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SEMINAR ON LARGE SEMISUBMERSIBLES

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Götaverken Arendal AB

ANCHORING PROBLEMS OF LARGE SEMISUBMERSIBLES

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INTRODUCTION

The demand for exploration-drilling and production platforms in the hostile environment and deep waters north of the 62:nd parallel in the Norwegian Sea has led to the development of ever larger floating platforms, designed not only for drilling and early production but also intended for the final production stage. Also for other purposes like chemical processing it is of interest with very large platforms.

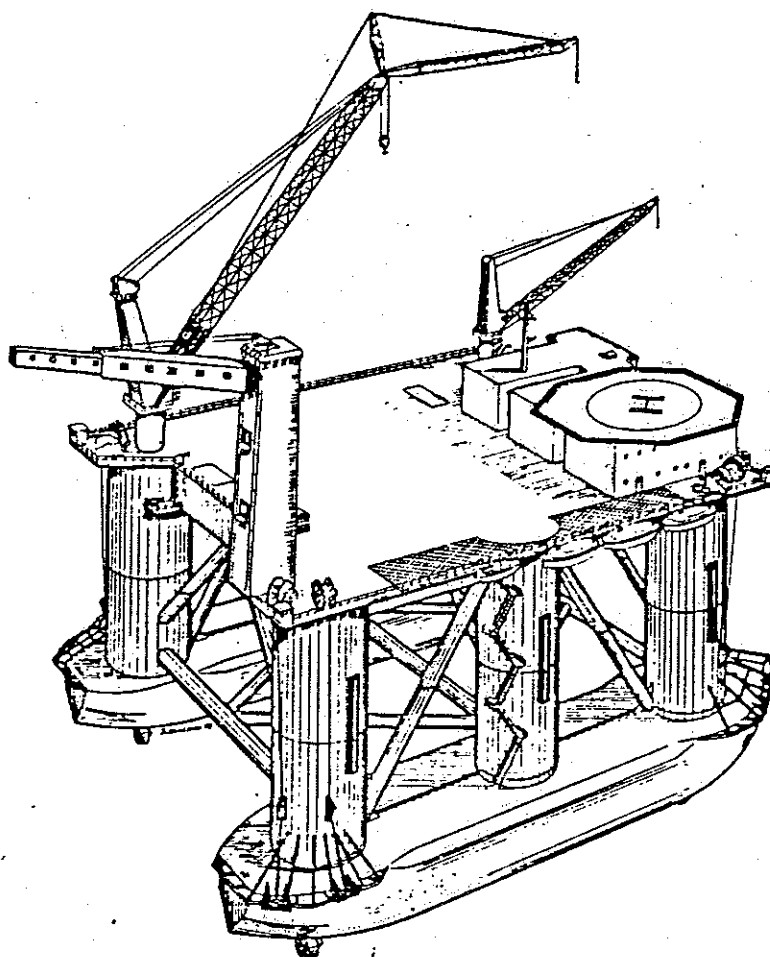


Figure 1 Arendal Flexrig of the Pacesetter design
(Ref. 2)

PLATFORM SIZES

Now , what will be the size of a future floating platform as compared to an ordinary present-day semisubmersible. In order to get an idea of the difference some characteristics are shown in Table 1 for a platform of conventional size; the Arendal Flexrig (Fig 1), a slightly bigger platform; the German RS35 and the concept of a concrete production platform Conprod (Fig 2). As can be seen in the table the concrete platform has ten times as big a displacement as the platforms common today.

Table 1 Platform sizes and load capacities

Platform	GVA Flexrig	RS 35	Conprod A
Displacement (tonnes)	24 600	32 500	238 000
Deck capacity (tonnes)	1 300	2 200	17 000
Oil storage (m ³)	3 000	1 700	55 000
Total variable load (tonnes)	4 200	7 000	73 000
	(Ref 2)	(Ref 1)	(Ref 4)

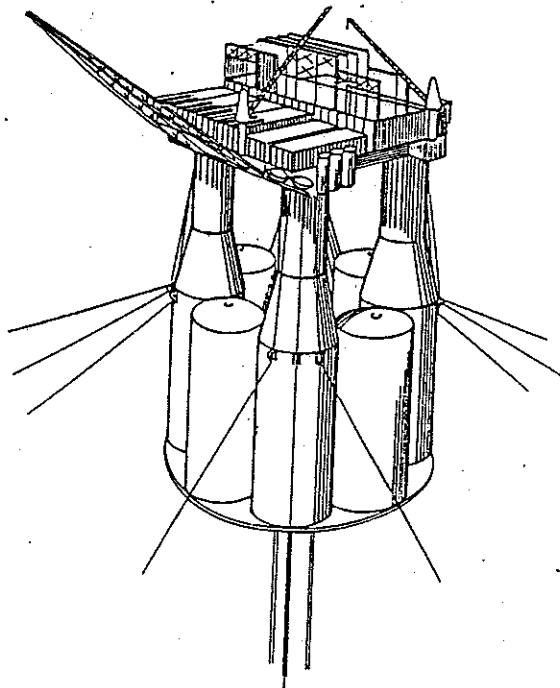


Figure 2 Conprod floating production platform (Ref 4)

ENVIRONMENTAL LOADS

The concept of a very large platform brings about the need of a stronger anchoring system because forces caused by wind, current and wave drift becomes greater. Very large platforms are also intended for deep water and this fact will also give more wide spread anchoring systems, if designed in a conventional way.

The wind and current forces are, in principle, proportional to the cross-sectional areas above and below the water line. The cross-sectional areas could approximately be set proportional to $V^{2/3}$, where V is the displacement volume of the platform. Thus roughly

$$F_w = \text{const}_1 V^{2/3} \quad \dots \quad (1)$$

$$F_c = \text{const}_2 V^{2/3} \quad \dots \quad (2)$$

The drift force on the other hand could be set proportional to some equivalent diameter of the structure:

$$F_d = \text{const}_3 V^{1/3} \quad \dots \quad (3)$$

As a matter of fact the drift force should also depend on platform diameter to wave length ratio, but this fact is disregarded here.

The results of a rough calculation using equations (1) - (3) is shown in Table 3 below, where the design figures for a conventional steel semisubmersible (Dyvi Delta) with a displacement of 36 000 tonnes have been used for extrapolating the environmental loads on the 240 000 tonnes Conprod concept. The environmental conditions are stated in Table 2.

Table 2 Environmental conditions for which the loads in Table 3 are calculated

Significant wave height	15 m/s
Zero-crossing period	14 s
Current at surface	1.3 m/s
Ditto at bottom	0.5 m/s
Wind speed (1 hour sustained)	41 m/s

Table 3 Environmental loads

	Dyvi Delta ¹⁾	Conprod ²⁾
Displacement (tonnes)	36 300	238 000
Wave drift force (MN)	0.4	0.8 ³⁾
Current force (MN)	1.2	4.2
Wind load (MN)	3.3	12.0 ⁴⁾
Total force (MN)	4.9	17.0

1) According to calculations by DnV (Ref 3)

2) According to the equations (1) - (3)

3) A check in a diagram cited in Ref.6 for a floating vertical cylinder in regular waves with the equivalent wave amplitude $\rho_o = H_s/16$ gives 0.72 MN

4) Norwegian Contractors states 10 MN (Ref 4)

According to the very rough estimates above the ratio between displacements is 6.5 while the ratio between environmental forces is 3.5 only.

ANCHORING CABLES

The great environmental loads must be balanced by a stronger anchoring system than what is used presently. This stronger system can be achieved by increasing

- o the number of anchoring legs
- o the diameters of the cables
- o the quality of the cables

It is not possible to increase the number of legs indiscriminately due to several reasons as for example

- o the winches may not be too many in each corner of the platform because of handling possibilities
- o the spreading of the cables on the seafloor must not be too intricate
- o there must also be areas spared for feeder pipes from the wellheads, for loading buoys, and for anchoring cables of service and living-quarters platforms

Neither may the diameter of the cables be increased much. For wires the difficulties to wind them onto wiredrums will increase because of large diameters of the drums. It may also be difficult to ensure good manufacturing quality if the diameters of the wire and chain get too big.

The quality of the chain may also be increased from, for example, Oil Rig Quality to Grade 4. The breaking load of a 130 mm (5 1/8") chain will in this way increase from 12 MN (1220 tonnes) to 15.6 MN (1590 tonnes), that is with 30%.

The solution must be a compromise, that is, the number of legs will be increased from eight to at least twelve, the wire diameter will be increased from 76 mm (3") to say 154 mm (6 1/16"), and the diameter and quality of the chain will also be increased. In Table 4 anchor cables are specified for three sizes of platforms.

Table 4 Anchor cables for some platform sizes

Displacement (tonnes)	25 000	36 000	240 000
Wire diameter (mm)	76	89	154
Chain diameter (mm)	76	83	132
Chain quality	G3, ORQ	G3, ORQ	G4
Number of legs	8	12	12

CLUMP WEIGHTS

The high forces and enhanced steel quality in combination with successively deeper anchoring places would demand very long anchoring cables in order to ensure nil vertical force at the anchor at half the breaking load, if a simple catenary type anchoring system were to be used. See Table 5.

Table 5 Minimum length of simple cables in a catenary type anchoring system

Type	Wire	Chain	Wire	Chain
Diameter (mm)	76	76	154	132
Depth (m)	200	200	400	400
Minimum length (m)	1700	800	2200	1100

The great lengths of the cables constitute a problem because of handling difficulties on board, and because the anchoring system gets very vast on the sea floor. The twelve 154 mm wires in Table 5 would, for example, have an approximate weight of 3000 tonnes plus anchors and winches.

The long anchoring legs also make the anchoring system comparatively compliant under normal conditions. In order to better this Norwegian Contractors has provided the anchoring system of the Conprod with clumpweights resting on the sea floor at operating conditions but providing extra compliance to the plat-

form at survival conditions when they are lifted from the bottom. See Figure 3 and Figure 4.

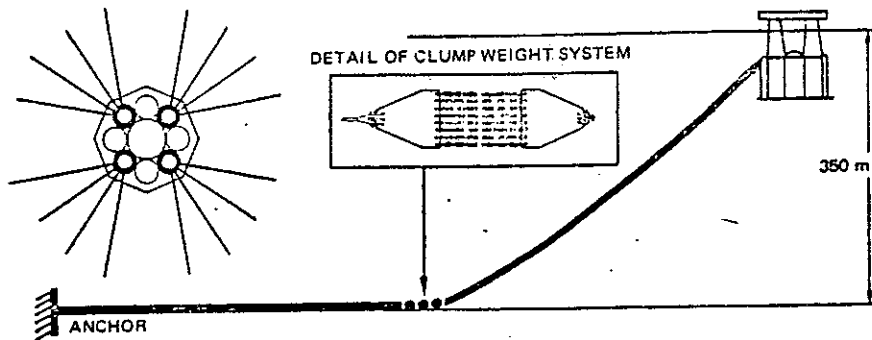


Figure 3 Mooring system of Conprod floating concrete platform (Ref 5)

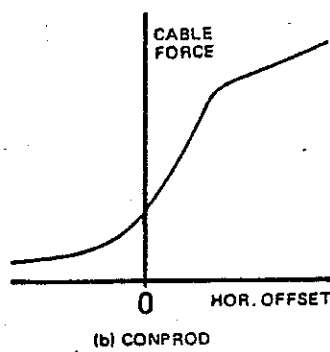


Figure 4 Typical static mooring leg characteristics for a clump weight system (Ref 5)

THE MOORING SYSTEM

The proposed mooring system of the 240 000 tonnes Conprod in Figure 3 consists of 12 cables, each with a 450 m long leading wire rope diameter 154 mm, a 50 m long clumpweight weighing 180 tonnes, a 500 m long chain diameter 132 mm and finally a drag embedment anchor or an anchor pile. The pretension in each cable is 1.33 MN (136 tonnes) and the breaking load 12 MN (1230 tonnes) (Ref 4).

SYSTEM DYNAMICS

Such a large semisubmersible platform as the Conprod is favourably untuned to both the wave periods and the characteristic periods of the slowly varying drift forces.

Table 6 Exciting periods and natural periods for a GVA Flexrig and the Conprod.

Typical wave periods (s):		14-17
Periods of the wave drift force (s):		60-180
Platform	GVA Flexrig	Conprod (A)
Displacement (tonnes)	24 600.	238 000
Degree of freedom:	Natural periods (s):	
Heave	19 ¹⁾	60 ³⁾
Pitch	33 ¹⁾	50 ³⁾
Surge	68 ²⁾	320 ³⁾

1) According to Götaverken Arendal AB (Ref 2)

2) Approximately calculated for an eight-leg system

3) According to Norwegian Contractors (Ref 4)

The magnification of the motions of a platform depends to a great deal on the ratio between the forcing frequency and the natural frequency. A typical diagram for a response amplitude operator in heave may look like the one sketched in Figure 5.

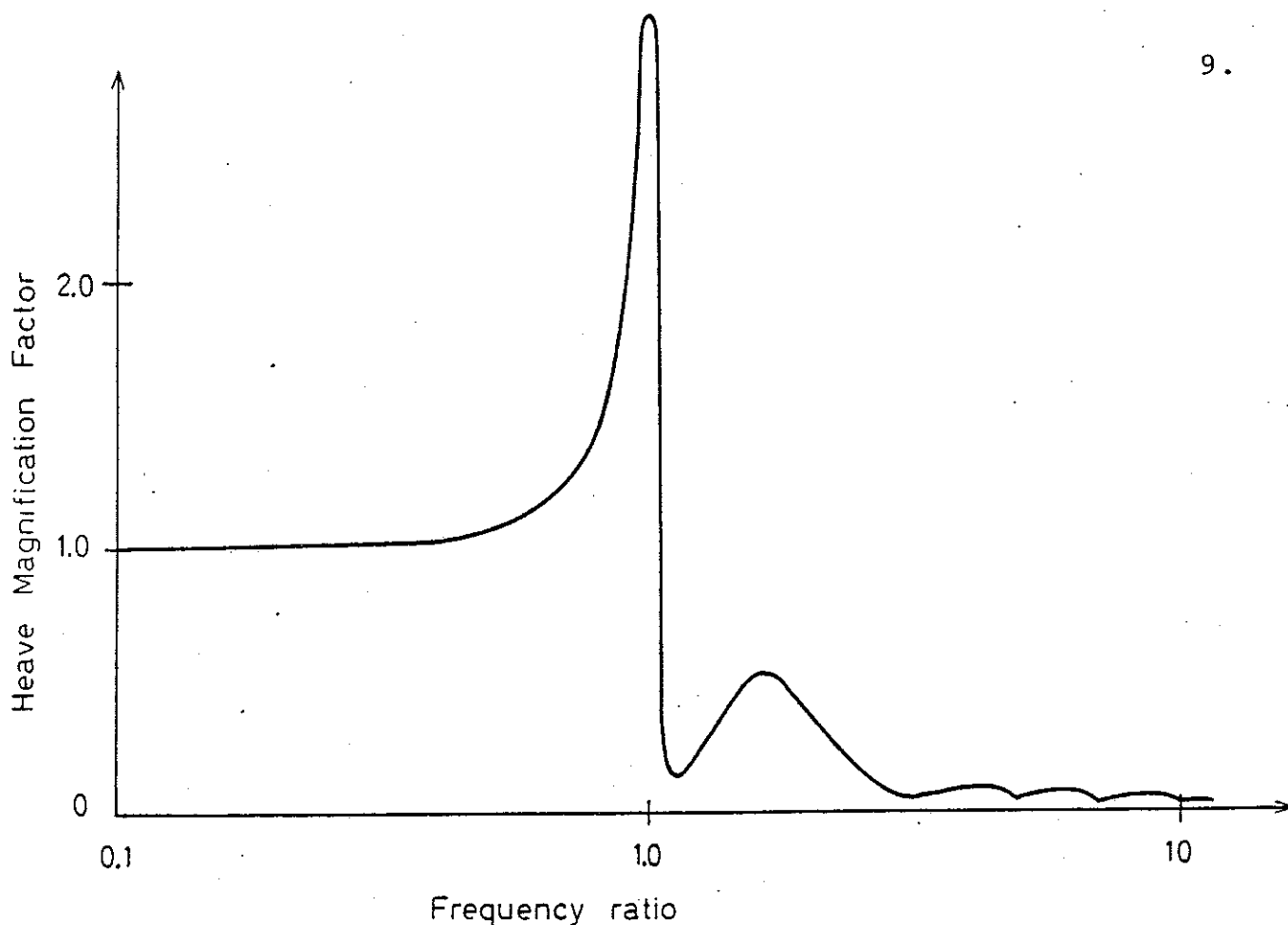


Figure 5 A typical magnification factor in heave (response amplitude operator) as a function of frequency ratio for a semisubmersible

$$\text{Frequency ratio} = \frac{\text{Forcing frequency}}{\text{Natural frequency}}$$

The frequency ratios for heave, pitch and roll are favourable for both the small and the large platform of Table 6. In Table 7 the frequency ratios for the same platforms in waves of 14-17 seconds are listed for their different degrees of freedom. The heave motion due to first order wave forces is small for the Flexrig, which can be seen from Figure 5 if entering the diagram at the frequency ratio 1.1 - 1.4. For the Conprod the heave motion is negligible at the frequency ratio 3.5 - 4.9.

Table 7 Frequency ratios in waves 14-17 s

	GVA Flexrig	Conprod (A)
Heave	1.1 - 1.4	3.5 - 4.3
Pitch and Roll	1.9 - 2.4	2.9 - 3.6
Surge	4.0 - 4.8	19 - 23

The responses of surge and pitch are more like the responses of single-degree-of-freedom systems, and therefore their magnification factors can be qualitatively illustrated by the following simple diagram, Fig. 6. From the diagram it can be seen that there is a significant reduction of pitch and surge motions caused by first order wave forces both for the large and the small platform.

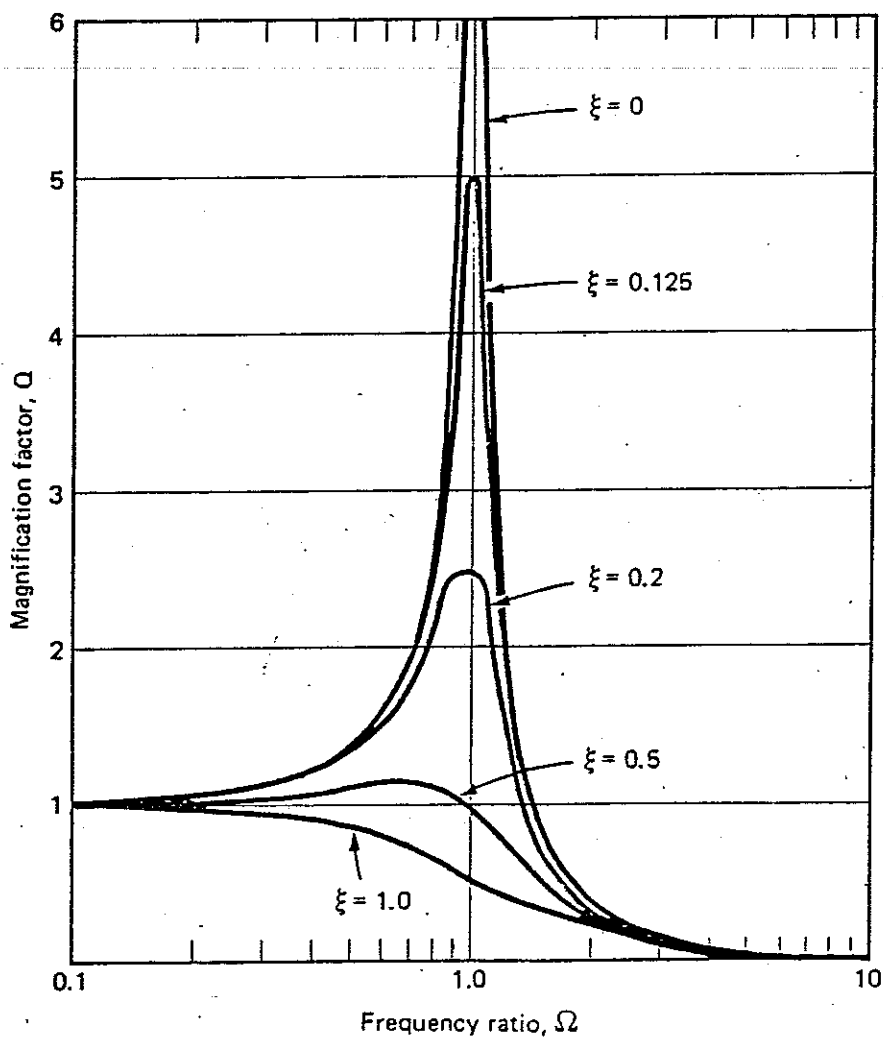


Figure 6 Magnification factor for a single-degree-of-freedom system as a function of frequency ratio and with the damping-ratio ξ as a parameter

RESPONSE TO SLOWLY VARYING DRIFT FORCES

According to the reasoning above the dynamic response to first order wave forces is small for an ordinary platform and almost negligible for the larger platform. The slowly varying drift forces may, however, become significant. The characteristic period of such exciting forces may in the North Sea and Norwegian Sea vary from 60 to 180 s. Their influence is greatest for the horizontal degrees of freedom. The frequency ratios for the slowly varying drift force are given for the two platforms in surge motion in Table 8.

Table 8 Frequency ratios in slowly varying drift forces. Periods of 60-180 s.

	GVA Flexrig	Conprod (A)
Surge	0.4 - 1.1	1.8 - 5.3

Entering the diagram Figure 6 at the range of frequency ratio given for the Flexrig it is seen that there can be a considerable magnification of motions caused by the slowly varying drift forces, and although these forces are of small amplitude they can thus cause considerable surge motions. It is also seen from the diagram that it is very important to know the damping of the system at resonance frequencies in order to tell anything about the amplitude response.

For the Conprod on the other hand it can be seen from the diagram Figure 6, that the slowly varying drift forces have comparatively little influence on the motions but may, still the same, constitute an important dynamic load on the platform itself.

ANCHORING PROBLEMS

Now, what about the anchoring problems of a large semisubmersible that was the title of the lecture? Well, they are connected with the great dimensions of the cables necessary to sustain the mean forces, but the local dynamics of the cables and clump weights also

shows up some distinct problems.

In order to illustrate these problems some diagrams of calculated forces and motions in a windward cable are shown in Figure 7 a-f. (Ref. 5). The diagrams and identifiable problems are commented below.

Figure 7a: Shows the upper end excitation motions. The effects of transients are small. Virtually the same response are obtained for first and subsequent cycles.

Figure 7b: Zero line tension occurs for both systems and should be regarded as an undesirable effect as it will cause

- 1 line unsteadyness (slack) and
- 2 shock forces

when the cable becomes stretched again.

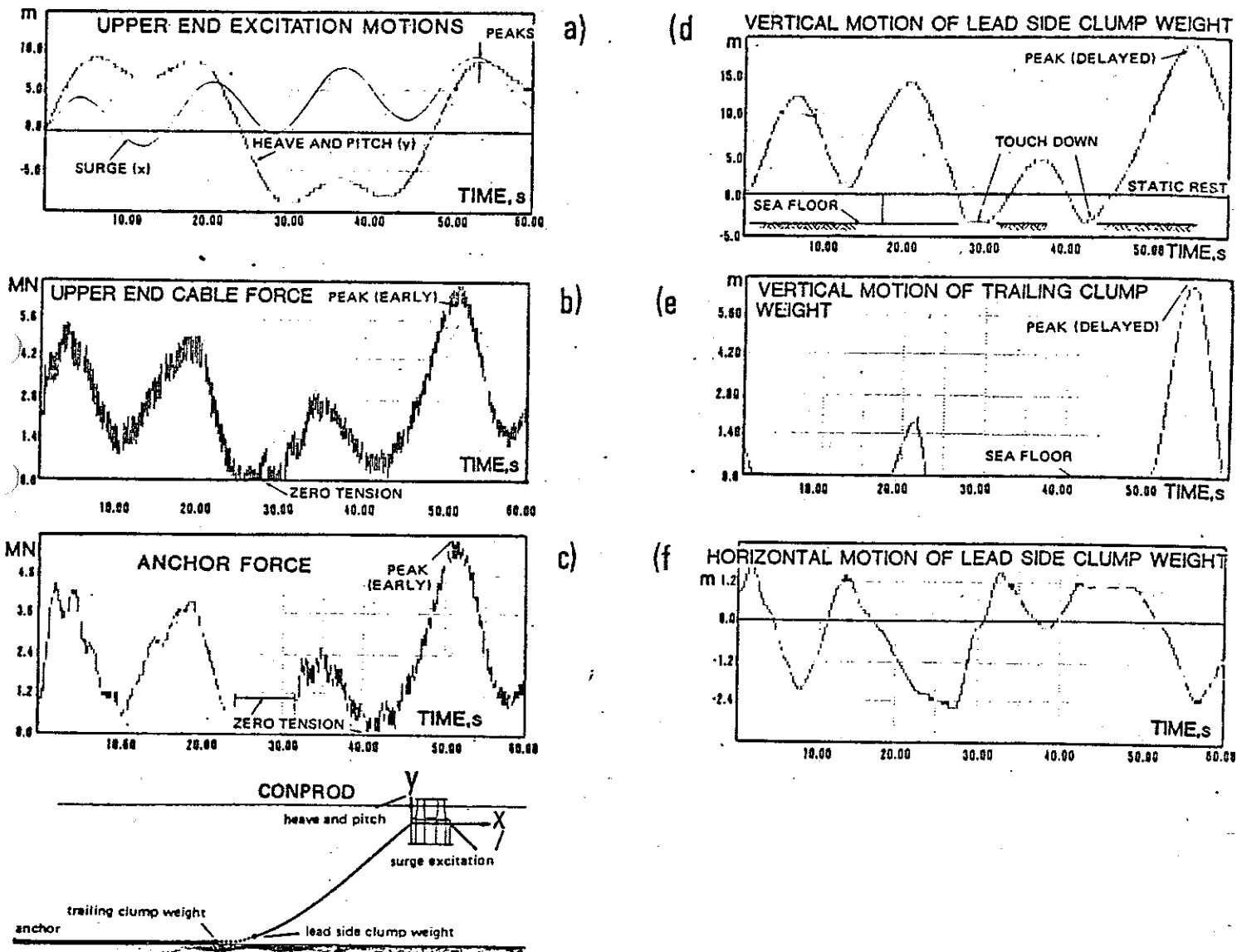


Figure 7 Non-linear dynamic response of CONPROD mooring line system - selected results (Ref. 5).

Figure 7c: Zero tension also occurs at the anchor but may not show up if bottom friction were included into the calculations. The shock following the slack may disturb the soil and cause

- 3 liquefaction or reduced anchor holding capacity

Figure 7 d,e: The clumpweights are lifting from and touching down on the sea floor. This can cause

- 4 staving and subsequent buckling of wire rope,
- 5 damage to the clumpweights,
- 6 damage to the soil and
- 7 ground suction if resting too long on the sea floor.

Figure 7 f: The horizontal motion of the clumpweight is significant, but will probably be reduced if bottom friction is included in the calculations. The horizontal motions of the weights may cause

- 8 soil erosion and
- 9 abrasion of clumpweights.

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