uncertainty and variability of the calculated loads.
- Propose further research work in this area.

Watertight Bulkhead Study

Lloyd's Register (LR) on behalf of the HSE undertook calculations on the water tight integrity of a specific jack-up unit.

Guidelines on Leg Fatigue

Lloyd's Register (LR) was contracted by HSE to produce an initial guideline [16] concerning leg fatigue damage during transit. As fatigue assessments can be of use to ascertain parts of the structure which will be vulnerable to fatigue damage, it was hoped that these recommendations and guidance would help enhance safety of jack-ups under tow.

Towing Guidelines

The criteria for moving on and off location had been studied in a JIP in which the HSE did not initially take part. HSE funded a follow-up study with Global Maritime with a view to look at the consequences of jack-ups in close proximity to fixed platforms [20].

Towing Guidelines

The UKOOA guidelines [22] concentrated upon the operational aspects of moving jack-ups. They make recommendations upon responsibilities, planning, towing arrangements, weather criteria, navigation, communications, preparations, seafastening, procedures under tow, arrival at the new location and, finally, placement at the new location or alongside another installation, as appropriate.

Guidelines on the Contents of Operations Manuals

To ensure operations manuals only held relevant information, NMD developed recommendations for the contents of the operations manual on towing operations (JSIT {18} and {37}). The work recommended that jack-up operations which should be described in the operating manual are:

- Jacking the hull into water
- Field moves
- Ocean towing
- Jacking the hull out of the water
- Position with final airgap.

The study also recommended that relevant limiting environmental parameters and other parameters should be given for all the above-mentioned conditions.

A system should also be established for the unit to document that the unit is at all times operated within its limiting design parameters, and that the required procedures were followed for all the operations mentioned above.

Towing Operations

According to JSIT {50}, towing operations were investigated by NMD, who commissioned MARINTEK to study the dynamic loads in the mooring lines, taking into account the towing vessel and jack-up, and the characteristics of the mooring lines and towing winch. The *TOWCAP* software [23] was written to give a means of estimating the maximum tension loads, which might occur. NMD also commissioned Dovre SafeTec (formerly SikteC) to carry out a risk analysis (phase 1) of towing operations [26] to derive risk based criteria for towing operations. Phase 2 of the project [25] was to contain further development of the models created in Phase 1. More specific to the different vessels equipment, tow locations and procedures.

Quantitative Risk Assessment

Work on Quantitative Risk Assessment, also sponsored by the HSE, was performed by Noble Denton Europe Ltd. The aim of the task was to identify and quantify the risks to a jack-up during operation whilst afloat, and to also identify areas in which deficiencies in knowledge are critical for risk assessment studies. This work was completed with the issue of reference [28].

APPENDIX E: SUMMARIES OF KEY REPORTS

HSE Sponsored Work

1. P45459r23: Stability Criteria for Jack-ups in Transit: Phase I, Review of Casualties, Seakeeping Data, and Numerical Methods, 1st March 1993, BMT Offshore Ltd, Ref: OTN-94101.
2. P44058r52: Stability of Jack-ups in Transit: Phase II Task 1, Assessment of Intact Stability Criteria, Ref: OTN-95173.
3. P44058r25: Stability of Jack-ups in Transit: Phase II: Task 2, Assessment of Dynamic Effects on Stability, Ref: OTN-95174.
4. P44058r33: Stability of Jack-ups in Transit: Phase II, Task 3, The Assessment of Water Impact Loads BMT Offshore Limited. November 1996, Ref: OTO-95022.
5. P44058r42: Stability of Jack-ups in Transit: Phase II Task 4, Assessment of Model Test Results, Ref: OTN-95175.
6. P44058r63: Stability of Jack-ups in Transit: Phase II, Final Summary Report, Ref OTO-98049.
7. P44217r12: Investigations into the Stability of an Intact and Damaged Jack-Up during a Wet Tow: Model Testing Report, 24th November 1999.
8. P44217r22: Investigations into the Stability of an Intact and Damaged Jack-Up during a Wet Tow: Model Test Interpretation and Assessment [4], 23rd May 2000.
9. Detection of Water Ingress into Jack-Up Units whilst in the Floating Condition, August 1995, Ref: OTO-95008.
10. Watertight Integrity of Internal Bulkheads and Doors on CFEM Design Type T2005C Jack-up Unit, January 1995, Ref: OTN-95100.
11. Guidance Notes: Fatigue of Jack-Ups During Tow, LR, 1992.
12. Criteria for Jack-ups Manoeuvring in Close Proximity to Jacket Platforms, Global Maritime, May 1994.
13. Investigation into the Effect of RP on North Sea Jack-Up Rigs, NDE, ref. L17290/NDE/MJRH, June 1995.
14. QRA of Jack-up Operations Afloat: Phase I - Definition of a Rig Move on the UK Continental Shelf - NDE, 18th July 1995.
15. Quantified Risk Assessment of Jack-up Operations Afloat, August 1998, OTO-98045.

Other Related Work

16. Risk Analysis of Jack-up Towing, July 1992, SikteC.
17. Site Specific Assessment of Mobile Jack-Up Units, SNAME, T&RB 5-5A, 1994.
18. Foundation Can Fixity Study for Jack-Up Units, SINTEF, ref. ST22 F96660, August 1996.

The following summaries have been taken directly from reports issued as a result of work generated by the JSIT Group, or from related activities elsewhere.

E.1 Stability Criteria For Jack-Ups In Transit: Phase 1: Review of Casualties, Seakeeping Data and Numerical Methods [1]

At the request of the Health and Safety Executive (HSE), BMT reviewed:

- a number of past jack-up capsize incidents,
- current HSE and other criteria concerning stability, watertight integrity and leg bending moments, applying to jack-ups during tow,
- the suitability of numerical and physical models in this context.

[4] This report was issued as OTO-2000 059, and papers on this work were also presented at The Jack-up Conferences, 1999 and 2001, City University, London.

This project represents the first phase of a research programme, being undertaken by HSE, into jack-up stability in transit. Essentially a review of existing documents, rather than a new technical investigation, this study aims to identify key outstanding issues. Views of individuals and organisations with direct experience of jack-up tows were also sought.

The review of jack-up losses identified a fairly typical sequence of factors:

- unexpected bad weather.
- towline failure.
- jack-up turning to an adverse heading.
- boarding seas.
- flooding.
- cargo breaking loose and causing damage leading to a progressive sequence of further flooding and (occasionally) structural failure.

Most of the fundamental causes are of an operational nature, and therefore outside the scope of the present review study. Present concerns are to ensure adequate watertight integrity and stability criteria.

Current intact stability criteria have been successful insofar that no losses seem to have occurred in the intact condition. A fundamental problem has been loss of watertight integrity, and consequently the damaged stability criteria are also an area of concern. The extent of multiple compartment flooding seen in recent incidents goes well beyond that assumed in the criteria, and several jack-ups have been lost in conditions close to the limiting wind speeds defined. It seems somewhat arbitrary to choose reduced wind speed and area ratio criteria in the damaged condition. Structural failures do not seem to be a primary cause of loss.

There has been little direct experimental validation of numerical models, and few sets of appropriate model test data were found. Physical and numerical models to investigate stability and capsize are likely to be more demanding than those required for general seakeeping purposes. They are likely to involve severe sea conditions, large motions of the rig, water on deck and flooding.

Despite lack of validation, existing numerical models may be useful for qualitative and investigative studies in moderate sea states, but should not be regarded as practical and established design tools. They must therefore be used with caution. Linear wave diffraction theory would seem to offer the best basis for analysing the seakeeping performance of jack-ups in moderate sea conditions, but requires additional empirical terms to allow for viscous damping from bilges, hydrodynamic and possibly aerodynamic drag on the legs, and flow into and out of the leg wells. In more severe sea states the model has to take account of large-amplitude waves and rig motions, water on deck, water flowing onto and off the deck, and flooding. Time-domain simulation programs may model some of these non-linear processes. Where such additions have been made in the past, they tend to have been justified on an intuitive basis only.

The report identifies a number of unexplained issues, and makes recommendations for Phases 2 and 3 of the current project. These recommendations include investigations into issues arising from existing stability and integrity rules, and from existing calculation methods, correlation between existing model test data and a suitable numerical model, leading to proposals for future model test work, and a quantitative risk analysis study to help identify key risk scenarios and priorities for future work.

E.2 Stability of Jack-ups in Transit: Phase II Task 1: Assessment of Intact Stability Criteria [9]

The present report describes the results of one of the tasks undertaken during Phase II of the HSE project ‘Stability of Jack-ups in Transit’.

The aim of the present task was to investigate the feasibility of carrying out a numerical study to assess the intact stability criteria of the HSE and other authorities, and the benefits of involving the certifying authorities in this process. BMT has contacted four certifying authorities during the course of this project, has established the basis on which they would collaborate, and has discussed the merits and difficulties of the study as a whole.

Involving certifying authorities in this study would have the advantage of bringing their considerable experience directly to the project, but would have the disadvantages of considerably increasing costs and administrative overheads, and would probably cloud many of the key issues. The study could become a comparison of the detailed procedures used by certifying authorities to calculate wind heeling moments and hydrostatics, rather than an investigation into the redundancy and consistency of the individual intact stability requirements of the HSE.

In order to focus on the redundancy and consistency of individual HSE stability requirements, it is suggested that the study should start with standard wind heeling moment and righting moment curves, obtained from existing calculations, and that the investigation should take the form of a sensitivity study. This sensitivity study would start with base case calculations using standard HSE criteria, and then vary individual requirements, one at a time. The effect on the unit's stability would then be assessed in terms of changes in the maximum allowable KG, based on a small range of VCG locations. The study would cover four typical jack-ups, as already selected for BMT's Task 2 study on the effects of the unit's dynamics on stability. This Task 2 study already requires wind heeling moment and righting moment curves to be calculated, and these would form the basis for an extension of the present study.

E.3 Stability of Jack-ups in Transit: Phase II: Task 2: Assessment of Dynamic Effects on Stability [10]

Conventional stability criteria do not have a clear and rational physical basis. BMT therefore reviewed a number of techniques which aim to put stability criteria on a more rational footing, and in particular aim to take explicit account of the dynamic effects of wave and wind gust loading.

Sarchin and Goldberg's procedure seemed to be one of the most promising in this respect, and was also the most easily understandable. It has been incorporated into US Navy and Coast Guard stability procedures, and (in a modified form) into the IMO code for merchant ships. The Sarchin and Goldberg procedure requires results that would normally be available from conventional vessel stability and sea-keeping analyses, such as righting moment and wind heeling moment curves, and the maximum roll response in a storm sea.

The present investigation considers whether Sarchin and Goldberg's proposed area ratio criterion is applicable to intact jack-ups undergoing a wet tow. It investigates whether the safety margins implied by conventional intact stability criteria are sufficient to allow for roll motions in waves, and investigates the importance of wind gusting. The Sarchin and Goldberg criteria are compared with conventional HSE area ratio criteria by means of sample calculations on a large three-leg jack-up unit in the intact (non-flooded) condition. Similar results were obtained from calculations on small and medium-size units. All units complied with conventional intact and damaged stability requirements.

The main difficulties in performing a dynamic stability analysis proved to be in selecting an appropriate design sea state, and in estimating realistic values of the unit's roll damping and maximum roll response in heavy seas. Previous experience and comparisons with available model test results suggested that the roll damping might be about 10% of critical. None of the four units complied with Sarchin and Goldberg-type area ratio requirements, however, when the roll damping was 10% of critical. Large increases in the damping would be required in order to achieve compliance.

Information about the roll damping of jack-ups is very scarce, however, and there are no established or validated theoretical procedures for predicting the motions of jack-ups in severe storm conditions. Available model test data suggest that non-linear mechanisms other than damping, such as water on deck, may also complicate the response and limit the maximum roll and pitch angles. It is therefore difficult to estimate with any degree of confidence either the amount of roll damping or the maximum roll response likely to occur during a wet tow in heavy seas.

The results from this investigation support the continued use of existing conventional intact stability criteria. It would be premature to consider the use of dynamic intact stability criteria until basic sea-keeping analysis issues have been resolved. Present results suggest that the Sarchin and Goldberg area ratio criterion is likely to be much more stringent than the traditional area ratio criterion for jack-ups, because of the shapes of the righting and heeling moment curves, and consequent effects on areas between these curves.

The four jack-up units considered during this investigation operate successfully in the North Sea and world-wide. Their seakeeping behaviour and stability seem to be satisfactory, with no major problems reported. If any changes to existing stability criteria are to be considered, all of these four existing units should comply automatically.

The complex technical issues surrounding the successive flooding of compartments, and the role played by deck-edge immersion, water on deck and wave-induced roll motions are likely to be worthwhile areas for research, which might eventually lead to improved stability criteria.

E.4 Stability of Jack-Ups in Transit: Phase II, Task 3: The Assessment of Water Impact Loads [14]

The present report describes the results of one of the tasks undertaken during Phase II of the HSE project 'Stability of Jack-ups in Transit'.

Current guidelines for jack-up operations discourage the carriage of deck cargo in unprotected locations during a wet tow. Procedures for estimating green water impact loads are nonetheless needed for unavoidable deck structures and equipment. BMT's Phase I review found considerable evidence of deck items breaking loose and causing damage in past severe storms, but identified no existing established and validated procedure for estimating green water impact loads.

Representative calculations have now been performed using a standard IACS design procedure, originally intended for designing end bulkheads of ships' deck-houses. These results were compared with estimates of wave slam and drag forces, calculated using standard procedures and coefficients. These sample values were also compared with typical maximum inertial and gravitational forces.

Maximum impact loads calculated using the IACS procedure were found to be several times larger than maximum gravitational and inertial forces. Sea-fastenings and deck equipment, designed using gravitational and inertial loads alone, are therefore likely to suffer substantial damage or failure in a severe boarding sea.

Peak impact forces estimated using the slam force calculation procedure and conventional slam force coefficients were found to be very much larger than those obtained using the IACS procedure. The slam force calculations contain several sources of conservatism, however, and these results should be regarded as upper bound estimates only.

Values obtained using the IACS procedure were found to be of similar magnitude to forces estimated using the standard drag force formula with conventional drag coefficients. This does not prove that either procedure or set of results is 'correct', but merely sets them in context with each other.

These results bear out the conclusions of an earlier study, and fully justify current recommendations to avoid carriage of cargo in exposed locations on deck, and to locate vent pipes and similar items in protected locations.

There is no obvious physical basis for the IACS procedure, although it seems to be supported by the historical evidence; ships' deck-houses, designed according to this procedure, do not seem to have suffered from general major structural problems.

Standard slam and drag force calculation procedures have the merit of being more easily interpreted in physical terms, but it is not obvious how to apply such procedures, or how to choose the coefficient values, when estimating green water loads on jack-up units.

No experimental data specific to jack-ups have been found. Results from green water model tests on fast-moving ships tend to support conventional slam load calculation procedures and coefficients, although somewhat lower coefficients were obtained from model tests on a moored floating production vessel. The measured force coefficients show a very large amount of scatter, and difficulties were reported in estimating the occurrence, height and velocity of green water impacts.

The results from this comparative study are inconclusive, and it is not possible to make clear recommendations about the use of any one design procedure or set of coefficients in preference to any other. In the absence of any proven alternative, however, it is suggested that the industry should continue to use the IACS procedure for the design of ships' deck-houses. This procedure does at least have support from actual operating experience. Any choice of design procedure, coefficients and safety factors must recognise the high inherent level of uncertainty in the resulting estimates.

Systematic model tests on a jack-up in boarding seas are recommended, in order to help validate impact force prediction procedures, force coefficients and particle kinematics, and to improve understanding of the physical processes. The inevitable scatter and uncertainty in the results, however, are likely to limit the quantitative benefits from such work.

E.5 Stability of Jack-ups in Transit: Phase II Task 4: Assessment of Model Test Results [11]

This report presents the conclusions from a feasibility study undertaken during Phase II of the HSE project 'Stability of Jack-ups in Transit'.

BMT's Phase I review highlighted the lack of experimental validation of numerical models for predicting jack-up seakeeping behaviour, especially behaviour in severe sea states involving water on deck and flooding. It was therefore proposed that a correlation study should be undertaken in order to validate existing numerical techniques, as far as is practical using existing model test and full-scale data, and to define precisely where the deficiencies in present techniques, data and knowledge lie. The present report describes the conclusions and recommendations from this feasibility study.

BMT has identified a number of sets of model test data, which should be suitable for validating numerical models of jack-up seakeeping during a wet tow. Several data sets have been rejected either because of anticipated communication difficulties, or because no detailed information was available, or else because the data were not extensive enough.

BMT identified one especially extensive and systematic data set, which is particularly suitable for the proposed purpose, two other fairly extensive and useful data sets, together with a fourth set of suitable but less extensive data. The first three relate to triangular, 3-leg units, and the fourth to a 4-leg, rectangular unit. BMT recommends that all four sets of data should be regarded as primary data sources for future validation studies, and that copies of the relevant model test reports should be acquired from their respective owners.

BMT has identified two further sets of data, which may provide some limited additional information for program validation work. Full details of the tests and rigs may be unavailable, or difficult to obtain, however, and it has not been possible to assess data quality. One of these data sets is unique in considering various levels of flooding. The other data set includes some full-scale data, but the reported information is incomplete and limited. No other sources of full-scale data were identified.

BMT recommended that numerical calculations should be undertaken, as part of a Phase III research programme, for comparison with all four of the primary data sets. The need for further systematic model tests or full-scale measurements will have to be re-assessed, following the Phase III programme.

E.6 Stability of Jack-ups in Transit: Phase II Final Summary Report [8]

BMT Fluid Mechanics Limited (BMT) was commissioned by the UK Health and Safety Executive (HSE) to investigate procedures used to assess the stability of jack-up units in transit, while undergoing a 'wet tow'.

In 1994 BMT undertook a Phase I review of stability issues involved in past jack-up capsize incidents, of existing stability and watertight integrity criteria, and a review of analytical and model testing aspects of jack-up seakeeping during a wet tow. Specific recommendations were made for work to be undertaken during a follow-up Phase II study, including the following four tasks subsequently undertaken by BMT:

- Task 1: Assessment of intact stability criteria,
- Task 2: Assessment of dynamic effects on stability,
- Task 3: Assessment of water impact loads,
- Task 4: Assessment of model test results.

This report presents a summary of results and conclusions from these four tasks.

Task 1 took the form of a preliminary study to find out whether comparative data on stability requirements already exist, and to assess the feasibility of performing the necessary calculations. Recommendations were made about future work.

Task 2 reviewed past attempts to include explicit dynamic terms in stability analyses, and whether such methods are likely to offer a practical, more reliable or more uniform approach to assessing stability than current static methods. Sample numerical calculations using one such method (the Sarchin and Goldberg approach) showed that basic seakeeping analysis issues need to be resolved before it is practical to consider the development of dynamic criteria.

Task 3 investigated alternative approaches to estimating green water impact loads on deck structures and equipment. Sample calculations showed large differences between forces calculated using a slam force procedure and a standard classification society procedure. There is historical evidence to support continued use of the classification society procedure, although it has no obvious physical basis.

Task 4 also took the form of a preliminary study to investigate the availability of suitable model test data to validate numerical methods for predicting jack-up seakeeping behaviour in severe seas. Very little openly published data were found, but a small number of commercially confidential data sets were identified. It was recommended that these data sets should be obtained and investigated further.

Lack of generally available model test data and lack of validated numerical procedures for assessing jack-up seakeeping behaviour have emerged as two important factors limiting the development of improved methods for assessing the motions and stability of jack-ups during a wet tow in severe seas.

E.7 Investigations into the Stability of an Intact and Damaged Jack-Up during a Wet Tow: Model Testing Report [12]

The UK Health and Safety Executive (HSE) commissioned BMT Fluid Mechanics Limited (BMT) to perform a series of scale model tests in order to investigate the stability of a jack-up during a wet tow in severe seas. Tests were performed on the model in the intact condition, after major waterline damage to corner and side compartments, and after internal flooding.

The work was performed under the European Union - Training and Mobility of Researchers - Access to Large Scale Facilities scheme, and the tests were carried out at the Danish Hydraulic Institute (DHI), in Hørsholm, Denmark. They were undertaken in collaboration with Marine Structure Consultants (MSC) bv and the University of Glasgow.

The purpose of this report was simply to document the test programme, the methods used, and the results and data produced. A companion report presented results from BMT's data interpretation and assessment study, and compared limiting conditions at which the model capsized with criteria derived from a stability analysis undertaken by MSC.

E.8 Investigations into the Stability of an Intact and Damaged Jack-Up during a Wet Tow: Model Test Interpretation and Assessment [2]

The UK Health and Safety Executive (HSE) commissioned BMT Fluid Mechanics Limited (BMT) to perform a series of scale model tests in order to investigate the stability of a jack-up during a wet tow in severe North Sea wind and waves. Tests were performed with the model in the intact condition, after major waterline damage to corner and side compartments, and after major internal flooding.

The work was performed under the European Union - Training and Mobility of Researchers - Access to Large Scale Facilities scheme, and the tests were carried out at the Danish Hydraulic Institute (DHI), in Hørsholm, Denmark. They were undertaken in collaboration with Marine Structure Consultants (MSC) bv and the University of Glasgow.

This report describes the model testing philosophy, presents key details of the test programme itself, and then discusses the analysis and interpretation of the test results. The aim of the tests was to establish the limiting value of *KG* at which capsize occurred, to compare the static heel angle, area ratio, stability range and second intercept angle in this condition with values predicted by a conventional stability analysis, and thus assess whether the stability criteria provide a satisfactory measure of the unit's ability to resist capsize.

Key findings from this investigation were as follows:

- Initial hydrostatics calculations showed that the 30^{o} second intercept angle condition was governing when the model was intact. The test model remained stable while it complied with traditional intact stability criteria, and only capsized after the centre of gravity had been raised 14m. Existing intact stability criteria therefore provided an adequate margin of safety against capsize in a severe storm.
- Initial hydrostatics calculations showed that the 1.0 area ratio criterion was governing in the damaged condition. Applying sufficient peripheral damage to bring the area ratio down to 1.0 caused a large increase in the initial static heel angle in wind, accompanied by a large reduction in the second intercept angle, reducing the static stability range, *SR*, to between 3 and 7 degrees. It is hardly surprising, therefore, that the test model capsized rapidly in waves after experiencing this degree of peripheral damage, because its dynamic roll and pitch angles were significantly greater than *SR*. The model's centre of gravity had to be lowered between 1.3m and 4.3m to make it stable in the damaged A1, B1, C1 and D2 conditions. The area ratios associated with these just stable damaged conditions varied between 1.5 and 2.6.
- The traditional area ratio criterion therefore did not provide an adequate measure of the model's dynamic stability when damaged, and did not provide an adequate margin of stability to prevent capsize in storm waves. It was difficult to see any consistent relationship between the point at which the physical model became dynamically unstable and conventional stability parameters. The limiting value of the stability range, *SR*, varied between 9^{o} and 15^{o} with peripheral damage, but the model remained stable down to much lower values of *SR* when the central compartment was flooded. No single parameter emerged from this study as being a completely satisfactory measure of the model's stability.
- The model consistently capsized towards the side that was damaged, even when this side was facing to windward. The model was less stable with peripheral damage on the leeward side rather than on the windward side. With the internal centre compartment flooded, however, the model was less stable when the damaged (lower) side was facing the waves. The dynamic behaviour of the model and damage location therefore influenced its stability more than the static wind heeling moment.
- In conditions where the model capsized to windward the wind heel was acting effectively as a 'righting moment' at the instant of capsize. The concept of a wind 'righting moment' is at odds with some of the concepts associated with traditional quasi-static stability criteria, such as the area ratio, and it is not obvious how one should rationalise these criteria.

- When the model was damaged and only just stable it showed evidence of a low-frequency lolling response in high wave groups. It was not possible to predict in advance, however, whether the model would capsize or survive during a particular test run. When capsize occurred, it took place very abruptly, with little prior warning.
- It should be borne in mind that the levels of damage inflicted on this model would represent very extreme multi-compartment damage on an actual jack-up unit.
- The conclusions from this investigation apply to this particular model and chosen test conditions. Systematic model tests on different types of units, with varying types of damage and test conditions, would be required before general conclusions can be drawn. It nonetheless seems reasonable to suppose that qualitatively similar results are likely to be obtained for other jack-up units. BMT notes that reliable analytical tools for predicting the dynamic behaviour of jack-ups in severe storm conditions are not currently available.

E.9 Detection of Water Ingress into Jack-Up Units Whilst in the Floating Condition [13]

On behalf of the Health and Safety Executive, the possibility for detecting water ingress into a jack-up unit whilst in the floating condition has been investigated.

The study found that there was a large variation in the void space configuration of jack-ups and also a significant variation in current practice for flooding detection and tank volume measurement. The effects of tank flooding on stability should therefore be assessed on a case-by-case basis in order to determine the extent of flooding detection system required.

Systems currently utilised on board jack-up units often rely on manual methods of flooding detection, such as by tape and sounding pipe, which may be hampered by severe weather conditions. Consequently, monitoring of a tank condition to detect water ingress, leading to a potential flooding situation is reactive rather than proactive.

A review of possible methods of flooding detection found that there is an extensive range of equipment available for water detection. These fall into two distinct categories:

Water Level Switches:	Switches that are activated when the water level rises past (or falls from) the switch level.
Level Monitors:	Continuous or intermittent measurement of the water level.

Both types of systems are effective, potentially allowing a centralised constantly updated monitoring facility, and quicker reaction times to flooding situations. The latter type are more sophisticated but also more expensive. There is not a single recommended system, and different devices will be appropriate for certain tank configurations. Each unit should be reviewed to design the most suitable system with the following considerations:

- Access/ease of installation
- Cost
- Fitness for Purpose
- Durability and reliability

Retro-fitting of flooding detection systems on jack-up platforms poses many problems, in particular the determination of which spaces require the system and the accessibility to these spaces. Consideration needs to be given to the location of detection equipment, and conformance to regulatory requirements in respect of watertight bulkheads and hazardous spaces.

E.10 Watertight Integrity of Internal Bulkheads and Doors on CFEM Design Type T2005C Jack-up Unit [15]

1. The following reference documents have been considered for this design appraisal:

   1.1 Transocean telefax addressed to the HSE, reference JCR/FA/FX348 dated 25.8.94 with enclosures.

   1.2 "As-Built" plan nos:-

   EA 4535 Longitudinal bulkhead at 7.5m off C.L.
   EA 4542 Transverse bulkheads on frames 6, 9 and 16
   EA 4545 Transverse bulkheads on frames 19 and 22

2. Internal bulkheads

   2.1 A structural assessment has been made of the transverse bulkheads at frames 6, 9, 16 and 22 and the longitudinal bulkheads at 7.5 metres from the centre line (port and starboard). All material has been assumed to have a minimum yield strength of 235 N/mm^2

   2.2 Based on Lloyd's Register's Rules for watertight bulkheads as defined in Part 3, Chapter 3.7 of the Rules and Regulations for the Classification of Mobile Offshore Units the bulkheads can sustain a head of water up to the main deck level without modifications provided all penetrations are made watertight.

3. Bulkhead penetrations

   3.1 A qualitative assessment has been made of the large bulkhead penetrations and the openings found to be adequately framed and suitable for the pressure head defined in paragraph 2.2 provided the arrangements can be made watertight.

   3.2 Small penetrations cut between bulkhead stiffeners will have no significant effect on the strength of the bulkheads. The penetrations are to be made watertight.

4. Double bottom tank top

   4.1 No assessment of the tank top structure has been made and no scantlings are indicated on the submitted plans. The tank top strength should be assessed for the pressure head defined in paragraph 2.2.

   4.2 Provided the tank top scantlings comply with the Rules of a Classification Society we conclude that the tank top strength will be adequate for the pressure head.

5. Cross-flooding arrangements

   5.1 The effects of cross-flooding between the compartments are not included in the study. Arrangements to prevent cross-flooding between watertight compartments should be provided.

6. Gastight doors

   6.1 The typical doors shown on the attached sketches are not suitable as watertight doors without modifications.

   6.2 Normally a watertight-hinged door should have scantlings that are compatible with the adjacent watertight bulkhead scantlings and the door thickness should not be less than 8mm.

6.3 From the strength aspects “type A” and “type B” doors could sustain a pressure head similar to the bulkheads as defined in paragraph 2.3 subject to the following:

6.31 The 5mm thick door plate should be adequately stiffened with not less than 3 equally spaced horizontal flat bar stiffeners 70 x 7mm or equivalent support provided.

6.4 The door should be fitted with a suitable gasket. A sufficient number of securing cleats should be fitted to ensure adequate compression of the gasket. The number of cleats required will depend on the stiffness of the door edge framing and in general 6 to 8 cleats will be required.

6.5 From the information provided it is not possible to assess the stiffness of the door edge framing. The door fittings should comply with a suitable standard and door penetrations should be designed to be watertight.

6.6 A typical modified door should be hydraulically tested to the pressure head defined in paragraph 2.2 before fitting the door in the unit.

E.11 Guidance Notes: Fatigue of Jack-Ups During Tow [16]

In the design of a jack-up rig, the towing case is usually one of the critical fatigue cases for the leg design. The results, however, are very sensitive to the assumptions made and there are many uncertainties in this area.

LR was commissioned by HSE to provide an initial guideline giving an approach to fatigue analysis of jack-ups under tow. It is hoped that this initial guideline may form a basis for industry review and comment and would enable some progress to be made to further the safety enhancement of jack-ups under tow.

The proposed guideline is presented in three parts:

- Guidance Notes

  A new section for insertion in the DEn Guidance Notes at paragraph 33.4.3 under the title of “Fatigue of Jack-ups during Tow”.

  This states a requirement for the fatigue problem to be addressed for the towing case in jack-up design and lists the aspects to be considered.

- Commentary

  This is the main part of the document. This indicates how the problem may be addressed in greater detail.

- Research

  As indicated above, fatigue analysis of jack-ups under tow is very sensitive to the assumptions made. This section highlights the main areas of uncertainty that could benefit from research.

E.12 Criteria for Jack-ups Manoeuvring in Close Proximity to Jacket Platforms [21]

Risks associated with jack-ups moving onto location next to a fixed installation have been investigated. Detailed finite element analyses were carried out, modelling impacts between the spudcan of a Marathon LeTourneau 116-C and a typical jacket.

The jacket model was based on a recent 6-leg platform in a water depth of approximately 75m, with only the bottom bay being represented. In the modelling, elastic elements were used wherever possible in order to reduce computational resources. Thus, detailed non-linear modelling was confined to the middle third of the struck brace and one quarter of the spudcan. Detailed modelling consisted of thick shell elements in which elastic-perfectly plastic properties were adopted having large deflection capabilities. The jacket was fixed to the seabed whilst the jack-up was supported by a vertical and a rotational spring to allow its natural modes to be fully reflected. The analyses were run in time integration mode with sufficiently small time steps to accurately capture all dynamic effects and to trace the spread of yielding. Likely impact locations and velocities were determined, based on a typical jack-up manoeuvring procedure, and impacts were modelled by giving the jack-up initial velocities.

In none of the cases examined did the loads at the lower guide (where the maximum leg loadings occur) exceed the limiting values and only in the case of a spudcan impact with a stiff part of the jacket did (limited) damage to the spudcan occur. Impacts to a bottom jacket brace resulted in the development of both local dents and overall bows. The maximum damage occurred under heave conditions and amounted to 153mm of denting and 66mm of bow.

The brace damage was found to compromise the jacket integrity from which it was concluded that impact velocities should be restricted to those, which generate minimum brace damage. Using existing information, it was found possible to evaluate the impact velocities for which no damage would occur and then, using motions data from an ongoing Joint Industry Project, to identify the corresponding significant heights across a range of zero-crossing periods considered of 4s to 11s. These resulting wave heights were very small and it was concluded that, for realistic wave heights, any contact between the spudcan and the brace would lead to the jacket's integrity being compromised.

The amplitudes of motion of the spudcan in typical installation seastates are sufficiently small that the probability of impact if the mean clearance exceeds about half a spudcan diameter (~5m) is negligibly small. The risk of impact is, therefore, associated with lack of adequate mean clearance either by mis-operation (unawareness) or occasioned by the failure of a mooring line or tug.

Graphs of mean distance of the spudcan from the jacket against probability of contact between the two were developed. To all intents and purposes, these graphs also show the probability of unacceptable damage occurring, assuming that a controlled operation is performed. These can therefore be used to determine the risk level for a given seastate, duration and intended clearance between the jacket and spudcan.

E.13 Investigation into the Effect of RP on North Sea Jack-up Rigs [18]

Noble Denton Europe Ltd (NDE), acting on behalf of the UK Health and Safety Executive (HSE), have been commissioned to carry out a Phase 1 study to investigate the effects of the Recommended Practice for the Site Specific Assessment of Mobile Jack-up Units, (RP) [17] on jack-ups operating in the UK Sector of the North Sea.

The objective of the study was to produce this report including the following items:

1. Approximate quantification of qualitative results presented at the May OC-7 meeting, with explanation of the methodology used.
2. To augment the above with information on other rig types that has been assessed to the RP by Noble Denton.
3. To list other North Sea rig types and qualitatively identify rig types that may or will be affected by analysis to the RP (this might include rigs in 1 or 2 at alternative water depths).
4. Review the jack-up fleet operating in the North Sea and provide an indication of the number of units that are close to their limits.

5. Provide a historical perspective on the results obtained in the above including comment on the calibration of the RP safety factors and any bias due to:
   - the ‘typical’ rigs selected, and
   - the basis used for targeting the reliability levels, with discussion of the expected impact of alternative methods.

The principal conclusions are as follows:

The rig survey identified 21 jack-up rig classes, which operate, or may operate, in the North Sea. Of these 13 classes have previously been assessed to the RP or similar criteria.

The review of the results of existing analyses to the RP shows the capacity to withstand environmental forces according to the RP assessment to be at variance with the Operations Manual/ design limits for all but the most recent designs (Friede & Goldman L750 Mod VI and MSC CJ62). This is particularly evident for smaller units at deeper water depths where the RP’s inclusion of dynamic and non-linear effects is of significance. The units most adversely affected are those where a significant degree of foundation fixity was assumed in the original design. In some instances older designs at water depth less than $^2/_3$ their Operations Manual maximum are relatively unaffected.

Those units where RP assessments do not exist are all to older designs i.e. first class built before 1990. It is therefore expected that these units will be affected by assessment to the RP at their maximum depths. At water depths less than about $^2/_3$ their Operations Manual maximum some units will not be significantly affected whilst others, with low nominal design wave capability, may possibly be shown to have limited capability due to their increased susceptibility to dynamic effects.

A comparison of the site specific environmental data with Operating Manual conditions for units actually operating in the North Sea has indicated that only a limited number of units are operating at sites, which are close to the Operations Manual limits. A greater number of units may be operating at sites, which are close to, or exceed, their estimated capability according to the RP.

The work leading to the Partial Safety Factors given in the RP has been summarised. The reliability calculations were targeted at the average reliability of the selected exemplary rig. The exemplary rigs had previously been assessed to a ‘best practice’ predating the RP i.e. second order and dynamic effects had been taken into account and the wave loads were considered to be realistic. This resulted in a partial load factor for environmental and dynamic loads of 1.25. At least for the overturning limit state the calibration using this approach was not sensitive to selecting subsets of the exemplary rigs; this finding is also expected to apply to the preload and leg stress limit states.

Had the calibration been targeted at the lowest reliability of the exemplary rigs it is estimated that the resulting partial load factor would reduce to 1.15 and the notional reliability would reduce by about 0.2. Such an approach is not without merit based on the successful history of jack-up operations to date. The calibration using this approach is more sensitive to the exemplary rig selection.

The findings of this report, which are based on the mechanical process of running calculations based on the RP, do not constitute an opinion by Noble Denton as to the approvability or otherwise of any unit or design.

E.14 Quantified Risk Assessment of Jack-Up Operations Afloat: Phase 1 - Definition of a Rig Move on the UK Continental Shelf [27]

On behalf of the UK Health and Safety Executive, Noble Denton Europe Ltd. has completed Phase 1 of a Quantified Risk Assessment (QRA) of a jack-up location move. This report details the definition of a unit and an example location move for the North Sea.

The unit selected is the Friede and Goldman L780 Mod V. Although this is neither the largest nor the most numerous type of jack-up in the North Sea it is a fairly typical example of the modern harsh environment units providing a wider range of operating conditions than the more numerous but smaller Marathon LeTourneau 116 C class.

The exemplar location move has been based on an actual move that occurred in 1992. This move covers all aspects of a location move in the North Sea including the often-critical aspects of timing and going on to an exposed location with a narrow 'weather window'.

The various stages and events for the move have been isolated. These stages form the boundaries of the QRA providing a framework for the detailed assessment of hazards and risks, which will be carried out in the subsequent stages of this study.

E.15 Quantitative Risk Assessment Study [28]

A quantified risk assessment of jack-up North Sea rig moves has been performed to determine the risks to a jack-up and personnel involved in a rig move.

It has been determined that a jack-up is vulnerable to 6 basic hazard categories as follows:

Afloat

a) Flooding (excluding that from b) to d) below).
b) Collision
c) Structural (due to excessive motions and wave action).
d) Grounding.

Weight on legs (Insitu)

a) Weather damage (at inadequate air gap due to a critical delay).
b) Punch through.

The quantified risk assessment shows that 83% of fatalities and 94% of the major accidents are likely to be associated with the main tow. Of the fatalities component 44% comes from cargo/seafastening and 18% from hull structure failure when these occur in conjunction with bad weather. Activities other than main tow, such as positioning over a jacket contribute 17%.

The largest individual factor contributing to fatalities and major damage potential is bad weather. The impact of moving from the commonly used categoric weather forecasts to probabilistic forecasts is significant. It is estimated that a reduction in fatality potential of about 30% can be achieved through using enhanced weather forecasting techniques.

All major risks identified can be reduced, or in some cases eliminated, by the application of appropriate risk management measures. The report identifies such measures. However, the study concludes that to reduce the risk of an accident during a rig move the major effort should be in focussed on improving weather forecast arrangements in order to avoid jack-ups being under tow in bad weather.

Other Related Work:

E.16 Risk Analysis of Jack-up Towing [26] [5]

The purpose of this risk analysis was to evaluate if there is a significant risk difference between using one advanced or two ordinary tugs during transfer, especially of jack-up installation, but also other installations.

Another objective was to find out whether standby vessels are necessary during towing operations or not.

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[5] See associated paper, Dynamics of Offshore Towing Line Systems, S. Moxnes, I.J. Fylling, Paper 10, Offshore 93, 17-18 February 1993.

This risk analysis project can be seen in connection with another separate project formed by MARINTEK. This project aims to perform a data simulation programme as input is developed during this project. Suggestions for risk reducing actions are also been made.

The project will be important when deciding the need for preparation of future regulations for tows of offshore installations.

E.17 Site Specific Assessment of Mobile Jack-up Units [17]

A Guideline for the Site Specific Assessment of mobile jack-up units has been drafted by the Working Group of the Joint Industry Sponsored Project "Jack-Up Site Assessment Procedures Establishment of an International Technical Guideline". Technical and administrative management has been provided by Noble Denton Consultancy Services Limited. The Working Group members and the other Participants provided funding.

General

This document is a Guideline for the site specific structural and foundation assessment of jack-up units. The purpose of this Guideline is to identify the factors, which are likely to be the main concerns for any site assessment of a jack-up unit. It is not to be interpreted as guidance for design or construction as there are existing rules and regulations, both by Classification Societies and Governmental Agencies, covering these aspects.

This Guideline has been developed by representatives of all parts of the jack-up industry working in a Joint Industry Project. It is intended to serve as a basic standard and to provide a common reference when comparing the work of different assessors. The user is advised to take due account of any Regulatory requirements that may apply to the particular geographic area of operation.

Reference Document

The accompanying document entitled "Recommended Practice for Site-Specific Assessment of Mobile Jack-up Units" (hereafter referred to as the Recommended Practice) provides further guidance and recommendations on the procedures and criteria for site specific assessment. It may be revised to account for technical developments.

Applicability and Limitations

An assessment should be made of the jack-up for each site location. This Guideline relates only to the assessment of the jack-up in the elevated condition. Transportation to and from the site and moving on and moving off location is not covered in this document.

Guidance on the Safety Factors that may be adopted is given in the Recommended Practice, however an owner, insurer, operator, etc., may justify different factors in particular circumstances.

This Guideline will apply to most jack-ups. It is recognized that there may be designs and/or circumstances when certain provisions may not apply. Such instances shall be reviewed on a case-by-case basis.

It is assumed that the jack-up is built to recognized standards, and has been maintained as required to continue to meet those standards. Any deterioration of the jack-up should be taken into account in the fitness for purpose site specific assessment.

Typical Approach to Site Assessment

Where a jack-up is to be employed - in conditions well within its design capacity and existing calculations in accordance with the Recommended Practice are available, the site specific assessment may be undertaken by appropriate comparisons between the parameters used in the calculations and those applicable to the new location. Otherwise, engineering calculations of various degrees of complexity are required to justify that the jack-up can be safely used at the location.

E.18 Foundation Fixity Study for Jack-up Units [19]

SINTEF has been commissioned by the SNAME OC-7 panel to review the document “Site Specific Assessment of Mobile Jack-up Units”, SNAME Technical & Research Bulletin 5-5A, which defines a “recommended practice” (RP) document for jack-up units.

The work has been conducted as a desk study, based on a vast number of earlier research documents. These included PhD theses, research reports and published papers, covering the range from theory and model development, via models tests, to field cases.

The study has identified the following points which can lead to increased seabed fixity:

The yield function is not recommended changed, except for fully embedded spud cans. For fully embedded spud cans with soil backflow, the yield function is proposed independent of the vertical force V for V/ V_{Lo}, less than 0.5, V_{Lo} being the preload.

For skirted spud cans, special design will be required. A simplified method is sketched in the present project report. It is however not recommended to be included in the RP.

The trend of the present stiffness reduction factor in the RP for sand is in principle proposed unchanged, and this function is proposed used also for clay.

The shear modulus in clays for extreme response analysis is recommended increased. The following is proposed:

G/s_u = 50 for overconsolidated clays, with an overconsolidation ratio higher than 20
G/s_u = 100 for overconsolidated clays, with an overconsolidation ratio 4 to 10
G/s_u = 200 for normally consolidated clays (overconsolidation ratio less than 4)

The sheer modulus of sands for rotation stiffness is recommended calculated according to the formula

$$G_r = 600(V_{Lo} / A)^{0.55}$$

This formula gives the higher stiffness of the two formulas in the present RP.

A method is proposed for the evaluation of plastic rotation stiffness due to further penetration. The effect is proposed included for legs with $VN > 0.5$. However, if more than one leg has a VN ratio lower than 0.3, one may want to reconsider the degree of moment fixity.

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