Design criteria for drillships

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Summary: *Dayrate and downtime of a drillship are two important design criteria. Selection of a drillrig, in this case a drillship, requires an investigation before the start of a design process. Various factors are determinative for this selection procedure, although ship motions and vessel holding ability are the most serious problems to be dealt with. In advance of possible model experiments certain design comparisons will lead to a number of form factors and coefficients. A selection of environmental conditions specified in area-dependant wind, wave and current spectra together with – from a drilling point of view – combinations of operating conditions, survival conditions and transit conditions give criteria for positioning equipment, power distribution system and ship motions. A close harmony of these criteria can lead to a sophisticated design, economical and thus highly competitive.*

Introduction

From the point of view of the drilling industry a most important factor in the ex·ution of offshore work is the decision w. .er to use a drillship or a semi-submersible, jack-up or any other drillrig. This question can be answered if the oil company knows the advantages and disadvantages of above mentioned rigs. It is then that the first problem arises: the choice between a specific rig or a world-wide rig. The designer is the one who chooses either one of them. Comparison of drillships and semi-submersibles leads to a number of similarities but also to some diverging differences. Some specific figures of ships and semi-submersibles compared in January 1975 are given in table 1. Costs per annual well based on a 60:45% operationalability, are for 3 wells in percentages 100:116. For newer types of semi-subs with 70% the ratio is 1 and for 80% 115:100.

This cost comparison was the motive for a study about the design criteria for drillrigs, in this case a drillship, specially for informati on downtime and dayrate. To start with, an investigation has been made about the main characteristics of drillships. From the data of many specifically designed ships as well as from conversions it was tried to determine a design-line. From there a more economic point of view was chosen, in order to determine the effect of the downtime on the complete design.

Table 1: comparison drillships/semi-submersibles 01-1975

		drillships	semi-submersibles
lightship/displacement		0.45-0.55	0.55-0.60
variable load/displacement		0.50	0.10-0.20
lightship		100%	200%
variable load		100%	50%
building costs	conversions	DP versions	
– $ × 10⁶	18	30	34
– %		100 (total)	140 (total)
towing costs ($ per day)		—	4,000
insurance (% building costs)		3	9
dayrate $/%		22,000/100	34,000/155
flexibility knots/%		12/100	6/50
downtime (in natural periods)			
– heave sec.		7,5	22,5
– pitch sec.		8,5	34,3
– roll sec.		11,6	33,7
– in averages			
North Sea conditons (North)		55%	40%
operational in %		100	138

Main characteristics

When information is needed about several similar types of ships, it would be easy if from these ships data would be gathered in a few specific groups. In order to keep a

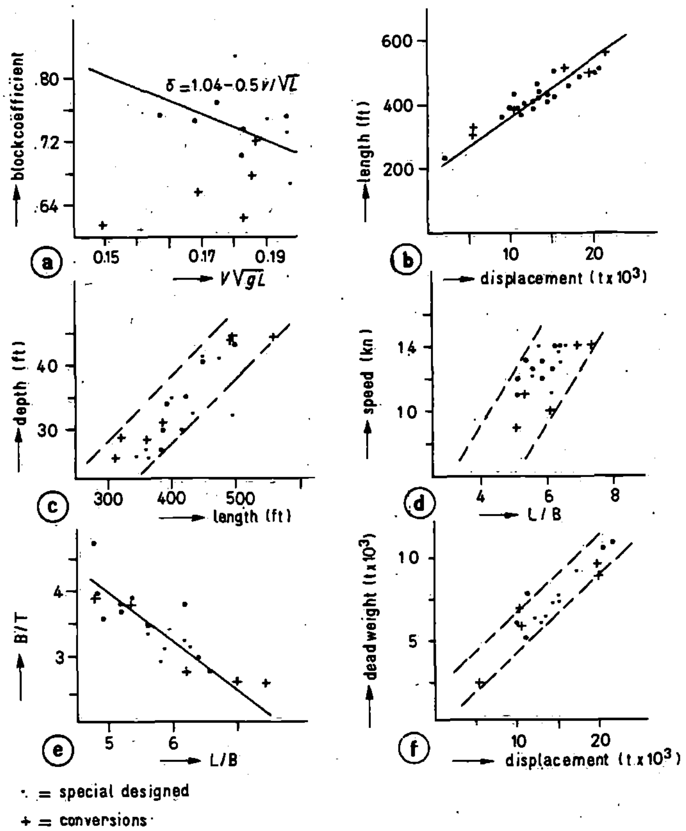
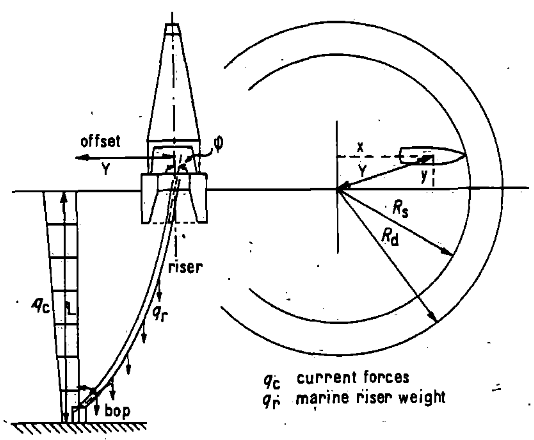


Fig 1: investigation of data: main dimensions of design

connection between the different types only three groups were formed, namely the specially designed ships, the conversions and a third group consisting of barges and others. For example ships could be divided in ships working in specific areas or 'world-wide' ships. From the start of the investigation it was felt that there had to be something like 'area dependent' designs. The validity of this feeling could only be proved after a detailed study.
For the grouping of the main characteristics is chosen:
- main dimensions
- deadweight
- stability
- anchor and/or DP-system
- propulsion
- general plan
- design criteria for operational areas.

Fig 2: offset-positioning criterion



Main dimensions
From all the possibilities only a few showed a reliable connection, other coefficients only gave a completely scattered pattern of points.
From figures 1a-1f it can be seen that not too much attention can be paid to these connections. They can only give a slight indication of the course of certain coefficients. Also no direct difference between conversions and 'special' ships can be seen. Later can be shown that the variable load is an important factor and is mainly determined by the number of wells to be drilled or the total number of days that drilling can be co[illegible]ed without re-supply. This is the self-sufficiency. When all the different loads – parts of the total deadweight – are compared the following coefficients can be determined (figures are averages):
light ship/displacement = 0.45 – 0.55
deadweight/displacement = 0.50
ballast water/displacement = 0.01 – 0.05
Subtraction of the fuel in order to compare dynamic positioned (DP) and anchored drillships gives:
fuel/deadweight = 0.24
net deadweight/displacement = 0.40.
The difference between the ratio fuel and deadweight of 'special' ships and conversions is 0.20 and 0.30 and the fuel/Δ ratio 0.12 and 0.15. It follows from all these data that the differences between the two types are not pronounced, or that even the choice for a certain composition of deadweight seems rather arbitrary!

Stability
Between the different ships a good comparison is not possible due to the lack of available data. When the ratios of metacentric radius and the breadth – which is a good criterium for the stability – are compared an average of 0.06-0.08 follows. Direct use of this value is not possible, the only thing that can be said, is that a variable GM/B value is needed in order to adjust the rolling behaviour in different loading conditions. From [1] a ratio of 0.05 maximum has to be taken when not too high accelerations for the rolling motions are wanted. As an indication for the motions of ships the natural periods can be useful. When only three motions are compared – i.e. rolling, heaving and pitching – the average values will be as follows:
$T_{0\varphi} = 11.6$ secs
$T_{0Z} = 7.5$ secs
$T_{0\Theta} = 8.5$ secs
From these natural periods a conclusion can be drawn that in areas with relative large wave periods the possibility of resonance is quite high. Again a reason to design a ship with adjustable natural periods either for rolling, heaving and/or pitching. Here a priority index might be introduced for areas where drilling for longer times is expected.

This indicates the problem mentioned in the introduction about the choice of the drilling company to drill in specific areas and the obligation for the contractor to offer this rig.

Power distribution
The distribution of ship's power is a very important part in the complete design. A number of factors determine the kind of distribution that seems most favourable for a specific condition.
From these can be mentioned the AC ve DC current system and the system of one complete power unit versus separate power units for the different consumers.

Th designer has to know exactly how the power is distributed, e.g. when there is a heavy storm and the drill pipe is stuck in the well, then a moment has come that maximum power is needed for thrusters to stay on location and maximum power to pull the pipe. That should be the right criterion for the power distribution.
The choice for the type of thrusters – nozzles, steerable thrusters (in nozzles), Voith Schneiders, bow thrusters – gives direct information in the AC or DC current system. The designer, in close co-operation with the drilling industry, meets the following criteria: the reliability of the positioning control, the power distribution in case of black-outs, weights and locations of the machinery and costs as an overruling criterion. Due to the enormous variety of installation, there is no general way of thinking. Therefore the designer has to start with the al -mentioned criteria.

Positioning systems
A division in specially designed ships and conversions shows that in the latter more use is made of dynamic positioning than in the former, 35% against 10%. The main particulars of the anchor systems are eight point moorings, anchors varying between 20,000 and 30,000 lbs. in weight and a maximum water depth of 1,000 ft. An exceptional water depth is 1,500 ft., although at this moment possibilities for 2,000 ft. are available. Compared with the dynamic stationing with thrusters the anchoring gives a few disadvantages:
– Longer handling time. Anchor handling tugs are necessary
– Positioning on wind, waves or current is possible in a lesser amount. The mooring pattern is an important criterion
– he criterion for positioning over the w ead, given in a horizontal offset as a percentage of the water depth, is fulfilled. In case of severe storms it takes longer to disconnect than with a dynamic positioned ship.

A clear advantage are the enormous fuel savings. An average consumption of 15 to 18 tons fuel per day [2], plus a net working time of 85% gives a fuel consumption per year of 4,600 ton. This would bring a net saving of $ 450,000/year, which corresponds with the rent of an anchor handling tug of approximately 40 days. These figures are only approximations based on data of early 1975.

In the foregoing, a few DP-systems were already mentioned. For the design of these systems the following criteria have to be fulfilled (see also figure 2):
– Offset criterion over wellhead. Refer e value is a maximum excursion of 5-6% of the water depth
– Positioning or heading priority for wind, waves or current. In case of storms, wind and wave forces are strongest, in normal weather, current forces can be strongest especially with beam current
– A reliable and safe control system. In a normal weather condition as well as in high waves, thruster loads have to be normal.
From [10, 11, 12] enough information was obtained for an analysis of riser motions. Investigated parameters were tensioning forces, mud weights, current forces and lower balljoint pulling forces. The net allowable offset, determined by maximum φ gives a radius R_d within which the ship has to stay.

This, together with the need for an operational ship in a specific area or areas, determines the total DP-system. For a good design complete weather information must be available. With this information, model experiments or computer simulation based on the criteria fixed by the designer can be a good help for an optimization of the positioning system. As workable water depth is still increasing, the allowable horizontal offset becomes more important. Because of the severe environmental conditions, for example 16 ft. significant waves, 50 knots sustained wind and 2 knots current, the necessary thrust is also increasing. Some information on this was derived from [7, 8].

Economic criterion
Financing of offshore drilling rigs is still a problem of 'updating' regularly. In this chapter only the basis of this financing, the dayrate, will be discussed. Nowadays drillships, but also other rigs are rented on a basis of rig performance.
This does not mean that two rigs with the same percentage downtime had the same penetration rate. These two factors have to form the basis for a rig selection. A comparison between a semi-submersible drillrig and a drillship gives a good indication why a company should want a drillship (see also table 1):
– a high flexibility, good speed, 2 : 1. If dynamic positioned lower thruster forces
– a high storage capacity
$\frac{\text{tdw}}{\Delta} = 0.50 : 0.15$
– low building costs, conversions 0.55: 1; DP rigs 0.90 : 1
– low dayrate (unless poorer performance) 0.65 : 1.
The above figures are gathered from references [3, 4] and some ship data, while the figures represent averages from a number of rigs.
The building costs are the most important part of the dayrate (approx. 64%); other contributions are:

– supply costs	9%
– towing costs (only non-selfpropelled unit)	—
– insurance costs	10%
– salaries	17%

This net sum is the amount an oil company has to pay for the rig, in other words the daily costs of the rig and its support equipment. For the calculation of the overall costs of a well, other factors are also important although their significance is smaller [21].
The drilling costs consist of:

– rent of equipment (net daily rate)	40-45%
– preparation costs	7%
– drilling installation running costs	30%
– evaluation costs	5%
– transport costs	8%
– overheads	5%

A decrease of daily drilling costs, as can be seen from given average percentages, is mainly achieved by cutting the net daily rate or rig rent. That is the main objective of this paper. An expensive rig is a rig with a high rent and a poor performance. The better the performance the lower the percentage downtime. Not only this performance, like rig motions, is essential but also the penetration rate should be a main goal.

Three major design criteria
From the preceding chapters two main criteria are adopted:
- building costs
- operational flexibility.

To begin with the second one, this criterion can be divided into two almost overlapping aims:
– operationalability
– flexibility.
The reason for this division is the more accurate determination of the possible downtime.

Operationalability
This can be explained by the behaviour of a drillship in a specific area. The behaviour of a ship can be expressed in terms of:
– ship motions
– accelerations and
– displacements.

An analysis of several ship motions results in only three critical motions: heaving, pitching and rolling. The other motions yawing, surging and swaying are of smaller significance, although for good positioning their influences are higher.

As mentioned before, under 'Stability', resonance factors can indicate excessive motions. For instance, operation in two extreme areas will lead to the following values, for long wave periods and short wave periods respectively:

	Long wave period	Short wave period
	280 m	120 m
	15 sec	8.7 sec
heave, T_{0z}/T	0.50	0.86
pitch, $T_{0\theta}/T$	0.57	0.98
roll, $T_{0\varphi}/T$	0.77	1.33

As can be seen from most response curves, resonance can be avoided when natural periods in the form of Λ are beyond $\Lambda > 1.25$ or $\Lambda < 0.75$. This is only an indication for the prevention of excessive motions.

Bases for *motion criteria* are in succession:

- heave: a mechanical criterion, determined by allowable stroke in compensator assemblies. Sometimes 20 ft., normal value is 15 ft.
- pitch: a human strength and structural criterion, determined by accelerations (see further), derrick structure
- roll.

The rolling motion, in a lesser extent the pitching motion, determines the moonpool dimensions. Rolling of the ship added to pipe deviation by offset gives stresses in riser and drillpipe. Because rolling is a dynamic process, bending stresses can cause fatigue.

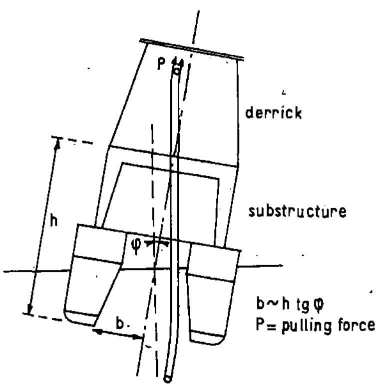


Fig 3: pipe stresses due to rolling motions (rotary table)

From [14-16] information was obtained to calculate these stresses. Well depth 20,000 ft. – 15,000 ft. (5'' pipe), 5,000 ft. (3½'' pipe), Vallourec S135 steel.

φ_{max} (proportional to bending stresses) = = 5.2°

φ_{max} (10,000 ft. well) = 9.6°

Pipe stresses at rotary table (figure 3), a sum of axial stresses plus bending stresses, are proportional to:

- bending stress
  - due to offset $\sigma_O : Y, \sqrt{P}, L^{-1}$
  - due to roll $\sigma_R : Y, \sqrt{P}$
- normal stress $\sigma_N : P$

Subtraction of static heel angles gives maximum allowable roll amplitudes.

The *acceleration criteria* are:

- vertical accelerations: pitch plus heave motions. The acceptable level is determined by a human criterion the seasickness. Especially with accommodations in foreships this can be the major reason why drilling has to be stopped.

Various attempts have been made to determine human behaviour [13], giving an upper limit of 0.15 m/sec.[2] with the expression:
$\ddot{\Theta}X + \ddot{Z} = \ddot{Z}(X) < 0.15$
as vertical acceleration, midships, station X, values can be calculated for maximum pitch and heave amplitudes. Because drilling must continue as long as possible, the vertical accelerations at the substructure drilling floor have to be as small as possible:
$\ddot{\varphi}y + \ddot{Z} = \ddot{Z}(y) < 0.15$
as vertical acceleration, half length, Y from midships.

- horizontal accelerations: roll motion:
$\ddot{\varphi}Z = \ddot{\varphi}(Z) < 0.15$

With these three expressions, values can be found for maximum permissible roll, pitch and heave motions, referring to maximum acceleration at certain critical points: accommodation and drillfloor.

The *displacement criteria* are mainly determined by horizontal offsets of the drillship. This corresponds with an offset of the marine riser top connection. As already mentioned, an analysis was made about the influences on riser deflections and stresses. Depending on the riser dimensions, important factors are:

factor	variation
– water depth	600 – 3,000 ft.
– current forces; distribution and forces	1 – 2 knots
– axial forces in tensioning system	1.0 – 1.4 times total weight
– mud weights	1 – 2 t/m³

The bottom riser balljoint rotation forms a main criterion. Although deflexions in the lower balljoint of 10° are sometimes possible, an average of about 4-6° should be taken in order to avoid too high bending stresses in balljoint – BOP connection. Optimization of the riser dimensions leads to an offset criterion, in its turn being the criterion for the positioning system. In literature the often used criterion of 6% of waterdepth L is found to be quite high. Without waveloads on riser and ship but with a 2 knots surface current a 33 inch riser in 2,000 ft. water (buoyant riser) gives a maximum offset of 4.5% L. Exact calculation of allowable bottom deflexions and riser dimensions gives the designer the criteria for possible riser offsets. Areas as well as tensioning systems need careful consideration because of their direct influence on riser stresses and deflections (figures 4-6).

Other criteria for an operational drillship are more or less mechanisms. Some are worth mentioning:

- casing handling system
- pipehandling system
- deck cranes
- motion compensator
- BOP handling system.

Flexibility

In close connection with the operationalability, the flexibility gives the oil company the possibility to go wherever it wants to drill at any time it wants. Although this may not be quite true, it is not far beside the truth. Because the existence of many semi-submersibles designed for specific areas, like the North Sea, there is hardly any drillship that can compete with these semi-subs. Hence the criterion for a drillship of an insensitiveness for different external influences. Criteria for this flexibility are ascertained with the downtime percentage as reference. Two main criteria are distinguished:

- positioning system
- power distribution.

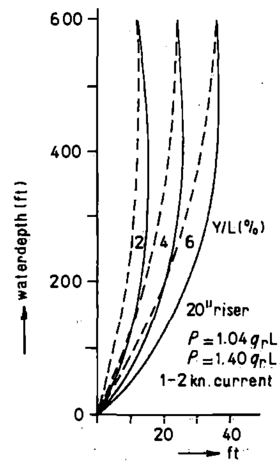


Fig 4: riser deflections

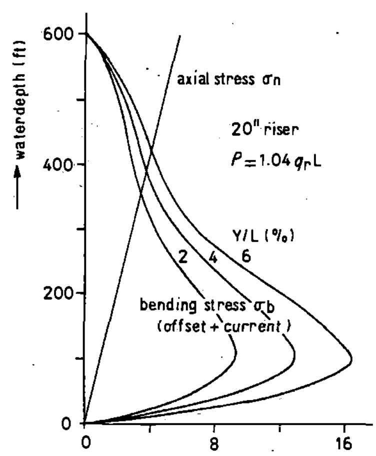


Fig 5: riser stresses (ksi)

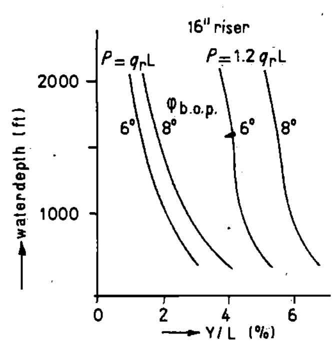


Fig 6: riser deflections for different depths

A good positioning system enables a drillship to start with drilling activity almost directly. The necessary thrust and power is determined by the criterion of maximum offset. This gives a radius of a circle within which the ship has to stay by means of the thrusters. Only a precise calculation of external and internal forces can lead to a reliable system.

A good power distribution is necessary for a drillship with a good efficiency. DP drillships with a great self-sufficiency carry a large amount of fuel. One of the latest drillships on order carries 6,600 tons of fuel [17]. It goes without saying that with many possible loadings in the different drilling operations the efficiency must be kept high. In the building costs almost 40-45% of the total costs can be invested in the machinery and thruster equipment. That is the reason why, with regard to the high fuel consumption, the composition of diesel engines, thyristors etc. needs careful consideration.

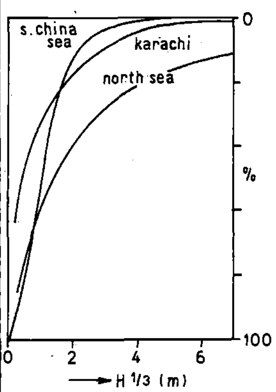


Fig 7: frequency distributions of waves in different areas

This flexibility leads to a number of extra requirements, to be considered as criteria when a decrease of downtime is a main objective. These so-called environmental conditions are:
- choice of area
- oceanographic conditions
- operating conditions.

Environmental conditions
Right now, as already mentioned in the introduction, comes the influence of the designer to design a drillship for specific areas or for every possible area. In view of a most economic shipsize, a ship for a world-wide flexibility might be too expensive due to the very diverging criteria.

Choice of the area
When a world-wide operation of a drillship is criterion the best approximation for a good behaviour is one area with short waves, short periods and an area with long waves and long periods. Two extremes might be the North Sea and somewhere off Nigeria.
From every possible area frequency distributions must be available of wind and waves; current data must also be available. Some influence factors must be mentioned:
- seasonal influence
- basis of frequency distributions (based on wave heights or periods or both)
- directional influence.

Good data are available in [18]. Elaborations of some data are given in figure 7. It is clear that, when frequency of occurrences are compared, differences might occur when different areas are compared (see figure 7).
Other criteria are:
- waterdepth
- drilling depth.

Both factors are area-dependent and they influence the positioning system as well as the carrying capacity. A high self-sufficiency for several areas indicates a variable deadweight composition.

Oceanographic and operating conditions
From summaries of drilling programs it is clear that certain operations take more time than others. If several ship performance data are gathered a time distribution might look like:

Operation	*% of time*
Direct productive	
– drilling	27.5
– tripping	14.0
– casing running	6.0
– BOP handling	10.0
– fishing, logging, cementing, testing, reaming	28.0
total direct productive	85.5
Downtime	
– moving, mooring	5.5
– waiting on weather	3.0
– repair etc.	6.0
total downtime	14.5
total direct productive	85.5
total	100.0

This time distribution of operations is reliable for areas with average conditions like the Mediterranean.
Some operations ask more accuracy than others, for instance with BOP handling the heave motion gives restrictions to handling operations. This is the reason that also different oceanographic criteria are set for different conditions. Current groups are drilling (1), tripping (2) and casing running plus BOP handling (3). All three are *operating conditions*. Beside this group a *transit condition* (4) and a *survival condition* (5) must be introduced.

If for instance only *moderate areas* are selected good criteria would be:

Operation	*Significant wave height* (ft)	*Wind speed* (kn)
1	15	45
2	10	25
3	8	20
4	–	–
5	37.6	100

Sometimes wave periods can be given too as design criteria. In many cases this period dependency is evaluated in the part of motion calculations.
A prediction of operating hours per year is possible in sequence of:
a motion calculations
b introduction of right criteria for right conditions
c prediction of exceedances of oceanographic conditions
d prediction of operating distributions
e multiplication of *c* and *d* gives percentage downtime.

Developing the criteria for the different operating conditions in view of the acceptable motions, is an effective tool in the design process. If the ship motions can be eliminated as a disturbing element in the drilling and operating cycle, prices can be lower and thus compatibility higher.

Ship motions
The main reason to stop drilling operations is determined by a number of factors. The first reason is the external disturbance characterized by seastate in a general sense. In spite of the figure of 3% downtime as given in the chapter on oceanographic conditions, in some cases, like at the North Sea with very high seastates north of latitude 62, downtime percentage as high as 30 to 55% can be expected (see introduction). That is the reason that motion characteristics must be improved to obtain a world-wide operationalability.
Motion criteria were calculated and some data were taken from [4, 6, 19] resulting in a reliable set of key figures for current design purposes, although in some cases though investigations would be necessary.

Motion criteria (max. amplitudes)

operation	heave (ft)	pitch (deg)	roll (deg)
drilling	7.5	5.0	7.5
tripping	8.5	6.0	7.5
casing running	5.0	4.5	7.0
BOP handling	3.5	3.0	—

Roll criteria were determined for some specific water depths and well depths. Crite-

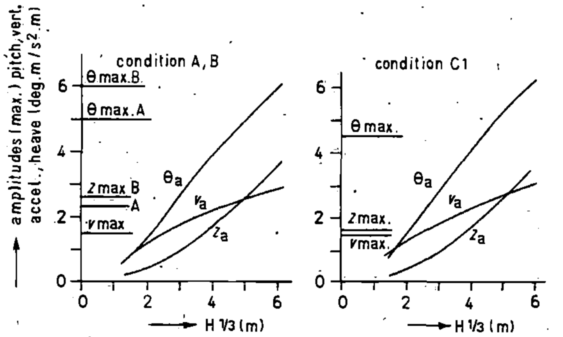


Fig 8: motion characteristics and criteria for different conditions

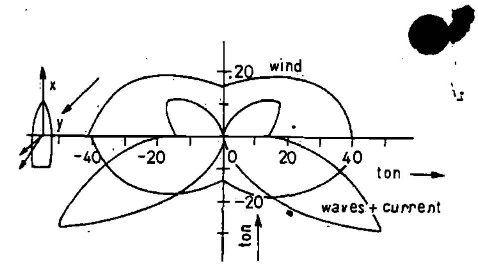


Fig 9: drifting forces for 'Pelican'

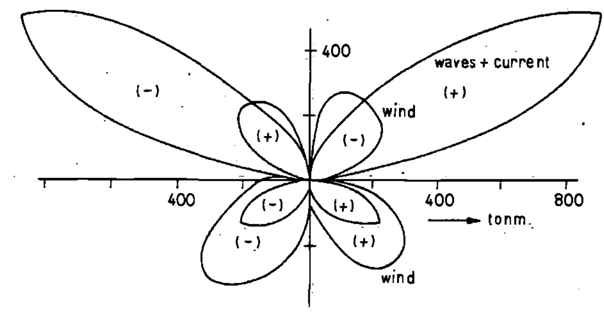


Fig 10: drifting moments for 'Pelican'

ria were based on pipe stresses at rotary table.
The mentioned acceleration criterion is based on theoretical investigations. An acceptable level of 30% seasickness corresponds with 1.50 m/sec². A good crew might endure a higher acceleration when this is only for a short time. That is the reason that in some circumstances higher accelerations can be tolerated.
At this point main dimensions must be chosen in such a way that an economic shipsize will follow. Two factors, the deadweight and minimum motions, are determinative. From several studies results were obtained about the influence of main dimensions and form factors on ship motions. In general the following influences can be taken into account:
- decreasing motions with increasing length: lower downtime versus higher building costs
- decreasing motions with increasing Cb.: highest influence on vertical acceleration for $\lambda/L>1$
- decreasing motions with V-frames in forward sections especially for $\lambda/L>1$. More influence on heave and vertical accelerations than on pitch.

If drilling in two areas with different wave lengths is required, variations in kyy-longitudinal radius of gyration, and L/T length-draught ratio may alter the motion behaviour. A right choice between these factors must lead to an optimized design. If amplitudes or accelerations are the main motion criteria, the accompanying measurements can be taken.
Based on the criterion of a maximum operational ship, ship motions have to be calculated for the following critical conditions, (for example):

Operating conditions

	drilling*	casing running**
casing	30" cemented	hook load with 7" casing
riser	all set	all set
drillpipe	drilling 26"	inpipe racks
BOP	all set	all set
liquid mud	s.g. 1.2	s.g. = 2.0
tanks	full 98%	8%

Notes
A variety of conditions can be distinguished. These four were chosen:
A: the beginning of drilling with a full load.
B: tripping at an arbitrary time*.
C1: casing running with the maximum hook load and rest load.
C2: BOP running just before drilling or just after casing running**.
Results of these calculations are given in figure 8. Applying these data the comparison of maximum heave, pitch and vertical acceleration amplitudes gives a direct indication that the acceleration criterion is most severe. In practice a solution between accelerations (because of workability by crew) and heaving (because of drilling difficulties with bit weight adjustment) is agreeable.
The downtime percentage calculated from occurrences of wave data (see fig 17) and performance data (fig 8).

* For ease of calculations tripping figures chosen the same as drilling
** For ease of calculations BOP running chosen the same as transit condition

Condition A

	maximum amplitude	$H_{\frac{1}{3}}$	exceedance (%)	conditions (%)	downtime (%)
heave	2.3 m	4.6 m	1.1	27.5	0.3
pitch	5.0°	5.0	0.6	27.5	0.2
vert. acc	$1.5\ \frac{m}{s^2}$	2.5	10.5	27.5	2.9

Total downtime percentage (Mediterranean)

wave height	%	downtime
$2.5 < H_{\frac{1}{3}} < 4.6$	9.4	2.9%
$4.6 < H_{\frac{1}{3}} < 5.0$	0.5	3.2%
$5.0 < H_{\frac{1}{3}}$	0.6	3.4%

In this total downtime no contribution of rolling was inserted. Originating form a good positioning system – heading on wind and/or waves, in storm conditions the same directions – rolling motions will be small. The maximum allowable motions will not be exceeded.

Holding ability and power distribution
The flexibility criterion determines that no time shall be lost in positioning over the well-head. In deep water with variable external forces dynamic positioning must ensure this. Within the calculations of these forces some problems are encountered. The dynamical behaviour of surge and sway motions and of thruster forces allows excursions from the well-head within a dynamic radius R_d, see figure 2. This corresponds to the offset criterion Y_{max} (% waterdepth). The calculable static radius R_s – resulting from wind, wave and current forces – enlarged with an extra allowance for non-compensative high frequent wave forces gives R_s. The resulting power distribu-

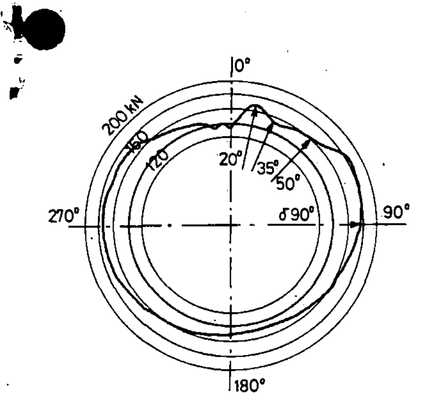


Fig 11: variations in thruster/hull interaction for 'Wimpey Sealab'

tion should be rejected to the various design operating conditions. Various combinations are possible. The following three conditions can be regarded as most critical:

condition	positioning	drilling
1 operating maximum	100% load	100% load
2 operating normal	50% load	100% load
3 transit	propulsion power	

From efficiency point of view the highest operationalability is required in condition 1. Calculation of thruster forces as a first estimation begins with the determination of criteria for wind, waves and current forces. In condition 1 the different forces should be calculated for:

- positioning on wind and waves. Direction $0 \pm 30°$ off bow
- beam current
- 30% extra allowance.

Figures 9 and 10 [8] are illustrative for the ab -mentioned criteria. As long as wave heading stays below 60°, wave forces are not too large to counteract with thruster forces and wind forces are dominant.

Three influences must be dealt with, one of which has already been mentioned. The first one is the interaction effect between thruster and hull. Tunnels generate a longitudinal force, if flow direction is not parallel to ship centreline. Losses of about 15% are possible. The second coefficient is introduced if rotatable thrusters are used. Rotation and therefore variation in flow direction gives variation in thruster forces in axial and lateral directions. An example is given in figure 11. For a 2 knots current a 10% decrease of thruster force is possible.

The third factor is an empirically determined coefficient. Weather forecasting should give exact information about the normal weather conditions. As the control system possesses a certain inertia and the ship re , as an inertia system too, installation of extra thruster forces is necessary to bring the ship back to the circle with radius R_d after excursion to radius R_s.

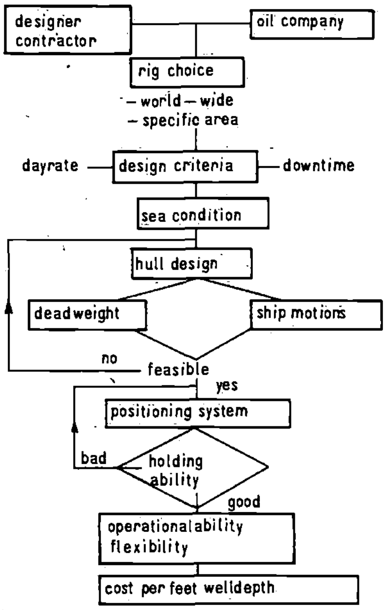


Fig 12: a possible design scheme for a drillship

A net increase of about 25% is needed although some designers installed about 50%. This latter figure can also be the result of the product of three coefficients:

$$\text{thrust}_d = \text{thrust}_s \cdot 1.15 \cdot 1.10 \cdot 1.25 = 1.60\, T_s \text{ (ton)}$$

Only an extensive model simulation with variation in wind, wave and current directions and heading priorities can give enough information for a good design.

Calculations for high operating conditions do not exclude the requirement for good thrust per horse power at normal loads. These normal loads, sometimes far under 50% over longer periods of time, demand a high flexibility of thrusters and power generators.

Conclusions

To an offshore contractor as well as to an oil company evaluation of rig costs is an important part in rig selection. Designs of such drillrigs, in this case a drillship, must therefore be reflecting the user's requirements. Prediction of ship motions and vessel's holding ability may add valuable information to this design process. Of course many other mechanical systems can give downtime too; for instance, the complete BOP handling system is a highly automatized but sensitive equipment. For economical shipsize days of self efficiency or deadweight capacity following from the number of wells to be drilled are other determinative factors too. With motion studies on one hand and form coefficients on the other criteria for main dimensions will result. A critical analysis of weather conditions, operating conditions and prospective area is necessary and may lead to a proper design with cost savings as result. This idea is realized in a scheme, fig 12.

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References

[1] BRÜHL: Zweckmässige obere Stabilitätsgrenzen für gutes Seeverhalten WRH 20, 1939 p 325, 341
[2] VASSEUR, B. J. M.: Four years of experience with DP drillships. Schip en Werf no. 23, 1975 p 467
[3] SEYMOUR, D. J., MC CANDELL, C. R.: Floating type offshore drilling vessels Marine Technology, October 1967.
[4] TURRENTINE, R. E.: Analysis of Drilling Ship Performance OTC paper 1973, p 315
[5] BROWN, N. A., NORTON, J. A.: Thruster design for acoustic positioning systems, Marine Technology, April 1975, p 122
[6] HAMMETT, D. S.: Sedco 445 – Dynamic Stationed Drillship OTC paper no. 1626, Houston, May 1972
[7] SJOUKE, J., LAGERS, G.: Development of Dynamic Postioning for IHC Drillship. OTC paper no. 1498, 1971, p 797
[8] BRINK VAN DEN, A. W., BRUG, J. B., TON, C.: Automatic Positioning and Heading Control of a Drilling Vessel. Paper TNO-IWECO Delft September 1972
[9] GRAHAM, J. R., JONES, K. M., KNORR, G. D., DIXON, T. F.: Design and Construction of the Dynamically Positioned Glomar Challenger. Marine Technology, vol. 7, no. 2, April 1970
[10] FISHER, W., LUDWIG, L.: Design of a floating vessel drilling riser. Journal of Petroleum Technology, March 1972, p 272
[11] BURKE, B. G.: An analysis of marine risers, OTC 1973, p 449
[12] ILFREY, W. T.: Use of float modules to supplement mechanical tensioning of marine risers. OTC paper 1769, 1973
[13] NIEUWENHUYSEN, J. H.: Experimental investigations on seasickness. Discussions Utrecht 1958.
[14] HANSFORD, J. E., LUBINSKI, A.: Maximum Permissible Horizontal Motions of a floating drilling vessel. OTC paper no. 1076, 1969, p 67.
[15] HANSFORD, J. E., LUBINSKI A.: Effects of drilling vessel pitch or roll on kelly and drillpipe fatigue. Petroleum Transactions Jan. 1964, p 77
[16] LIND, E. R.: How to evaluate pipe stresses when drilling from a floating vessel. World Oil, June 1961, p 95
[17] — Neddrill will convert two bulk carriers to drillships. Ocean Industry October 1975, p 45
[18] HOGBEN, N., LUMB F. E.: Ocean wave statistics HMSO
[19] CHEVALLIER, J.: Wave induced motions of floating rigs. Petroleum Engineer, May 1975, p 52
[20] WISE, D. A., ENGLISH, J. W.: Tank and windtunnel tests for a drillship with Dynamic Positioning Control. OTC paper 2345, 1975, p 103
[21] JENKINS, P. B., CROCKFORD, A. L.: Drilling costs Offshore Engineer Spring Meeting SPE, Dec. 1975

Enkele indrukken van de Achema '76

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De Achema '76 (van 20-26 juni) deed haar naam 'grootste tentoonstelling ter wereld voor de uitrusting voor de chemische en procesindustrie', alle eer aan. Het aantal exposanten was 2278, afkomstig uit 27 landen; er waren slechts 717 buitenlandse deelnemers. Het aantal nederlandse deelnemers bedroeg 47.
De totale netto standruimte bedroeg 102 000 m^2. De organisatie was uitstekend en de Dechema-persdienst verstrekte uitvoerige, goed gefundeerde informatie aan de vakpers. De Achema vormt een belangrijke economische impuls voor West-Duitsland. Dit blijkt niet alleen uit de grote belangstelling van de overheid: uit de ontwikkelingslanden werden wederom vooraanstaande personen (zonodig met vergoeding van reis- en verblijfkosten) uitgenodigd, zoals o.a. uit Egypte, Afghanistan, Kameroen, Irak, Libanon, Marokko, Nigeria, Pakistan, India, Zambia e.a. Ook waren verschillende officiële delegaties uit het Oostblok aanwezig, alsmede zeer veel bezoekers uit het industrieland Japan die zich zeer actief op de hoogte stelden van de stand van de techniek.

Aandacht voor de economische achtergrond t.a.v. het milieu bleek uit de uitgave van een afzonderlijke catalogus over het onderwerp milieubeheer en -bescherming (met 500 deelnemers en 5000 produkten) terwijl daarnaast een grote serie voordrachten (63 in aantal, w.o. onderwerpen als 'Abgas, Abwasser, Abfall' en recycling) werd gehouden. Een ander voorbeeld hiervan was de hoofdvoordracht van Dr. K. L. Schmid over Technologie Transfer, waarbij uitsluitend uitgegaan werd van economisch-technische motieven, uiteraard met aandacht voor de cultuur en de sociale omstandigheden in de ontvangende landen. Een uitvoerige studie in samenwerking met het ontvangende land is nodig, terwijl tijdig moet worden voorzien in de scholing van de nodige mankracht. Bij een discussie over dit onderwerp met de pers zat in het forum (fig 1) ook een vertegenwoordiger van Nigeria en een van Kameroen. De afgevaardigde uit Nigeria merkte o.m. op dat een proces-technologie die voor een industrieland niet meer optimaal is, voor een ontwikkelingsland nog steeds waardevol kan zijn.

Fig 1: het internationale forum bij de persconferentie over 'Technologie Transfer'

Tijdens de Achema werd een internationaal colloquium gehouden over het voorkomen van bedrijfsongevallen en over beroepsziekten.
Door prof. D. F. Othmer (USA) werd een voordracht gehouden over vloeibare brandstof uit vaste stof. De enige Fischer-Tropsinstallatie, uitgaande van kolen die vergast worden en dan door synthese weer omgezet in vloeibare produkten is in Zuid-Afrika in werking. Indien op korte termijn zou moeten worden overgeschakeld op olie uit 'shale' (leisteenformaties) en asfaltzand, waarvan de voorraden zeer groot zijn, zou dit een zodanig groot aantal ingenieur-manjaren eisen, dat voor andere nieuwe investeringen onvoldoende mankracht over zou blijven.
Door fabrikanten werden enkele honderden *informatie*-voordrachten gehouden: in een aantal gevallen bleef het bij een oppervlakkige informatie zonder een meer fundamentele ondergrond. Vooral gezien de betekenis van de hoofdvoordrachten, zou het misschien te overwegen zijn deze te houden voorafgaande aan de Achema. Hierdoor zou ongetwijfeld het aantal toehoorders worden vergroot.
Zoals gebruikelijk werd door de Achema aan de Max Buchner-Stichting ruim één miljoen DM overgedragen voor researchbeurzen; ook hiermee wordt de duitse industrie indirect gesteund.
Het bezoek aan de tentoonstelling was – ondanks de hoge temperatuur – overweldigend; daarbij viel het grote aantal jonge mensen op. Voor studenten organiseert de Achema per groep 2 studiedagen, waarbij 's morgens deskundige voorlichting over het tentoongestelde wordt gegeven en de middagen beschikbaar zijn voor eigen studie. De follow-up staat hierbij op de voorgrond. Een duitse fabrikant merkte op: 'Dit zijn mijn potentiële toekomstige afnemers en ik neem dan ook gaarne de moeite aan deze studenten een technische uiteenzetting te geven'.
Vanuit Nederland was een groep studenten (in chemical engineering) van de groningse universiteit afgevaardigd, onder leiding van prof. Gerretsen.
De uit de jaren vijftig daterende stelling van de Dechema dat het tentoongestelde ter *discussie* staat, doet ook thans nog opgeld en volkomen terecht. De economische impuls is hieraan gekoppeld.

Kunststoffen in opmars
Als algemene indruk van de omvangrijke hoeveelheid tentoongestelde apparatuur kan vastgesteld worden dat zowel presentatie als afwerking goed mochten worden genoemd. De toepassing van *plastics*, ook van glasvezelversterkte plastics, komt nog steeds meer naar voren. Von Roll toonde een type Saunder-afsluiter met een ingegoten polytetrafluoretheen (PTFE)-voering drie tot vier mm dik. De grotere afsluiters (boven NW 50) hebben een gesinterde voering van PTFE. Polyvinylideenfluoride (PVDG)