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DYNAMIC POSITIONING CONFERENCE

RELIABILITY

Quantification of the Frequency of an Unsuccessful Disconnection because of a DP Problem.

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1. Introduction

DP drilling is on the increase and all clients are very interested in the reliability of the DP rig's DP system. The drilling contractor is very interested in the DP rig's overall availability particularly if their is any clause in his contract that puts his rig off hire when all the DP equipment is not working. For most of the time these questions are a matter of opinion and the weather. This debate ceases as soon as the rig has to stop work and prepare to disconnect (Yellow alert) or has to emergency disconnect (Red alert). A new debate will then begin depending on whether the disconnection was successful or unsuccessful, necessary or unnecessary.

Studies to calculate the probability of an emergency disconnect in the past have always searched for DP incident data and found the DPVOA or IMCA data to be the only major source. The frequencies derived from this data are also very high. This has forced the Safety and Project engineers to reconsider whether the data is relevant to DP drilling or whether sound argument is possible to reduce the frequency of position loss. This paper puts forward a method which enables all the IMCA DP incident data to be used to provide answers that are relevant not only to drilling but also to water depth and weather.

2. Types of Position Loss

The two most commonly quoted types of position loss are the drive off and the drift off. The drive off is characterised by the thrusters going to high unwanted thrust usually because the DP control system believes the position is wrong.

A drift off is also relatively easy to visualise because it is the result of having insufficient power or thrust. The problem with the drift off is the range of velocities it covers. Total loss of main power (blackout) in high seas and strong currents being the worst case.
A drift off where there is nearly enough power and/or thrust is still a drift off but this is not an adequate description if there is a natural recovery.

The same argument also applies to a drive off (this is very important for the risk analysis). A drive off that is transitory such that the system recovers and returns to the original wanted position cannot be treated the same as a drive off that is heading for the horizon.

It was these arguments that created a third type of position loss namely the large excursion. The large excursion is an excursion that takes the DP vessel beyond its

normal excursion characterised by the footprint. A footprint is the outline of the vessels movement in a particular sea state.
This is a function of the:

- control system
- the position references
- the thruster respond times
- environmental conditions

Thus if the rig is moving ± 5m in certain weather conditions and suddenly moves to +10m this is a loss of position and the type of position loss is a large excursion.
If the vessel is next to a platform the 10m could be a large relative to the clearance. If it is drilling in 1000m then of course the extra 5m means very little.

It is here that the DP incident data base has to be treated with caution when used for the assessment of the frequency of an emergency disconnection on a deep water DP drilling rig.

3. Outline of Method

3.1 Footprint

The first step is to quantify the DP footprint for all the operational sea conditions in which the rig plans to remain connected. There are several ways this can be done:

i. from model tests
ii. from a mathematical model
iii. from actual data
iv. by an informed guess

Generally the footprint can be plotted against wave height unless the sea area is subjected to sudden changes of wind and current forces.

When the DP system is well set up and the position references are working well and the thrusters are as the DP control system expects the footprint for a semi submersible is close to that shown in table 1 below. If the above assumptions are not correct this footprint can double or if a "relaxed" mode is employed in good weather the footprint might be ± 10m for all these wave heights.

WAVE HEIGHT Hs m	FOOTPRINT m
0 - 1	± 2.0
1 - 2	± 2.0
2 - 3	± 2.0
3 - 4	± 3.0
4 - 5	± 4.0
5 - 6	± 5.5
6 - 7	± 7.0
7 - 8	± 8.5
8 - 9	± 9.5

Table 1 : Relation between wave height and normal excursion

The nature of the distribution has to be decided and generally a normal distribution is adequate together with the values representing a 68.3% probability.

The next step is to determine the probability of occurrence for each of the wave heights. This can be obtained from the meteoro logical data for the location in question and the table below shows the probabilities that may be assigned. However in some locations an allowance for swell may also be necessary either combined with the wave heights or as a separated variable independent of the wind waves.

Hs m	PROBABILITY OF OCCURRENCE	FOOTPRINT m
0 - 1	0.1	± 2.0
1 - 2	0.3	± 2.0
2 - 3	0.2	± 2.0
3 - 4	0.2	± 3.0
4 - 5	0.1	± 4.0
5 - 6	0.05	± 5.5
6 - 7	0.02	± 7.0
7 - 8	0.01	± 8.5
8 - 9	0.01	± 9.5

Table 2 : Footprint excursion probabilities

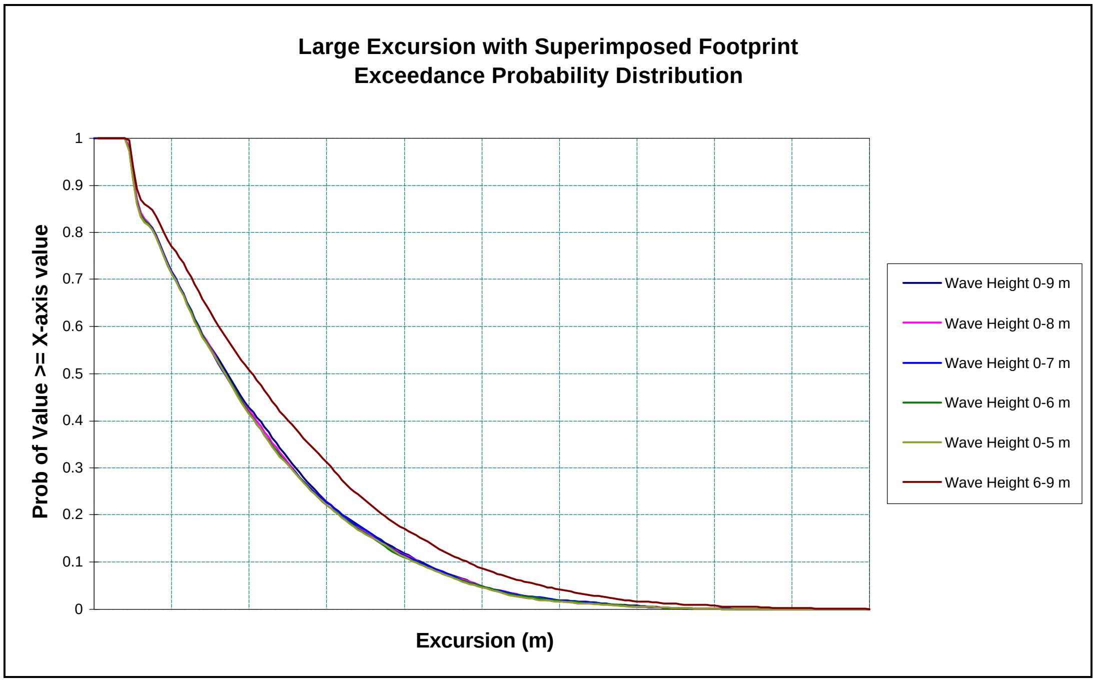
Now if the rig is always drilling in deep water perhaps it is reasonable to ignore the footprint but if the study is to cover all reasonable water depths and drilling is to be 364.7 days per year the footprint should be included.

So for all these weather conditions we have the rig moving about the optimum position. Of course the optimum position depends on the current profile and the riser and perhaps one should add an error factor for the rig not being in the best position for riser angle or slip joint. To this movement we must add the effects of a loss of position.

3.2 Large Excursion

For a first pass at a risk analysis for a drilling rig in deep water this type of position loss, like the footprint, could be ignored. However a large excursion represents perhaps a third of all DP incidents and if the disturbance occurs at the same time as a normal excursion in marginal conditions the effect can be an emergency disconnection.

We have looked at the incident data and simulated typical causes of this type of position loss and characterised their probability of exceedance for various wave heights and superimposed the footprint.



Graph 1 : Large excursion with superimposed footprint exceedance probability distribution (disturbance of DP control system)

The procedure involves the generation of an adequately large number of random values of the large excursion and the footprint according to their distributions thus enabling the creation of a record of the total excursion (absolute value).

The results show that for water depths greater than 500m a large excursion, even in rough conditions should not be a problem provided the operator does not over react and

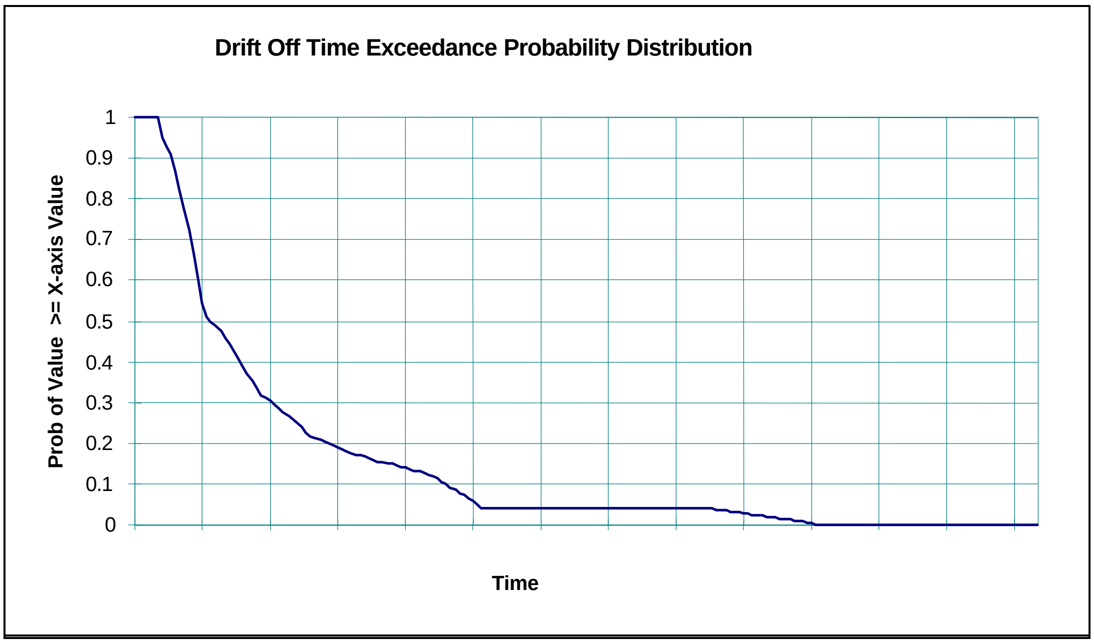
i. the rig is at the optimum position,
ii. the DP control system is well tuned and on the optimum settings and
iii. the position references and thrusters are performing correctly.

3.3 Drift Off

Drift off can take place from a number of causes but generally they can be grouped as follows:-

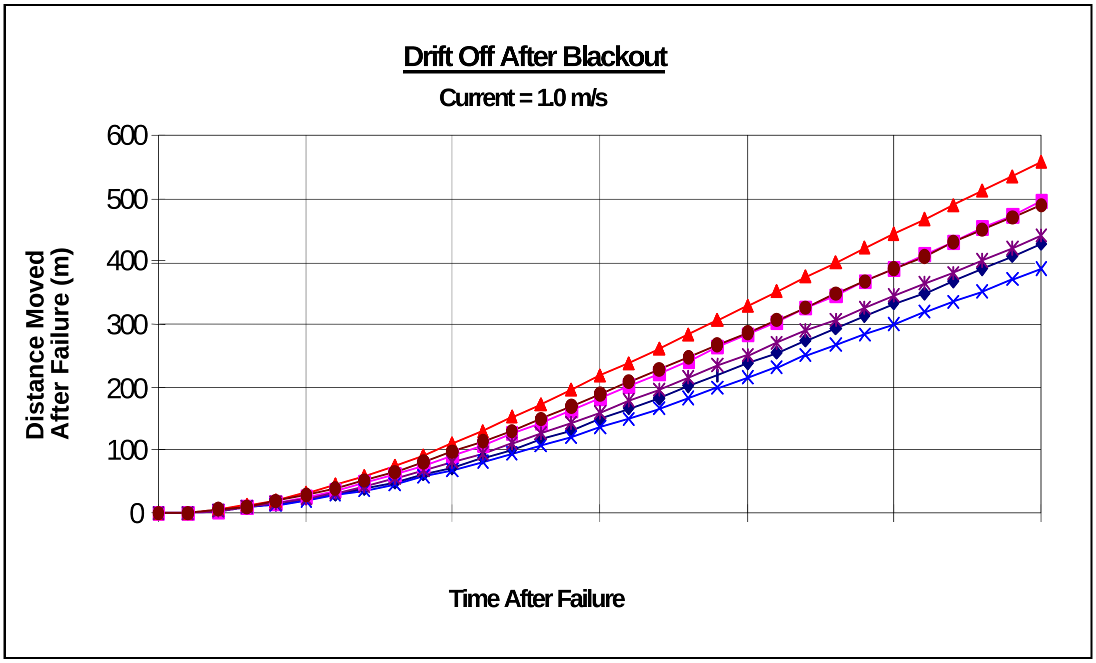
- Blackout (no thruster power)
- Partial blackout (insufficient thrust)
- Incorrect or no thrust commands.

The time to make a blackout recovery is of course critical for a deep water drilling unit. From the DP incident data base we have constructed a curve showing the probability of exceeding various times. It shows that recovery in under a couple of minutes is not possible and that in the worst case it can take an hour. These are of course general and derived from historical data when in some cases there was perhaps not the same urgency as there might have been on a drilling unit.



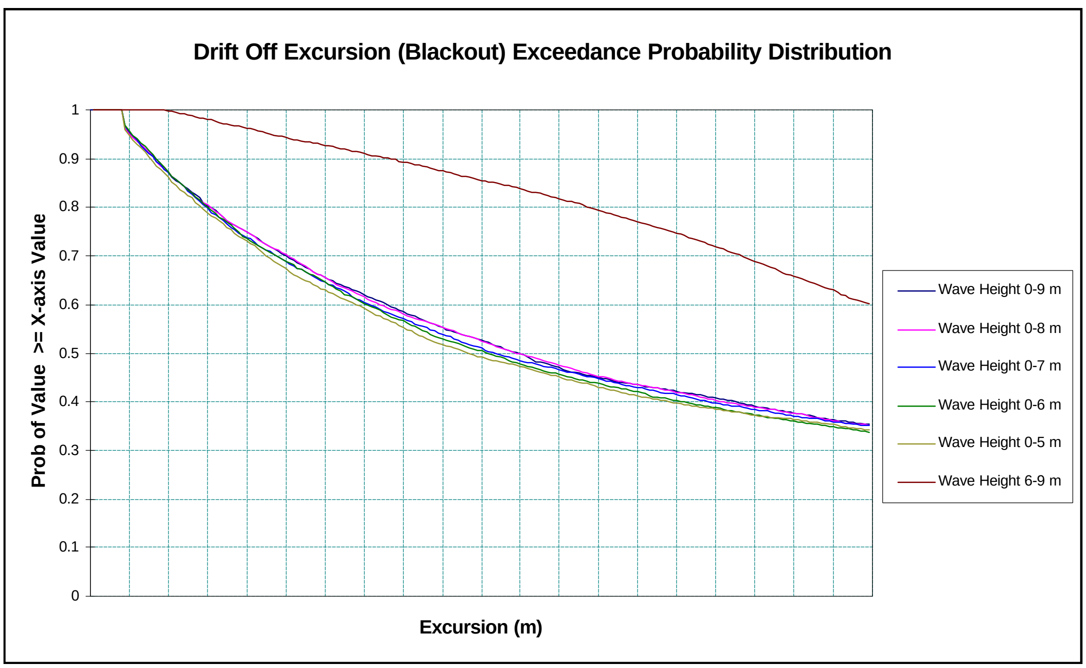
Graph 2 Drift off Time Exceedance Probability Distribution

For any particular rig a representative graph can be constructed particularly if there is an automatic blackout recovery facility that should work say 9 times out of ten. Using this graph and our model of the vessel (or drift off curves like the ones shown below) the drift off excursion as a function of the drift time can be calculated.



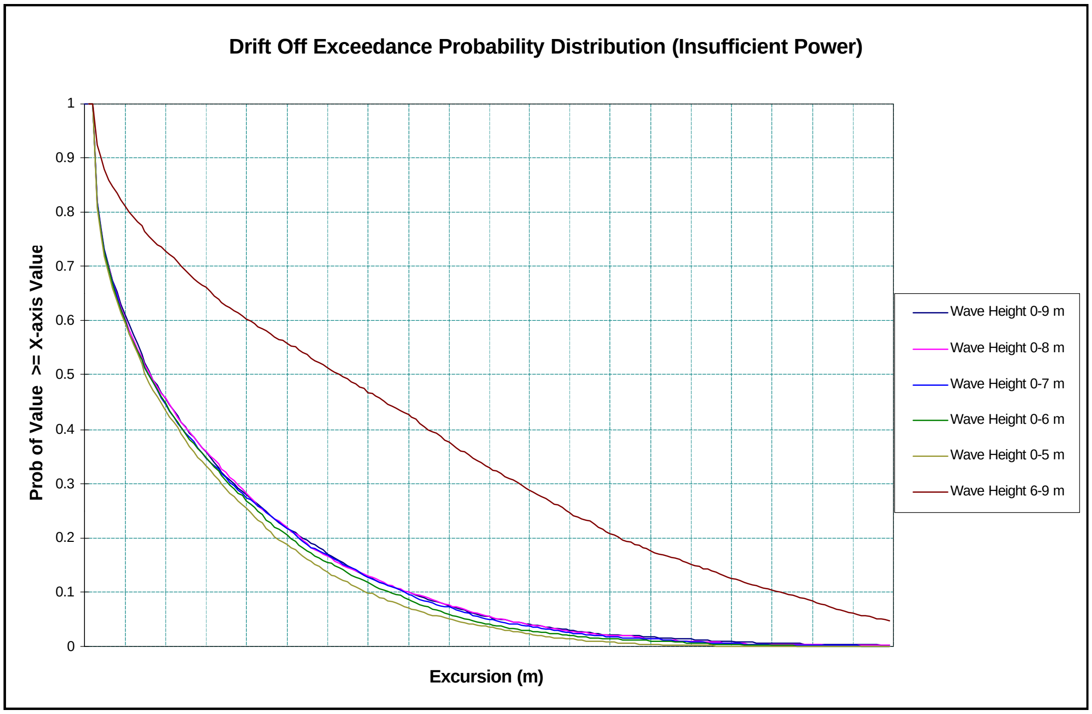
Graph 3 Typical Drift Off Curves

A sufficiently large record of drift off excursions may be created by using randomly generated drift off times and wave heights according to the location working weather conditions. This record is then analysed statistically to obtain the drift off exceedance curve. The curve below shows that based on graph 2 blackout is critical but that the influence of working in higher sea states is small overall but significant once actually connected in bad weather.



Graph 4 Drift off Exceedance Probability Distribution due to Blackout

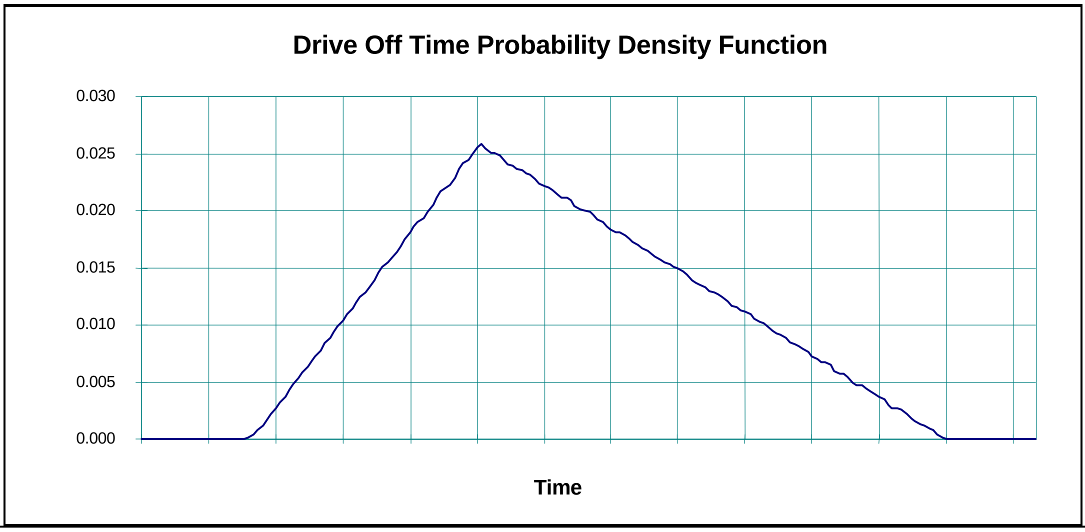
For drift off incidents where some power and thrust remains the recovery time is generally short, similarly if the DP system has stopped giving thrust commands the system can be rectified quite quickly in comparison to the time for the riser to reach a critical angle when drilling in deep water. To cover these situations we have taken a distribution of recovery times between 1 and 10 minutes and a distribution of drift off distances that correspond to these times for the working weather conditions. This provides an insufficient power drift off exceedance curve as shown below.



Graph 5 : Drift off exceedance probability distribution due to insufficient power

3.3 Drive off

There are no historic records to establish the time for drive off and recovery and the opinions' of operators vary from a few seconds to over a minute. The problem with this type of data is that operators begin counting, if at all, from the time they first notice the problem which is not the same as the total drive off time. We have taken more than one type of distribution to model drive off time but we generally assume that it takes between 10 seconds and 72 seconds for the operator to be aware of the problem and start to take action. This can be modelled as a triangular distribution with the most common time as 30 seconds or changed to suit the particular rig.



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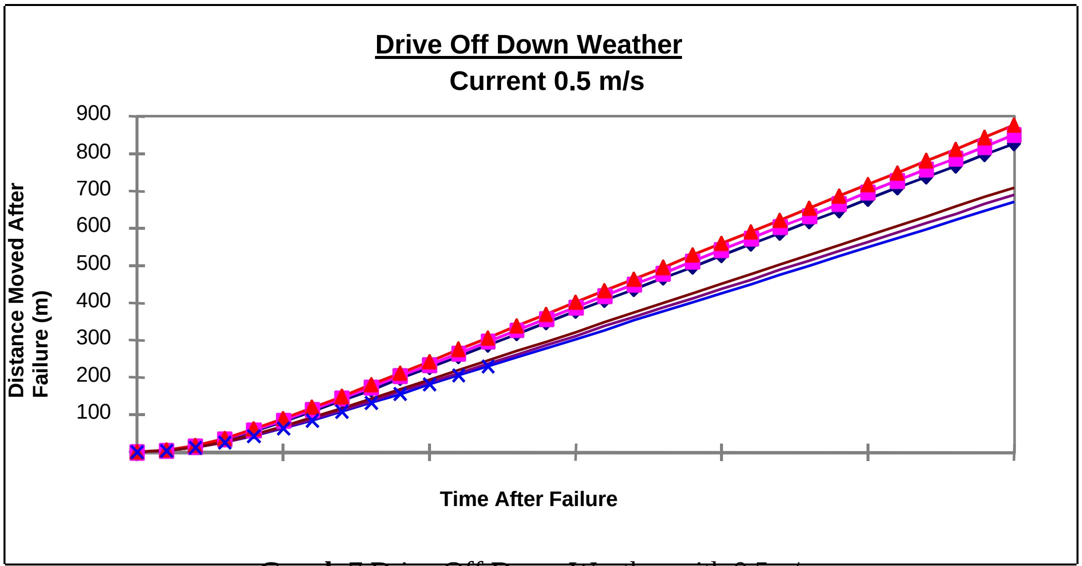
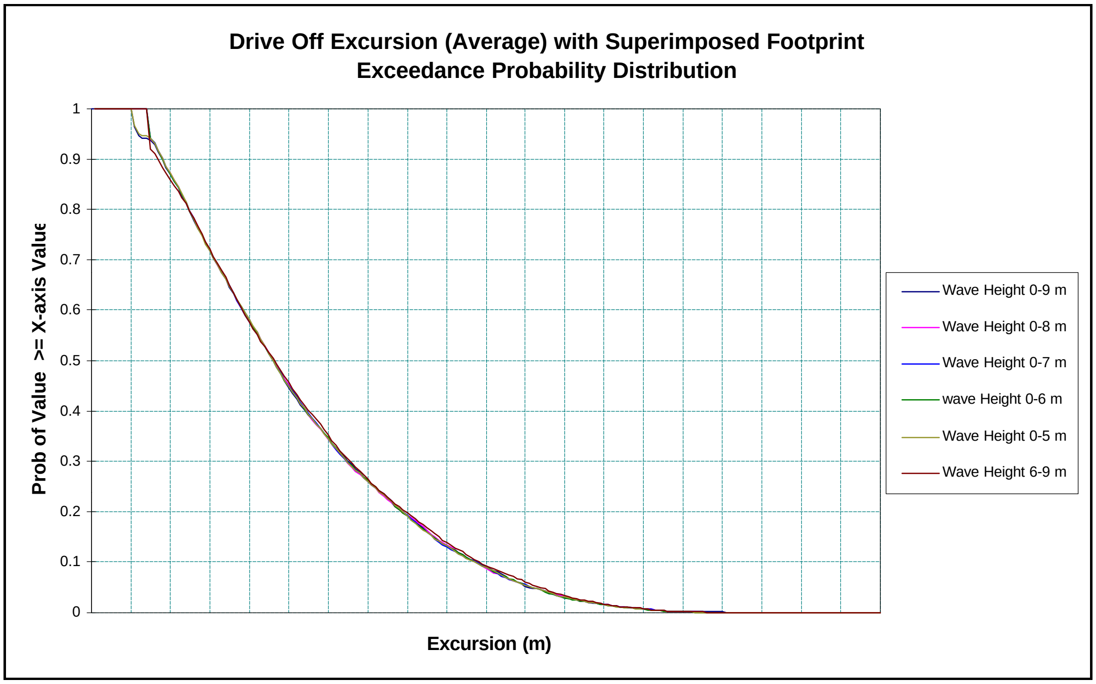
Graph 6 : Drive off time probability density function

The drive off time distribution is used to derive the exceedance distribution of the combined excursion (absolute value) of the drive off and the superimposed footprint. To generate the exceedance probability distribution curve the drive off time has to be calculated with a model of the rig or drive off curves. Similar to the one shown below for a down weather case.



Graph 7 Drive Off Down Weather with 0.5m/sec

For the calculation of the representative drive off curve all directions and all weather conditions have to be considered in numerous simulations to produce an average Drive Off Excursion Exceedance Curve like the one shown below.



Graph 8 : Average Drive Off Excursion with Exceedance Probability Distribution

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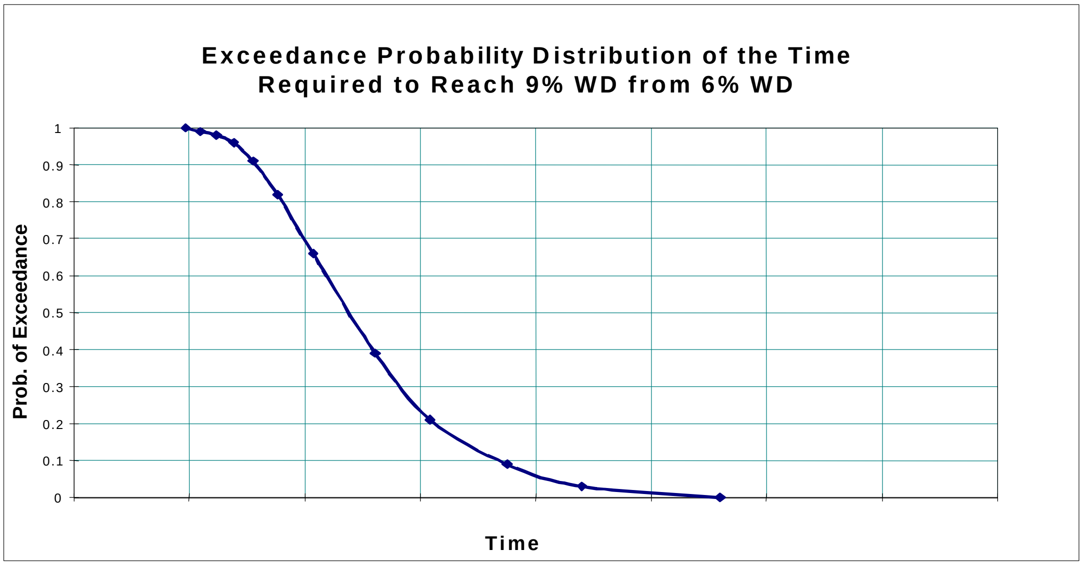
4. Emergency Disconnection

From the analysis exceedance probability distributions have been produced for three different types of position loss. These now have to be used in conjunction with the time required for disconnection and the distance off position the rig can move before emergency disconnection has to be instigated. To combine all three the relative frequencies of each position loss must be known. Alternatively each can be treated separately.

The rig's operations manual can provide the data required on emergency disconnection, alternatively these curves can be used to provide the input to the operations manual. In practice of course it is sometimes very difficult to know what time is available because the drive off and drift off velocities are dependant on the weather conditions. However what is known or can easily be determined and proven at full scale are the maximum drive off and drift off velocities for the given conditions. In addition the time from pressing the emergency disconnect button to final unlatching of the LMRP should be known.

For the rigs we have used this method to assess unsuccessful disconnection we have also quantified the frequency of the three types of position loss from the DP data base and the equipment and experience of the particular rig. We then combine the position loss exceedance curves and, based on various emergency disconnect initiation start distances produce a series of curves like the one shown below.



Graph 9 Exceedance Probability Distribution of the Time Required to Reach 9%WD from 6%WD Excursion

The distribution of times to move from 6% water depth to 9% water depth for the all year weather conditions shows that if emergency disconnection is initiated at 6% water depth for this particular case and the disconnection time is 30 seconds the probability of no disconnection when 9% water depth is reached is 0.05.
However if the disconnect time is 80 seconds then this probability becomes 0.72. Conversely if the emergency disconnection time is only 15 seconds then there will always be time to disconnect.

To calculate the probability of an unsuccessful disconnection one must consider the possibilities of a subsea failure as well as whether there is insufficient time and the two trees below illustrate possible approach.

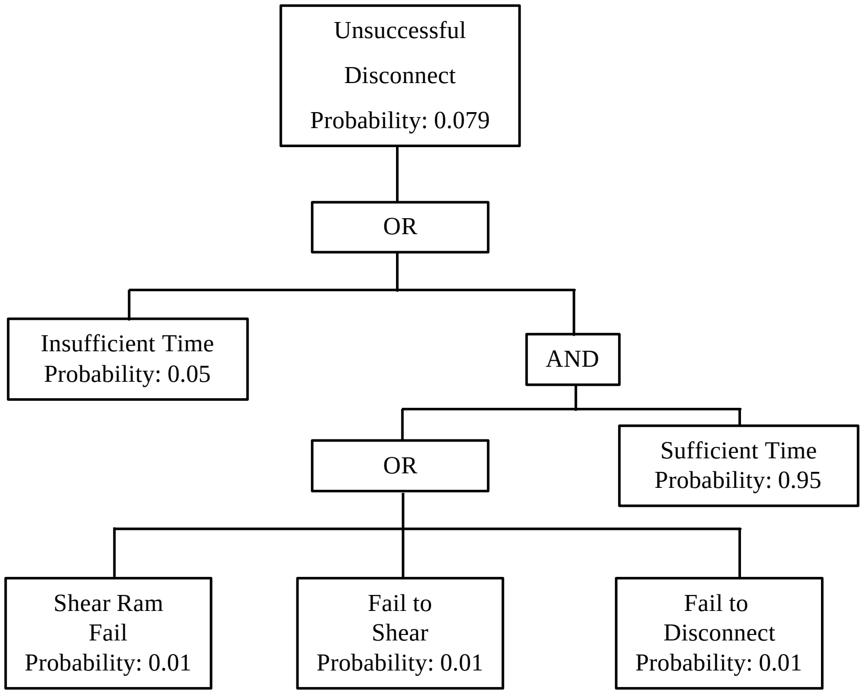


Figure 1

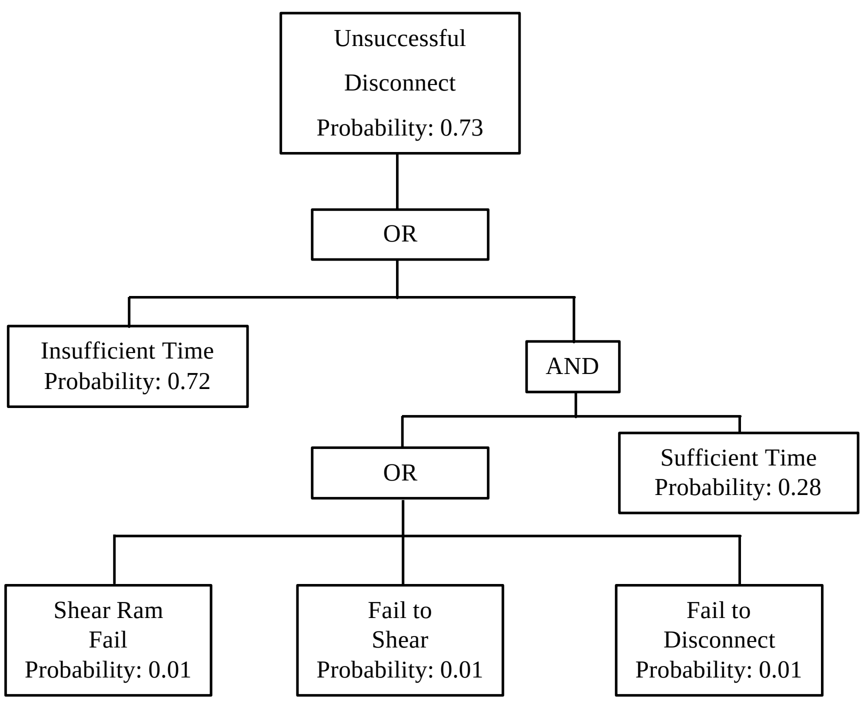


Figure 2

To these probabilities the frequency of position loss needs to be applied. So these figures represent the frequency of an unsuccessful disconnection if the frequency of a loss of position is once per year. The probabilities of the emergency disconnection itself failing are indicative but they serve to illustrate the point that if an emergency disconnection sequence is started there is a chance that it will be unsuccessful.

In some drilling contractors DP operational manuals there are several conflicting emergency disconnection criteria and for each well location it is necessary to modify these general statements. This may lead to unclear instructions and provide ground for hesitation in giving a red alert.

If the weather is practically calm with little or no current and a blackout occurs and the instructions are to emergency disconnect if there is a blackout (loss of all main power) then the result could be an emergency disconnection before the vessel is 10m off position. In addition all thrusters could be back on line before the rig has moved 50m. Thus for safe and efficient disconnection it is essential that the DPO knows:

- the limits of movement in all directions to preserve the riser
- the distance likely to be covered in all directions by a maximum drift off or drive off after various elapsed time periods.
- the time necessary for an emergency disconnection with a safety factor.

This may result in the optimum position of the rig being in a position other than directly above the well.

There is of course a risk that a complicated emergency disconnection criteria that changes with:

- weather (surface)
- current (subsea)
- water depth
- rig present position
- number of thrusters on line

will itself increase the risk of an unsuccessful disconnection because of inadequate time. Two particular problems are:

- the actual position of the rig when there is a problem (which position reference does the operator believe)
- the likely maximum distance the rig could travel before a drive off was stopped.

Conclusions

Using DP incident data from vessels other than deep water drilling units to quantify the frequency of an unsuccessful disconnection can be valid provided allowance is made for the water depth and the additional acceptable position loss distances and the times to reach them.

In order to reduce the number of unnecessary emergency disconnection's the DPO needs to know how long he can wait to restore position before pressing the red alert.