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Stability of Jack-Ups in Transit: Phase II Final summary Report

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EXECUTIVE SUMMARY

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.

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1. INTRODUCTION

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. Conclusions and recommendations from the Phase I study were reported in Reference [1][1]. These included specific recommendations for work to be undertaken during the Phase II study. In particular the four following Phase II tasks have now been undertaken by BMT, and are summarised in the present report:

- 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.

BMT's proposals for the Phase II study were contained in proposal document no. Q/94048, dated 24 January 1994, and revised in the form of a project report [2], dated 27 September 1994. The agreement between HSE and BMT is described in [3]. Further details of the results from this investigation may be found in the four task reports: [4, 5, 6 and 7].

This work was undertaken under the auspices of an HSE working group on 'Jack-ups: Safety in Transit' (JSIT), comprising representatives from the HSE, the Norwegian Maritime Directorate, certifying authorities, jack-up owners, designers and operators.

1.1. OVERALL OBJECTIVES

The overall objectives of the Phase II investigation as a whole were outlined in the HSE Agreement document [3], as follows:

- to review the consistency and consequences of current stability requirements,
- to review dynamic effects on stability,
- to assess methods used to estimate water impact loads,
- to carry out a review of information available for correlating the results of numerical predictions and model or full-scale data.

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1 *A list of references may be found in Section 5 on page 17.*

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1.2. INDIVIDUAL TASK OBJECTIVES

Specific objectives for each of the four individual tasks are listed in [4, 5, 6 and 7], and are reproduced below.

1.2.1. Task No. 1: Assessment of Intact Stability Criteria

Task 1 took the form of a preliminary study to investigate the availability and suitability of existing stability calculations for carrying out a comparative study on intact stability requirements, and to assess the feasibility of performing such calculations.

The objective of the preliminary Phase II investigation was limited to the following:

- To discover whether suitable comparative data on stability requirements already exist, and, assuming that they do not, to assess the feasibility of performing such calculations.

The ultimate long-term objectives of this investigation would be to perform systematic calculations covering a range of jack-up sizes (e.g. small, medium and large):

- To investigate whether any of the existing HSE intact stability and leg bending moment rules are inconsistent or redundant, and the circumstances in which this might occur.

- To investigate whether 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 differences between the various stability criteria currently operated by different bodies, in order to determine their practical significance.

1.2.2. Task No. 2: Assessment of Dynamic Effects on Stability

Task 2 reviewed past attempts to include explicit dynamic terms in stability analyses, and investigated whether such methods are likely to offer a practical, more reliable or more uniform approach to assessing stability than current static methods. The task objectives were as follows:

- To review past attempts at developing methods which include explicit dynamic terms in the analysis.

- To investigate whether such methods are likely to offer a practical, more reliable or more uniform approach to assessing stability than current static methods.

- If considered appropriate, to develop and validate the 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.

1.2.3. Task No. 3: Assessment of Water Impact Loads

Task 3 investigated alternative approaches to estimating green water impact loads on deck structures and equipment. The task objectives were as follows:

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- To establish, by reference to the published data, the basis of the two (IACS and HSE) calculation methods identified.

- To compare these methods with each other, and to set the forces calculated in the context of the other (eg. inertial and gravitational) forces acting.

- To arrive at conclusions regarding the uncertainty and variability of the calculated loads.

- If justified, to propose further research work in this area.

1.2.4. Task No. 4: Assessment of Model Test Results

Task 4 also took the form of a preliminary study to investigate the availability of suitable model test data for validating numerical methods for predicting jack-up seakeeping behaviour in severe seas.

The objectives of the preliminary Phase II investigation were limited to the following:

- To seek access to, and permission to use, confidential model test and full-scale data identified in BMT's Phase I review.

- To evaluate these tests and results to see whether they are likely to be suitable for validating a numerical seakeeping model.

- To draw appropriate conclusions, and make recommendations about any further numerical analysis, validation studies, model testing and/or large-scale measurement requirements.

The ultimate long-term objectives of this investigation would be as follows:

- To validate, as far as is practical with existing model and full-scale data available to the project, numerical methods for the calculation of jack-up seakeeping behaviour.

- To arrive at conclusions regarding the relevance and suitability of existing data for present purposes, the need for further numerical model development or analysis, and for further model tests or large-scale measurements.

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2. METHODOLOGY

BMT's Phase I work [1] showed that:

- no known jack-up capsizes or losses have occurred as a result of deficiencies in the intact stability criteria; all have occurred following extensive damage and flooding;

- flooding occurred only after the unit had taken an adverse heading to waves, allowing extensive water on deck and bulwark submergence, resulting in wave impacts on deck structures and equipment, with items breaking loose or being carried away by waves.

Despite the importance of damage and flooding in past incidents, it was agreed that BMT's Phase II work should concentrate primarily on aspects of stability and seakeeping in the intact condition, this being a necessary first step towards understanding the damaged condition. BMT therefore investigated four separate aspects of stability and seakeeping in the intact condition, covering the following individual sub-tasks, as set out in BMT's report [2].

Task No. 1: Assessment of Intact Stability Criteria

BMT's Phase I review found that present intact stability are adequate, in the sense that intact, undamaged and unflooded jack-ups have not capsized in the past. Present intact criteria also offer a reasonable basis for developing new requirements. There are, however, a number of differences between the requirements of different authorities, and there has been some industry criticism of possible inconsistencies and redundancies in existing criteria. It was therefore recommended that these issues should be addressed by means of systematic calculations on a range of typical units.

At the time the present task started, there were uncertainties concerning the extent and availability of existing information, and the feasibility of involving certifying authorities. BMT's initial work programme was therefore intended to be a feasibility study, which would lead to recommendations for systematic calculations. The calculations themselves would be undertaken during a later phase of the work.

BMT have now completed this initial feasibility study, and the results and recommendations are reported below and in [4]. Individual sub-tasks within this feasibility study were as follows:

- Identify the contacts in the classification societies (and others amongst JSIT group members) who should be able to assist with this task. Contact these, and secure their help in this preliminary phase.

- Conduct meetings and exchange correspondence with the contacts with the objectives of:

  a) determining what comparative information (if any) already exists,
  b) obtaining views on the most efficient means of performing such calculations and the resulting comparison,
  c) identifying key parameters which are common to most stability codes, and may therefore be compared,
  d) seeking views on how different levels of redundancy on the rules might be assessed and compared.

- Following the discussions, and based on the information obtained, BMT would form a view on whether it is advisable for this part of the work to proceed further.

- Assuming that BMT's view is that the work should proceed, BMT would plan the work, and would provide a detailed specification, indicating which other parties or organisations it is proposed to involve. Where appropriate, costed proposals would be obtained from third parties.

- The outcome of the work would be recommendations and (if appropriate) a costed proposal, presented to HSE for a decision on whether the work should proceed.

Task No. 2: Assessment of Dynamic Effects on Stability

Current guidelines and regulations for assessing stability of jack-ups in transit make no explicit allowance for the vessel's dynamic roll response in waves, and the purpose of the present task was to review and assess, by numerical examples, possible procedures for incorporating some of these dynamic effects, and their significance for jack-up stability.

Individual sub-tasks undertaken as part of Task 2 were as follows:

- Review earlier published work on stability analysis methods which include an explicit dynamic term to represent effects of waves and possibly wind gusting. These methods include that of Sarchin and Goldberg [8] and subsequent developments by Bush and Ahilan [9] for jack-ups.

- Decide on the basis of the above which methods to pursue in the remainder of the work. Determine whether the analysis can realistically include damage.

- Design, write and test any computer software necessary to apply these methods.

- Develop a specification for the design information required for the candidate jack-ups for use in the study.

- Seek guidance from JSIT group members on which jack-up designs should be the examples used in the study. By reference to jack-up designers, determine which jack-up design and stability information can be provided. Make final selection of the jack-ups to be studied, and procure the necessary design information.

- Perform dynamic response calculations for a single typical severe storm sea state, using a conventional linear three-dimensional wave diffraction program, with viscous damping corrections to the roll and pitch damping based on current knowledge, but not taking account of water on deck.

- Perform stability analyses firstly using HSE's current intact criteria, and then including explicit dynamic terms, so as to investigate the differences, relative reliability and uniformity.

- Calculate leg bending moments using the existing HSE criteria, and then using motions predicted by the above analysis.

- Compare and assess results from the above; draw conclusions about likely relative advantages, reliability and uniformity for stability assessment; make recommendations about any further enhancements to the dynamic method, and any further systematic calculations necessary.

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- Prepare a report on the above work, and submit to HSE.

Results from this investigation are presented below and in [5].

Task No. 3: Assessment of Water Impact Loads

Current guidelines for jack-up operations discourage the carriage of cargo in unprotected locations on deck during a wet tow. Certain items will inevitably have to be carried on deck, but there seem to be no established and validated procedures available for calculating green water impact and sea-fastening loads. There have, moreover, been numerous incidents in which sea-fastenings or structures on deck have been damaged or failed as a result of impact from green water washing across the deck.

Task 3 involved carrying out representative calculations of water impact and drag forces on a number of different items in various boarding seas scenarios, using two alternative calculation procedures. Conclusions were then drawn about the validity of current calculation methods, and the significance of the loads.

Individual sub-tasks undertaken as part of Task 3 were as follows:

- Obtain references and published data on which the two calculation methods are based.

- Consider the type of wave conditions in which failures have occurred, and select a 'typical' boarding seas deck impact scenario.

- Select a few different body shapes and sizes representing typical equipment that might realistically have to be carried on deck; and select a suitable location for the body on an idealised jack-up deck.

- Perform calculations using both the IACS and HSE Guidance Notes methods for wave impact calculations, making different assumptions about wave particle velocities: using, for example, Stokes fifth order or random linear wave theories.

- Compare the forces calculated with each other, in order to determine sensitivity to the assumptions made; and compare these forces with typical inertial forces expected due to the jack-up motions.

- Derive conclusions on the different methods, and the uncertainties and variabilities in the calculations.

- Prepare a report for submission to the HSE.

Results from this investigation are presented below and in [6].

Task No. 4: Assessment of Model Test Results

BMT's Phase I 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 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 Phase I report considered it likely that existing model test and full-scale data would prove extremely limited in scope for validation purposes, that they would be of limited relevance to present requirements, that only limited data would be available about the rig and conditions tested, and/or the quality of results might be suspect. Scaling problems were also anticipated in extrapolating from the model to full scale.

In view of the expense and time involved in performing new measurements, however, the following preliminary tasks were recommended. These were intended to investigate what information is currently available, to assess its likely value for validation studies, and to make recommendations for further numerical analyses, validation studies, model testing and or full scale measurements to be undertaken during subsequent phases of the project.

The present task included an assessment of the availability and suitability of existing data, but did not include any actual correlation work. Recommendations were nonetheless made about the need for such correlation studies.

BMT has now completed this initial feasibility study, and the results and recommendations are reported below and in [7]. Individual sub-tasks within Task 4 were as follows:

- Seek access to, and permission to use, confidential model test and full-scale data identified in BMT's Phase I review.

- Circularise model basins and other appropriate parties in order to identify any further (perhaps more recent) model test data, and any appropriate full-scale measurement data.

- Evaluate these tests and results to see whether they are likely to be suitable for validating a numerical seakeeping model. That is:

  a) whether the measurements and available data are suitable and relevant for present purposes,

  b) whether the tests appear to have been conducted competently, and the results are of good quality,

  c) whether there is sufficient information about the model parameters, test conditions, and model shape, and

  d) whether the tests covered a sufficient range of conditions to be useful, or whether they are so limited as to make comparisons meaningless.

- Carry out a similar evaluation of any full-scale measurements that have been identified; assess likely consequences of scaling effects, and difficulties of making full-scale predictions.

- Prepare a report for HSE drawing appropriate conclusions, and making recommendations about any further numerical analysis, validation studies, model testing and/or large-scale measurement requirements during subsequent stages of the project.

3. MAIN RESULTS AND CONCLUSIONS

3.1. TASK NO. 1: ASSESSMENT OF INTACT STABILITY CRITERIA

The aim of Task 1 was to investigate the feasibility of carrying out a numerical study to assess the intact stability criteria of the HSE [10] and other authorities, and the benefits of involving the certifying authorities in this process. BMT contacted four certifying authorities during the course of this project, established the basis on which they would collaborate, and discussed the merits and difficulties of the study as a whole.

Involving the 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 was proposed 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. BMT proposed to investigate 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 might form the basis for an extension of the present study.

After further consideration of the issues and priorities, however, BMT and HSE agreed to proceed no further with this task.

3.2. TASK NO. 2: DYNAMIC EFFECTS ON STABILITY

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.

There have been no known losses of jack-ups while in the intact, non-flooded condition. Capsizes and sinkings have occurred only after a substantial amount of water has been taken on board. There is no obvious need to develop improved intact stability criteria, and no obvious better alternative to existing criteria at this stage. The development of a viable alternative would, moreover, probably require a substantial programme of research and validation.

BMT originally intended to consider the effects of vessel dynamics on leg bending moments. Uncertainties in predicting sea-keeping behaviour made it difficult to assess existing leg bending moment criteria. Historical methods, based on assuming 20° of roll and pitch at the appropriate natural periods, seem to offer a reasonable and practical approach in the light of present limited knowledge about jack-up motions in severe seas. BMT's sea-keeping calculations suggest, however, that a maximum roll angle of 20° is by no means excessive, and might on occasions be exceeded.

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.

There seems to be little obvious merit at this stage in developing dynamic stability criteria for jack-ups in the damaged condition. The issues surrounding past jack-up losses have involved a complex sequence of events, in which roll motions, water on deck, watertight integrity and flooding have all played a part. A programme of research aimed at a better understanding of this sequence of events is likely to be worthwhile.

3.3. TASK NO. 3: ASSESSMENT OF WATER IMPACT LOADS

Representative calculations were performed using a standard IACS (International Association of Classification Societies) design procedure [11], 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 [10] and

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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 were 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.

The main recommendation for future work is to obtain systematic model test data, in order to validate impact load calculation procedures, and to improve understanding of the physical processes. These model tests would have to be performed on a jack-up in severe boarding seas, and would have to include measurements of green water impact forces on typical deck structures and equipment, together with the occurrence, heights and velocities of green water on deck. Special care would be needed to simulate the waves in a realistic manner. The inevitable scatter and uncertainty in the results, however, are likely to limit the quantitative benefits from such work.

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3.4. TASK NO. 4: ASSESSMENT OF MODEL TEST RESULTS

BMT 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 were rejected either because of anticipated communication difficulties, or because necessary details of the model or tests were not available, or else because the data set was not extensive enough.

BMT identified one especially extensive and systematic data set, which appeared to be particularly suitable for the proposed purpose, two further fairly extensive and useful data sets, together with a fourth set of suitable but less extensive data. BMT obtained a copy of the fourth model test report, and the other three reports can be made available when required, subject to meeting certain confidentiality and anonymity restrictions.

BMT identified two further sets of data which may provide some limited additional information for program validation work. Full details of the tests and models may be unavailable, or difficult to obtain, however, and it was not possible to assess data quality. One of these data sets is unique in considering various levels of flooding, and there is already just sufficient information in the published paper to carry out adequate calculations and comparisons. The jack-up was mat-supported, however, and was considered unrepresentative of units used in the North Sea. 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.

It was noted that none of the four primary sets of model test data met all the criteria laid down earlier, although the first data set came closest. All four primary data sets consider the intact rig only, and do not represent the flooding and capsize process. It was also noted that the only available full-scale results are of limited value.

It is likely, therefore, that the recommendations from a further Phase III programme might well include:

- additional model tests to investigate flooding and capsize, together with associated numerical studies,
- a full-scale measurement programme.

These model tests and full-scale measurements would ideally take place on one or other of the rigs selected for the primary investigation. It would be premature, however, to propose such additional tests and measurements before the maximum possible information has been extracted from the data that are already available.

BMT therefore recommended as follows:

i) All four of the identified sets of data should be regarded as primary data sources for future validation studies, and copies of the test reports should be acquired from their respective owners.

ii) Numerical calculations should be undertaken, as part of a Phase III research programme, for comparison with all four of the primary data sets.

iii) The need for further systematic model tests or full-scale measurements will have to be re-assessed, following the Phase III programme.

iv) In order to satisfy the concerns of owners of model test data about confidentiality and anonymity, the results from the Phase III study will not be identified with any particular unit, and will be made non-dimensional or otherwise disguised. This study will aim to

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validate numerical methods, but the results will not allow the performance of different units to be compared.

v) BMT also proposed to visit some of the owners of test data at a suitable stage during the Phase III work, in order to discuss the results, and to ensure a more positive involvement and benefit for all companies concerned.

After further consideration of the issues and priorities, however, BMT and HSE agreed to proceed no further with this task.

3.5. OVERALL CONCLUSIONS

BMT's investigations have met the Phase II objectives, and have largely followed the original list of sub-tasks and methodology, except where results from the study suggested that an alternative approach would be more worthwhile.

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.

4. ACKNOWLEDGEMENTS

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- Lloyd's Register of Shipping,
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- The American Bureau of Shipping,
- Noble Denton Europe Limited.

BMT also gratefully acknowledge assistance from rig designers and owners, who made results from stability calculations and data available for use in these investigations.

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5. 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. P45459, revised final report, 18 July 1994.

2. BMT Offshore Limited, 'Stability Criteria for Jack-ups in Transit. Phase II, Report no. 1: Expanded Work Scope and Schedule', report to the Health and Safety Executive, project no. 44058/00, 1994.

3. Marine Technology Support Unit, Agreement no. MaTSU/8671/3245, 31 October 1994.

4. BMT Fluid Mechanics Limited, 'Stability of Jack-ups in Transit: Phase II. Task 1: Assessment of Intact Stability Criteria', Report 5, BMT project no. 44058/00, HSE ref: OT-N-95173, 1995.

5. BMT Fluid Mechanics Limited, 'Stability of Jack-ups in Transit: Phase II. Task 2: Assessment of Dynamic Effects on Stability', Report 2, BMT project no. 44058/00, HSE ref: OT-N-95174, 1997.

6. BMT Fluid Mechanics Limited, 'Stability of Jack-ups in Transit: Phase II. Task 3: The Assessment of Water Impact Loads', Report 3, BMT project no. 44058/00, HSE ref: OT-O-95022, 1996.

7. BMT Fluid Mechanics Limited, 'Stability of Jack-ups in Transit: Phase II. Task 4: Assessment of Model Test Results', Report 4, BMT project no. 44058/00, HSE ref: OT-N-95175, 1995.

8. Sarchin T.H. and Goldberg L.L., 'Stability and buoyancy criteria for U.S. naval surface ships', Trans. SNAME, vol. 70, pp. 418-458, 1962.

9. Bush R.B. and Ahilan R.V., 'History, theory and extension of current jack-up quasi-dynamic stability criteria', in "Mobile Offshore Structures", edited by Boswell L.F., d'Mello C.A. and Edwards A.J., pp. 81-103, 1988.

10. The Health and Safety Executive, "Offshore Installations: Guidance on Design, Construction and Certification", 4th Edition with amendments, 1993.

11. International Association of Classification Societies, Unified Requirements, Requirement 63, 'Strength of end bulkheads of superstructures and deckhouses', 1973.

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