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Offshore Structures — Implementation of Reliability

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This paper deals with relevant applications of the present state of the art in particular relating to constructional codes. The emphasis is on structural systems. A novel approach to the calculation of structural systems which utilizes basic concepts and certain features of level two calculations is presented. The approach is computationally efficient and overcomes a number of the traditional problems of treating load and failure mode correlations, but requires the exercise of some engineering judgement.

INTRODUCTION

Traditionally, structural codes of practice have specified element design without giving consideration to the appropriate assembly of multi-element structures. The "Ronan Point" disaster in 1968 suddenly brought home the need to give consideration to the problem of "progressive collapse". (In other fields of industry this problem is often referred to as the "domino effect".) Subsequent to this, British and other national structural codes of practice have incorporated design requirements aimed at reducing the probability of progressive collapse. Such requirements have also been incorporated in the Veritas (1977) Rules for Fixed Offshore Structures. (5)

The design criteria which were initially formulated some ten years ago were designed by ad hoc committees to meet the immediate need for design guidance. Only a limited research background was available to these committees, which had to formulate criteria largely based on common sense and engineering judgement.

Further development of such criteria must necessarily be based on research into the effect of structural configuration on reliability of multi-element structures.

In the case of offshore structures these are normally pure load-bearing structures with no significant reserve capacity in the form of nominally non-load-bearing components. It is thus natural that the offshore industry has been at the forefront in the study of the overall reliability of multi-element structures. So far the emphasis has been on developing the necessary analytical tools for this purpose. This paper thus also sets out by reviewing an analytical approach for determining the reliability of multi-element structures.

The present approach has been devised in order that the analysis can be accomplished with basic tools which are immediately available to the analyst. These tools consist of a facility for making approximate full distribution Level II analysis of element reliability and a facility for non-linear structural analysis. For the purpose of this analytical approach element failure is defined as commencing yielding. Similarly, structural failure is defined as the full development of a yield mechanism.

The calculative approach bases itself on two principal features which will be outlined prior to going into the calculative approach proper. The first feature is illustrated in fig.1. Here the principle of a two parameter Level II calculation is illustrated. The parameters x_1 and x_2 are plotted in normalized form in units of standard deviations. The failure boundary is shown as a heavy line and the linearized failure boundary as a dashed line. These two touch at the linearization point which is also known as the "design point". This particular point is the point on the failure boundary with the maximum probability density. Projected on this diagram are shown the unconditional distributions of the stochastic variables x_1 and x_2.

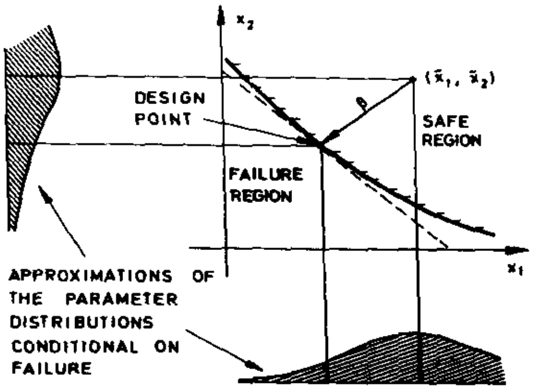
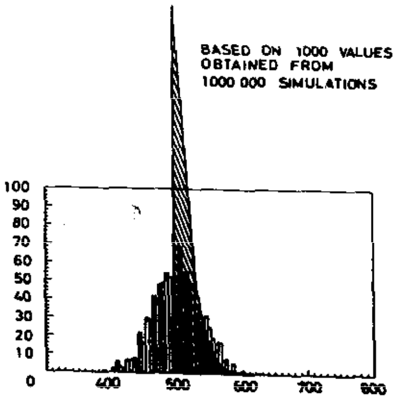


Fig. 1

The problem which is being approached is the assessment of the distributions of the variables x_1 and x_2 conditional on a failure having occurred. By definition, failure occurs when the failure boundary is exceeded. As a result there is a very high probability of the failure boundary being exceeded in the immediate vicinity of the design point. By assuming exceedance of the failure boundary at the design point, the parameter distribution conditional on failure must correspond to the unconditional parameter distribution being truncated at the point corresponding to the design point. Having obtained such conditional distributions, conditional reliabilities can immediately be obtained by repeated application of the Level II calculation.



	CUMULATIVE PROBABILITIES	
ABCISSA VALUES x	TRUNCATED VALUES	SIMULATED VALUES
547. 40	0. 95 49	0.8000
560. 30	0.98 25	0.9500
583. 80	0.99 76	0.9900
600. 32	0.99 95	0.9990

MEAN VALUES

SIMULATED DISTRIBUTION : 500. 39
TRUNCATED DISTRIBUTION : 512. 84

Fig. 2

The accuracy of approximating the true conditional distribution with the truncated distribution is illustrated in fig.2. Clearly the approximation will be more accurate when the trucation is applied to the tail ends of the distributions; that is, for high element reliabilities. The illustration in fig.2 is based on a case giving a reliability of $1-10^{-3}$. This should be a lower limit to element reliabilities obtained in practice, and consequently the case will also represent a lower level of accuracy of the proposed approximation. From the graphical and tabular presentation it is seen that in the tail of the distributions the two curves represent a satisfactory close approximation even in this extreme case.

The second feature of this calculative approach is the utilization of the principle of taking repeated conditional expectations. The following notation is utilized:

R = Unconditional system reliability
r_i = Unconditional reliability of element i
$R(1_i,1_j,1_k)$ = System reliability conditional on the survival of elements i,j and k
$r_i(1_j,O_k)$ = Reliability of element i conditional on the survival of element j and the failure of element k
π = Product operator

We now have the following basic relationship:

$$R = r_i \cdot R(1_i) + (1 - r_i) \cdot R(O_i)$$

By repeated application we obtain

$$\begin{aligned} R = {} & r_i \cdot r_j(1_i) \cdot R(1_i,1_j) + \\ & + (1 - r_i) \cdot R(O_j) + \\ & + r_i \cdot (1 - r_j(1_i)) \cdot R(1_i,O_j) \end{aligned}$$

At this stage we will approximate all unconditional element reliabilities with the corresponding element reliability conditional on the survival of all elements not defined as failed. This approximation is necessary in order to determine the load distribution in elements with the aid of an ordinary deterministic programme for structural analysis. In normal structures element reliabilities are extremely high. As a consequence this approximation is numerically insignificant. We thus modify our notation of conditional element reliabilities by only indicating the condition of failed elements with a straight vector, thus: $r_i\ (j,k)$.

By recurrent expansion of the first term we thus obtain:

$$\begin{aligned} R = {} & \prod_i r_i + (1-r_i) \cdot R(O_i) + \\ & + r_i \cdot (1-r_j) \cdot R(1_i,O_j) + \\ & + r_i \cdot r_j \cdot (1 - r_k) \cdot R(1_i,1_j,O_k) + \ldots \end{aligned} \tag{1}$$

The term $\prod_i r_i$ is a well-known lower bound. The residual terms can again be evaluated by repeated application of the above expansion, thus:

$$\begin{aligned} R(1_i,O_j) = {} & \prod_{k \neq i,j} r_k(j) + (1-r_k(j)) \cdot R(1_i,O_j,O_k) + \\ & + r_k(j) \cdot (1-r_l(j)) \cdot R(1_i,O_j,1_k,O_l) + \\ & + \ldots \end{aligned} \tag{2}$$

On the above basis the calculative approach can now be outlined:

<u>Step 1</u>: The global loads and their distributions are established. In the case of correlated loads these must be split up into fully correlated and fully independent components.

<u>Step 2</u>: All elements of the structure are initially defined as intact and consequently as linearly elastic. Characteristic values (such as the mean value) of the global loads are applied to the structure, and the corresponding characteristic values of element forces are determined using a conventional deterministic facility for structural analysis. As the structure is assumed linear, the distribution of elemental forces will completely conform with the distribution of the global forces. The linear assumption is an approximation:

a) It neglects the effect of the random nature of geometric and elastic properties of elements.

b) As previously mentioned it assumes all elements which are not defined as failed to be intact.

In normal structures these effects will be of minor importance - insignificant in comparison to the quality of the basic data.

Step 3: With the elemental loads and properties the individual element reliabilities are now determined using a Level II approximate full-distribution calculation. These are again introduced into equation 1., giving us a first lower bound on the system reliability $(\prod_i r_i)$ and a series of residual terms essentially consisting of a coefficient $(1-r_i)$ and a conditional system reliability such as $R(1_i,O_j)$. By inspection of the $(1-r_i)$ coefficients most of the residual terms will be found to be numerically insignificant, permitting one to disregard these terms. This arises due to the fact that in a structure, under one load condition only a limited number of elements will be fully stressed.

Step 4: In order to evaluate a conditional system reliability such as $R(O_i)$ the structure must be remodelled to include this condition. First of all the truncated approximations to the conditional parameter distributions corresponding to the computed element failure probability is computed. In the case of the element loads which are fully correlated with the global loads, the truncations are carried over to the global loads.

The structure is now reanalyzed with the mean values of the new truncated global load distributions. The failed element (i) is modelled with the mean values of the truncated distributions of its geometrical and material parameters. New element loads and corresponding reliabilities are obtained in the same manner as previously and are entered in an expression of the same type as Equation 2.

Step 5: Successive conditional system reliabilities are evaluated as in Step 4 until all significant contributions have been evaluated and the calculation terminates. This will normally be achieved at a level of three or four successive failures with something of the order of five significant failure modes. This is, of course, somewhat dependant on the nature of the structure and typically applies to a four-legged structure.

The successive failures introduce a further distortion from linearity. As this distortion

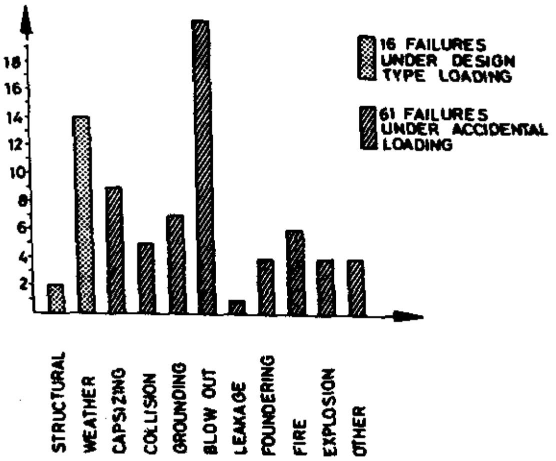
Accidents to fixed and mobile offshore structures						
Type of accident	Structural loss					SUM
	Total	Severe	Damage	Minor	No.	
Weather	4	10	29	18	7	68
Capsizing	6	3	3	1	-	13
Collision	3	2	8	14	21	48
Grounding	2	5	2	4	1	14
Blow-out	11	10	11	12	9	53
Leakage	-	1	3	-	-	4
Machine, etc.	-	1	5	5	-	11
Fire	3	3	12	17	-	35
Explosion	2	2	9	8	-	21
Out-of-pos.	-	-	3	-	6	9
Foundering	4	-	-	-	-	4
Structural	-	2	12	21	2	37
Other	2	1	-	8	13	24
SUM	37	40	97	108	59	341

Table I: Number of accidents distributed on initial event and degree of structural loss.
Period of occurrence: 01.01.70 - 31.12.77.

becomes more significant with an increasing number of failures, the contribution of the calcuted reliabilities at the same time progressively decrease. As a result this effect is, in total, modest.

STRATEGY FOR MULTI-ELEMENT STRUCTURAL RELIABILITY

Table 1 shows the distribution of structural failures occurring to offshore structures, related to initial circumstances. Failures under accidental loads are seen to be completely dominant. This is more clearly demonstrated in fig.3. The reliability of an element under design loading is thus a parameter of little significance in relation to controlling the probability of initial damage. The robustness of an element being its ability to sustain exposure to given degrees of accidental impact is obviously relevant, in particular if statistics for these properties could be developed in practice. The dominant parameter relating to an element's probability of sustaining an initial failure is clearly exposure - locality and bulk of exposure.



GRAPHICAL PRESENTATION OF OFFSHORE ACCIDENTS WITH TOTAL AND SEVERE STRUCTURAL LOSSES IN THE PERIODE 01.01.70-31.12.77 DISTRIBUTED ON TYPE OF PRIMARY CIRCUMSTANCE.

Fig.3

Another parameter of significance in this context is the contribution to the reliability of the total structure from each individual element. As this is the difference between two levels of reliability, this parameter can be assessed with relatively fair accuracy in spite of the limitations imposed by the basic data.

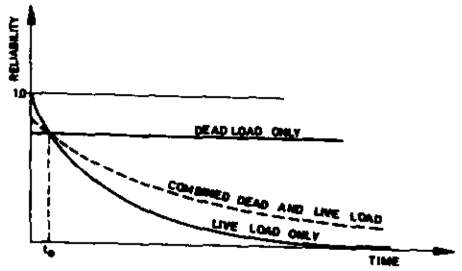
In order to obtain a uniform and adequate level of reliability of multi-element structures it will be necessary to limit the product of element contribution to the reliability of the total structure and the probability of element failure under accidental load. What level is acceptable must necessarily be established by calibration. For this purpose it will be necessary to analyze structures based on established concepts with a known acceptable performance. It will, in fact, not be realistic to expect that the probability of individual elements sustaining initial damage can be assessed with reasonable accuracy. Calibration studies for establishing acceptable levels of element contribution should thus relate to appropriate broad groups of basic structural elements.

Such a study is presently being undertaken by Veritas with joint industry sponsorship. A jacket structure is being analyzed with the main emphasis on establishing element contributions to the reliability of the complete structure.

COMBINED DEAD AND ENVIRONMENTAL LOADING

Reliability is normally defined as the probability that, when operating under stated environmental conditions, the system will perform its intended function adequately for a specified interval of time.

For live loads such as environmental loads such a time-dependent definition applies. Structures purely subject to time-independent dead load fall outside this definition. When explicit recognition of this difference is required, probability of success or some other suitable term is used to describe the pure dead load case and differentiate it from reliability. This differentiation is in fact not purely academic. This is illustrated in fig.4. The probability of failure under pure dead load will be constant, independent of time, whereas the probability of failure under live load will increase asymotically toward unity. The reliability under combined dead and live loads will lie between these two extremes.



TIME (t_0) AT WHICH DEAD AND LIVE LOAD RELIABILITIES ARE COMENSURABLE.

Fig.4

It is thus first of all seen that it is necessary to specify two parameters in order to define a specific reliability level under arbitrary combinations of dead and live load. Obviously, the probability of success under dead load and the exposure period, at which the reliability under live load has the same value, is a unique point at which dead and live load effects are commensurable.

It has also been recognized that it is necessary to define an exposure period to live load in order to calculate reliabilities. Amongst workers in this field it has become accepted practice to calculate reliabilities for a "design life" or "design period" of 50 or 100 years. What probably is not recognized is that in doing so, when applying such calculations to code calibration, a political decision is being made in this process, which heavily affects reliability levels.

In analyzing existing codes it can be seen from several references, (1),(2),(3),(4), that the exposure period entrenched in existing codes is of the order of one year rather than a century. In performing code calibration studies, it will thus finally be necessary to determine whether the exposure period for the calibrand should be some rational design period or whether the exposure period of the established code used as a calibrator should be adopted. If an exposure period corresponding to a rational design life is adopted, it will further be necessary to determine rationally whether the calibrator code shall be analyzed in terms of a design life exposure period or the exposure period inherent in its own safety format.

SYSTEM RELIABILITY AND QUALITY CONTROL

Provided all relevant data are known, verification of structural safety should ideally be based on probabilistic methods throughout. If a directly probabilistic method is used, the different factors governing the probability of failure are to be based on thorough knowledge of their probabilistic nature. Special attention must then be paid to the statistical distribution of load components, material strength parameters, structural behaviour, tolerances, uncertainties involved by the analysis, design and fabrication, and so on.

In case a design is being verified on the basis of direct probabilistic methods, the target probability level to reflect common standards of safety are subject to approval in each case (5).

Still, design of a structure will basically be on the element level, thus ensuring sufficient reliability of all structural elements and joints. As for the progressive collapse limit states (PLS), however, the safety requirements are put forward for the entire structural system subject to local accidental damage or overload. Thus, for this design situation, calibrated methods for analysis of reliability of multi-component structures are needed to demonstrate consistent safety.

The safety provisions of present codes, whether in terms of central safety factors, partial safety factors or target reliabilities, pertain to the structures as designed and planned. From the conceptual stage, through design, fabrication and up to the installed and operating structure, there are a number of stages involving interface and judgement of humans.

Schemes for quality control are therefore implemented, either by government regulations or through industry's own control, in order to survey and control all stages of design and fabrication to ensure acceptable compliance between structure "as designed" and structure as built and installed. For ship and offshore structures operating in ocean environment, the Classification Societies have long since played major roles as independent certification and verification agencies.

According to experience and available statistics, most failures occur due to human errors or external hazards. For design of systems that are more insensitive to incorrect operation and also less vulnerable to accidental damage, Risk Analysis (RA) and Quality Assurance (QA) procedures have become indispensible tools. In recent years they have become more and more commonly adopted before and under the design process with the objective of identifying and quantifying the risks involved, including performance of humans.

Clearly, all these aspects bear on the reliability of the end product, that is, the installed and operating platform. A platform that has been designed to allow for easy and reliable inspection of critical joints and members, can be operated with more confidence than others. Redundant structures with options for alternative load paths and redundant monitoring and emergency systems will enhance the overall reliability of the platform further.

All codes of practice for offshore structures put forward certain minimum requirements regarding structural strength, serviceability, inspection, etc. To ensure adequate quality of the end product, the codes also make provisions for control and surveillance of all major stages of design, fabrication and installation. Design requirements and securing of quality on all stages therefore clearly combine in ensuring the reliability of the structure as installed.

It is difficult, however, to differentiate the influences from quality control and the explicit provisions for design strength on the resulting reliability of the structure. Further, it should be made quite clear that the requirements of all recognized codes are minimum requirements to be implemented in combination with a certain minimum scheme of quality control and surveillance. Otherwise, the codes will not apply. Increased amount of independent control and further scrutiny of the various design situations will better insight in human interfaces and communication, thus reducing possibilities of human errors. The overall improvement of reliability, although difficult to demonstrate by numbers, is recognized as a wise and profitable investment by those involved.

As the resulting reliability of the operating structure has strong ties to the procedures of quality control and risk analysis, a brief outline of relevant QA procedures is given in the following.

Definitions:

QUALITY ASSURANCE: All those planned or systematic actions necessary to provide adequate confidence that an item or a facility will perform satisfactorily in service.

QUALITY CONTROL: Those quality assurance actions which provide a means to control and measure the characteristics of an item, process or facility to established requirements.

The aim of the quality assurance programme is henceforth to attain required quality and fitness for purpose in an effective manner. As for Quality Control, this is the common denominator for the activities providing means to control and measure the physical characteristics of an item or a facility to predetermined requirements.

A complete QA system for a major project should cover all project phases, i.e.,planning, design procurement, construction, installation, commissioning and operation. Thus, QA is much more far-reaching than traditional product control, although this will be an essential element of the QA programme. The fact that proper control over activities during the early stages of the project is of utmost importance to the quality of the finished product and its use, is well appreciated by the industry.

Risk and reliability analyses offer new approaches for the achievement of intended safety of a system and its operation within the QA programme.

The risk analysis is an overall systematic analysis of a project or activity, to identify and assess all significant risks associated with it. A risk analysis will include:

- identification of hazards (accidental loads)
- assessment of probability of hazardous events
- assessment of consequences

This type of analysis can be adapted to conceptual safety appraisal or, alternatively, to evaluation of hazards and risks associated with a specific installation.

Analysis of structural reliability will inevitably become an integrated part of a more all-embracing risk analysis of a platform and its operations. It is therefore important to be aware of the interfaces and mutual impacts on the resulting reliability of the system.

FEEDBACK OF EXPERIENCE DATA

One widely-accepted way of learning is learning by experience. Learning to avoid failures and accidents thus could be enhanced by taking account of past events.One feature of today's technological development, in contrast to designers' more direct involvement in the past, is that the various decision-makers are more remote from the back-flow of in-service experience. The designer may not ever physically see the materials or components he is using in his design. The same can be true for the final result of his design, - the plant or the structure, - he will not be present where and when the undesired events take place. The experience will have to be provided to him through some formalized feedback system.

Another example could be an operator who is supposed to react reasonably to certain abnormal events, like a fire, a blow-out or evacuation. To a large extent, the operator has no personal experience with these rare events. Possible practical experience with such events will have to be transferred from those with the experience, in some form or other.

Asking to whom the feedback of experience should be directed, the answer seems quite evident:

> To those who have influence on failure/accidents and prevention. This, in fact, could mean a lot of different people.

They will include designers on all levels, from the plant level to the component or part level; the repair and maintenance people as well as the planner of maintenance systems; the operators of a plant, the planners of procedures and for training purposes.

Authorities must have some reasonably well-based opinion about the risk levels in order to exercise their duties. Also the establishment of engineering design and acceptance criteria would be almost impossible without a feedback describing the safety level.

Also research should be mentioned. Feedback of real-life experience is one of the most important means to help keep research down to earth. It helps define important research areas, and will provide real-life calibration of theoretical models.

When some information feedback systems, accident,and reliability data "banks" have failed, the main reason is probably this: It has, for some reason, failed to provide the information in the right form, at the right level of detail or as timely as necessary for the individual user.

The clue is usefulness. The different users and their needs will define the best possible ways to provide useful feedback of experience.

The most fruitful approach probably is:

- first: Identify each users typical actions or decisions. Through this the "free variables" at his level are established. (Like a process system designer who will be able to decide which component to apply, or the structural designer who will make the choice between materials or decide the welding procedure.)
- Through the identification of the actual decisions, analyse the effects of these decisions on safety.
- To be able to do such analysis, certain knowledge/information is required. Some of this knowledge is best provided through some kind of experience information.

Availability of Experience Data

Existing data files on accidents, failures and exposure data have evolved through the years in a seemingly random way. The areas and activities covered and the types of accidents contained in the files have been decided by such factors as:

- borderlines defined by delegations of authority/responsibility to different bodies/institutions.
- specific legal requirements covering certain areas like "escape of flammable fluids to be reported to inspectorate of explosives".
- within a company like an oil company, it is often found that one department, like the maintenance department, has well-developed systems for covering their own needs, while the needs of other departments, like the engineering and design departments, are less well covered.

These factors obviously will be different for different countries and companies, and thus bring about a large variety of systems.

This is one of the difficulties in utilizing experience data at a larger scale. The individual, small-scale systems are not compatible, and pooling of data to get a broader base is troublesome.

The following can be said about some of the main risk areas relating to offshore activities:

Fatal accidents and injuries are generally the best covered events since such events are reported on standard forms. These forms give mostly information about the person and the immediate circumstances around the individual fatal accident, and is best suited for typical occupational accidents like "fall to lower level", "hit by falling object".

The annual reports of the Norwegian Petroleum Directorate contain summary statistics tables on injuries and fatal accidents on the Norwegian Continental Shelf for fixed installations.

The Norwegian Directorate of Seamen will in the future publish statistics on injuries and fatal accidents on mobile platforms, drilling ships and other types of Norwegian-registered vessels connected to the offshore activities. (Until now such statistics have been incorporated in statistics on accidents and injuries on board Norwegian-registered ships, and not sorted out as an own area of statistics.

The statistics published in /6/ and /7/ are based on forms which,according to law enforcement, are sent to the Norwegian Petroleum Directorate. (This Directorate has for internal use worked out statistics on fatal accidents and injuries on mobile units in the foregoingyears. This material is available upon request.)

In the report "Overall Risk Assessment of Offshore Petroleum Activities" published by the Norwegian research program Safety Offshore, is given a relatively detailed overview of fatal accidents on the Norwegian and the British Continental Shelf until December 1978. The circumstances around the accidents are incorporated in the overview. The statistics are updated in a revised version of the report (in Norwegian) from March 1980.

The report "Risk Analysis, Accident Experience" (in Norwegian) from the Engineering Research Foundation at the Technical University of Norway gives a detailed description of 21 fatal accidents on the Norwegian Continental Shelf. The analysis is based on police reports. Each accident is described verbally and by means of a graphical accident chain. The accidents cover a wide spectrum from usual working accidents to diving accidents and accidents caused by structural failures./9/

Another reference of interest is the Norwegian Underwater Institute report"Preliminary diver fatality data on the Norwegian Shelf" (January 1980). /10/

The "Burgoyne Report" (March 1980) contains statistics on failures, accidents (fatal, serious and minor) and dangerous occurrences on the British Continental Shelf. It also contains an overview of US and Norwegian legislation and enforcement. /11/

US Coast Guard is now working on a report covering injuries and fatal accidents in connection with offshore activities on the US Continental Shelf in the past. The report is expected to be finished in the near future. USCG is also preparing a data bank for analysis and periodic statistical reporting of such accidents. The system is expected to be operable in the near future. /12/

Large accidents. The larger accidents will be reported in news media. A typical information source is Lloyd's List. /13/

The information obtained from these sources is generally non-structured, and the information content varies in each case. Generally the causes or causal factors are not given in detail. However, it is possible to build up a world-wide coverage. One such "bank" is continuously being up-dated at Det norkse Veritas, and some examples of output from this bank is described in the last section of this paper and has provided a.o. the input given in Table I above.

Other References

The January 1981 edition of Offshore Mobile Drilling Rig Data Services, Houston, Texas, claims to contain a chronological tabulation of all significant mobile rig accidents in the period mentioned. Information tabulated for each accident is rig name, owner, year of accident, year put in service, accident location, type, rated water depth, design, a short description of the accident and cost of damage. Approximately 200 accidents are tabulated. /14/

The article "Tracing the Causes of Rig Mishaps" in Offshore, March 1981, contains an overview of 140 major mishaps in the period 1955 - 1981, and statistical tables, diagrams and discussions. /15/

The article "Study Analyzes Offshore Rig Casualties" in the Oil and Gas Journal, November 1976, presents discussions of the statistical tables and diagrams, Economic considerations are emphasized. /16/

Technical Failures, Malfunctions

Of course there are enormous amounts of such information stuck away or filed in the different operating companies. Only to a very small extent are such data generally available. The most extensive system outside of the oil companies themselves is probably the Failure and Inventory Reporting System (FIRS), which started operation in 1980. This is operated by USGS and covers failures of certain specified components in oil and gas production plants like safety valves, gas detectors, level sensors.

An account of the applicability of the abovementioned FIRS system to Offshore Production is given in a paper presented by Leslie E. Bennet, USGS, at a seminar in Stavanger, Norway, 10-11 June 1981. /17/

A research project is presently under way in Norway to develop a data handbook, OREDA (Offshore Reliability Data Handbook), by extracting experience data from the inspection and maintenance files of oil companies operating offshore and, based on this, to generate reliability data.

Near-miss/hazardous states

When large accidents occur at such long intervals as they actually do (rare events), this is because a number of measures are taken to avoid these events, often in the form of "barriers", redundancy or safety systems. Obviously the information contant (number of events observed/recorded) could be increased considerably by recording events which under certain other conditions would have developed into an accident.

Very few systems exist for systematic utilization of near-miss events. The aircraft industry seems to have solved the near-miss event reporting better than most other industries.

There are certain principal problems about how to approach such a task. In particular the human failure area is an important area where near-miss reporting and analysis could be pursued further.

OFFSHORE ACCIDENTS WORLDWIDE

This section presents examples of simple analyses of records of large accidents offshore. The information is based on Det norske Veritas accident data bank covering world-wide accidents in the offshore industry, excluding ships, which are covered by a separate data bank.

This data bank is continuously updated and is based on basic events reported through Lloyd's List and other news media covering this field. In a way the criterion for an event to enter this data bank is that the seriousness or characteristics of the incident are such that they give rise to public or news media interest. Therefore, it will be practically complete for "total loss" and accidents involving loss of life, but will not cover typical occupational accidents.

The bank covers the time period 1970 to 1980 and contains 472 accidents. (The ship accident data bank contains approximately 10,000 accidents in the period 1965 to 1980). The information coded in the bank for each accident is (to the extent it is available): year, month and day of the accident, rig name, shelf, classification society, owner, water depth, year built, rig type, function, type of accident (when appropriate, chain of incidents), location on board, geographical location (Marsden code), operation mode, weather conditions, number of lives lost for crew and third part respectively, number of injuries for crew, amount and type of spill and degree of structural damage. When appropriate a short verbal description of the accident is also registered.

Background Data, Exposure Data

In most cases, to be able to draw meaningful conclusions, or, when using accident data for prediction, factors influencing the accident probability must be known. The most obvious factors are population, time spent in different operating states,etc. Environmental factors also are important. Examples of such data are number of platforms at any time, of different types- in different operating states; number of employees- number of foggy days compared to clear days, etc. Background data are sometimes harder to obtain than information concerning the actual event.

The September issue of Ocean Industry presents a Directory of Marine Drilling Rigs. The rigs are sorted into the following four groups: submersibles, drill ships and barges, semi-submersibles and jack-ups. For each rig is given name, owner, time and place of building, maximum water depth, maximum drilling depth, information on accomodations quarters capacity, storage, drilling equipment, derrick, cranes, contractor, work area and other information when appropriate. A photo is shown for most of the rigs. An overview of rigs under construction is also given. /18/

The April issue of Offshore presents an overview of world-wide rig locations for mobile rigs. The rigs are sorted according to the following working areas: Africa, Australia, Caribbean, Celtic Sea, East Canada and Greenland, Eastern Europe, Great Lakes, Japan, Louisiana, Mediterranean, Mexico, Middle East, North Sea, Pacific, South America, Southeast Asia, Texas, U.S. East Coast and Western Europe. For each rig is given name, type, owner, contractor, location, maximum water depth and maximum

	GEOGRAPHICAL AREA AND ESTIMATED NUMBER OF RIGYEARS					
	USA (904 rigyears)		NORTH SEA (460 rigyears)		WORLD-WIDE (3244 rigyears)	
Type of accident	Acci-dents	Accidents per 1000 rigyears	Acci-dents	Accidents per 1000 rigyears	Acci-dents	Accidents per 1000 rigyears
Weather	10	11.1	18	39.1	62	19.1
Capsizing	9	10.0	-		19	5.5
Collision	10	11.1	8	17.4	47	14.5
Grounding	1	1.1	3	6.5	13	4.0
Blow-out	15	16.6	3	6.5	34	10.5
Leakage	-		2	4.3	7	2.2
Machine,etc.	2	2.2	4	8.7	11	3.4
Fire	7	7.7	5	10.9	25	7.7
Explosion	2	2.2	5	10.9	14	4.3
Out-of-pos.	-		1	2.2	7	2.2
Foundering	-		-		1	0.3
Structural	11	12.2	6	13.0	41	12.6
Other/unknown	3	3.3	12	26.1	19	5.9
Sum	70	77.4	67	145.7	199	92.2

Table II. Number of accidents, and number of accidents per 1000 rigyears for mobile units in three different geographical areas in the period 1970-1980.

water depth and maximum drilling depth. An overview of rigs under construction is also given. /19/

The Offshore Rig Location Report is a monthly report on the drilling location and contract status of all mobile offshore rigs worldwide. Information includes water depth and planned TD of well, major subcontractors, shore base and future contract commitments. Special sections list Rigs Under Construction, Inland Water Drilling Barge Locations, Platform Rig Locations with operating information, and Leases/Concessions Recently Granted or Relinquished. In addition numerous graphs and tables monitor rig utilization, list idle units and those operating in other modes and summarize world-wide activity by type of unit and area of the world./20/

Drawing Conclusions. Identifying improvements

We have to be careful in drawing firm conclusions from a statistical material like this. There are several reasons for this, such as:

- The number of events are small, especially when divided/sorted into different categories, types of accidents, etc.
- The number of factors influencing accidents are very large, and we can take only a few into account. For instance we know that the level of competence and training is an important factor, and it may change from time to time (say from 1970 to 1980) or from one area to another (say US Gulf to North Sea). This is a factor which is not explicit in the material presented.

An example of an in-depth study on structural reliability and residual strength is the research project "Calibration and Offshore Structural Reliability" recently under way, sponsored by 6 oil companies and Det norske Veritas. The purpose of the project is to utilize, verify and calibrate by means of "real life" experience data a new method for analysis of structural reliability of platform structures. The candidate platform selected for this study is the "Argus Island" tower operated as a neutral research facility by the U.S. Navy off Bermuda and finally demolished in 1976. This platform sustained significant distortions due to yield of brace members in several severe storms with maximum wave heights up to 70 feet, the design wave being 50 feet.

Table 2 gives some data from Veritas' data bank regarding accident with mobile offshore units (1970-1980) in different geographical areas.

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