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PILE DRIVING ANALYSIS SHEET

1. INPUT BY CLIENT.

client = ____________________
clients Code = ____________________

1.1 HAMMER: Make = ____________________. Type = ____________________

1.2 PILE : (incl. followers)

top of pile ____________________

Total pile length = _______ m.

Penetration below mudline = _______ m.

<table>
<thead>
<tr>
<th>pile parts (m)</th>
<th>O.D.</th>
<th>I.D.</th>
<th>area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>parts</td>
<td>length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td>9</td>
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<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.3 Soil : soil investigation by = ____________________

<table>
<thead>
<tr>
<th>soil layers (m)</th>
<th>skin friction (ton/m) varies between</th>
<th>type of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>from</td>
<td>to</td>
<td>_______ and _______ 1</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1 ton = 1000 kg)

damping factor for skin friction 2 = _______ sec/m. (0.6 unless client states differently).

fixed plug supposed to be formed 3 = _______ (yes or no).

unit-endbearing 3 = _______ ton/m².

(Notes 1 - 4 : see INFO SHEET)

2. OUTPUT SUPPLIED TO CLIENT.

2.1 set per blow = _______ cm. blowcount = _______ blows/ft.

2.2 net hammer energy at impact = _______ ton-meter.

2.3 buffer force = _______ ton. (for Hydrobloc hammers only).

2.4 total skinfriction = _______ ton. 4

2.5 endbearing = _______ ton. 4

2.6 total driving resistance = _______ ton. 4

2.7 dynamic stresses in pile (kg/cm²: \( R_{\text{min}} = \)) \( R_{\text{max}} = \))

price:

hydrobloc

hollandsche beton maatschappij bv
p.o.box 82 - rijswijk - the netherlands.
INFO SHEET  (Info to "Piledriving Analysis Sheet")

This information is to assist clients filling in all questions under the heading INPUT of the standard "Piledriving Analysis Sheet".

We must apologize in anticipation for not being able to process incomplete forms; they contain the bare minimum of information needed for a first quick analysis.

In many cases a concise analysis along these simple lines will be inadequate. We are prepared to go more deeply into detail in specific problems, if the client wishes so, though we than have to agree upon different terms and conditions in advance.

Problems may arise concerning a proper input from clients side, in the way it is needed for simple standard computer processing. For clients convenience therefore examples are given in this Info Sheet concerning pile-input and soil-data-input.

On a few points suppositions have to be made as for instance whether a fixed plug will form during driving or not; we deliberately ask the client to give his view concerning certain assumptions that must be made. This concise analysis does not allow for a thorough investigation on crucial points, as for instance "plug-forming".

Concerning pilecap, anvil and capfilling manufacturers standards are incorporated in our computer programs. If the client wishes to have non-standards to be incorporated in the analysis he should supply relevant information, preferably a dimensional sketch and a specification of the capfilling material.

"Pile Driving Analysis Sheets" completed with the output of the analysis will be returned to the client.

Clarification on the 4 notes of the "Piledriving Analysis Sheet":

Note 1. Basic Value of Skinfriction

The basic value of the skinfriction is equal to the product of unit skinfriction (metric tons per sq.meter) and circumference of pile (meter).

If inside friction is to be expected (open ended pile with soil plug moving relative to pile) the basic skinfriction is equal to the sum of unit outside skinfriction multiplied with the outer circumference plus unit inside skinfriction multiplied with the inner circumference.

Basic skinfriction may have discontinuities at the boundaries of the soil layers. The Analysis Sheet table provides for this. Within each layer a linear distribution of the skinfriction is assumed in the analysis.
INFO SHEET

**Note (2) Damping factor.**

The skinfriction is assumed to depend on the velocity of the pile (as a function of depth and time) according to the formula:

\[ W = (\text{sign of } v) \cdot W_0 \left( 1 + \alpha |v| \right) \]

with \( v = \) velocity of pile; \( |v| = \) absolute value of \( v \)

- \( W_0 = \) basic skinfriction
- \( \alpha = \) damping factor (ranging from 0.25 to 0.60 sec/meter)
- \( W = \) acting skinfriction

\( \alpha \) depends on nature of soil and degree of consolidation.

If \( \alpha \) is not known \( \alpha = 0.6 \text{ sec/m} \) will be used automatically in the analysis.

**Note (3) Plug and Unit-Endbearing.**

When an open-ended pipe pile is driven, a certain quantity of soil will enter into the pipe; the "soil plug" or "plug".

When driving either of two possible conditions may occur:

a) the plug moves into the pile.

b) the plug is fixed i.e. the plug moves downward with the pile: the pile behaves like a pile closed at its toe.

**Remark I** The condition b) "fixed plug" during driving is not the same as the condition "fixed plug" for static loading. Often the plug will move into the pile (condition a). Even when a static analysis shows the fixed plug possibly to form, this plug might move into the pile (condition a during driving).

In cases of doubt it is suggested that pile driving analyses are to be made for both cases: a) "moving plug" b) "fixed plug"

(seperate "Analysis Sheet" per each case!)

**Remark II** Unit internal skinfriction generally has a lower value than unit external skinfriction. (say \( \frac{1}{4} \) to \( \frac{1}{2} \) )
INFO SHEET

Remark III. As a guidance for the unit-endbearing the following values may be assumed:

- sands 100 x unit-skinfriction at pile toe
- clays 30 x " " " " "

(Values given by soil consultants may supersede these indications).

These values may be used as such for condition a) (plug moving into pile).
For condition b) (fixed plug) these values apply only if pile toe has penetrated sufficiently into a uniform hard layer.
If not, the unit-endbearing in this case reduces to a value depending on penetration into hard layer and on the strength of layers on top of this hard layer (reduction up to, say, 1/3 of values given).

Note: Total skinfriction and total endbearing and total driving resistance are calculated with the data supplied by client. (These values may be checked by client).

Remark = Total driving resistance need not be equal to total static resistance.

References: 1 De Ingenieur, no. 8, 21 Feb. 1974, pages 146-153.
2 De Ingenieur, no. 18, 2 May, 1974, pages 345-353.
3 1976 OTC, Houston, no. 2477, pages 593-609.
INFO SHEET

1. Conversion factors  For input (foot-pound units to metric units)

Length, area, volume

1 ft = 0.305 m
1 inch = 0.0254 m = 25.4 mm
1 sq ft = 0.093 sq m = 0.093 m²
1 sq.in. = 6.45 sq cm = 6.45 cm²
( 1 cu.ft = 0.0283 m³ = 0.0283 m³ )

Forces, weights

1 ton = 1 metric ton = 1000 kg
1 (long) ton (2240 lbs) = 1017 kg ≈ 1 metric ton
1 (short) ton (2000 lbs) = 908 kg = 0.908 metric ton
1 kip = 0.454 metric ton

Stresses and pressures.

1 ksf = 4.88 t/m² = 4.88 metric tons per sq m. (use for conversion of Unit skinfriction and Unit endbearing.
1 (long) ton/sq ft. = 10,93 t/m²

Skinfriction.

1 kip/ft = 1.49 t/m
1 (long) ton/ft = 3.33 t/m
Skinfriction asked for in 1.3 is unit skinfriction — circumference of pile (eventually outside and inside together).

Damping factor for skinfriction

1 sec/ft = 3.28 sec/m
0.6 sec/m = 0.183 sec/ft

Velocities (eventually)
1 ft/sec = 0.305 m/sec

2. For Output (metric to ft-pound units)

1 cm = 0.394 inch
1 ton meter = 7222 ft lbs
1 ton = 2202 lbs = 2.202 kips
1 ton = 0.983 long tons
1 ton = 1.103 short tons
1 kg/cm² = 1 kg/sq cm = 14.21 psi = 2.046 ksf.
1.2. PILE : (incl. followers)  

**top of pile**

<table>
<thead>
<tr>
<th>Parts</th>
<th>Length (m)</th>
<th>O.D.</th>
<th>I.D.</th>
<th>Area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.00</td>
<td>36&quot;</td>
<td>32&quot;</td>
<td>709</td>
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<tr>
<td>2</td>
<td>30.00</td>
<td>36&quot;</td>
<td>32&quot;</td>
<td>1378</td>
</tr>
<tr>
<td>3</td>
<td>20.00</td>
<td>36&quot;</td>
<td>33.5&quot;</td>
<td>880</td>
</tr>
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<td>4</td>
<td>30.00</td>
<td>36&quot;</td>
<td>33&quot;</td>
<td>1049</td>
</tr>
<tr>
<td>5</td>
<td>5.00</td>
<td>36&quot;</td>
<td>30&quot;</td>
<td>2007</td>
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</tr>
</tbody>
</table>

**total pile length = 405 m.**

**penetration below mudline = 60 m.**
1.3. SOIL: soil investigations by COMPANY XYZ.

<table>
<thead>
<tr>
<th>soil layers (m) from</th>
<th>to</th>
<th>skin friction (ton/m)</th>
<th>type of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>mudline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>10</td>
<td>2.5</td>
<td>SILTY SAND</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>45.0</td>
<td>FIRM CLAY</td>
</tr>
<tr>
<td>20</td>
<td>30</td>
<td>40.0</td>
<td>SOFT CLAY</td>
</tr>
<tr>
<td>30</td>
<td>40</td>
<td>8.0</td>
<td>HARD CLAY</td>
</tr>
<tr>
<td>40</td>
<td>50</td>
<td>8.0</td>
<td>FIRM CLAY</td>
</tr>
<tr>
<td>50</td>
<td>60</td>
<td>4.0</td>
<td>SANDY CLAY</td>
</tr>
<tr>
<td>60</td>
<td>70</td>
<td>35.0</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>85</td>
<td>48.0</td>
<td></td>
</tr>
</tbody>
</table>

damping factor for skin friction $\varphi = 0.5 \text{ sec/m}$. (0.6 unless client states differently).

fixed plug supposed to be formed $\varnothing = \text{NO}$. (yes or no).

unit end-bearing $\varnothing = 700 \text{ ton/m}^2$.

Notes 1 - 4: (see Info Sheet)

hollandsche beton maatschappij bv
P.O. Box 82 - Rijswijk - The Netherlands.

June '76

Page 6 of 6
Dear Mr. Thomason,

Subject: Demonstration with Hydroblok HBM 4000 piledriving hammer

As published worldwide last year in offshore magazines, two HBM 4000 piledriving hammers were ordered for delivery by the end of 1978. These hammers are the most powerful among presently proven ones. The initial full scale testing meanwhile has confirmed that the rated energy output measured on the testpile goes far in excess of the 1,700,000 specified feet-lbs. The number of blows reached was 80 per minute.

For particulars we refer to the attached sheet.

The above testing of the hammers happens in combination with a 4400 HP hydraulic powerpack which has been built especially for their drive. At clients' demand it is a skid mounted, containerised and fully self sustained unit.

The HBM 4000 hammers are now striking their testblows on top of an 84 in. O.D. 1:5 batter testpile. This testpile passed a dense sand layer at 225 feet depth which caused a temporary refusal of 25,500 blows/foot. At the time this letter was written, the hammers have been driving over 29 hours.
We are now organizing a demonstration of the piledriving capabilities of the above Hydroblok hammers on Thursday, February 22, 1979, for which we gladly invite you. This demonstration is set up in cooperation with the future Owners.

The program is as per attachment.

Our guests are invited to assemble on the 22nd of February at 09.15 hrs a.m. in front of the Rotterdam Hilton Hotel, located in the very centre of the city.

From there transport will be arranged by buses.

In case you prefer to have your own transportation, we advise that our presentation will start at Motel "Papendrecht", Restaurant "De Staatse Schans" on the first floor.

This place can easily be found at the freeway entrance of the town of Papendrecht.

For your easy reference you will find enclosed herewith copy of a map of the pertaining Rotterdam-Papendrecht area.

By road, the distance Rotterdam-Papendrecht is approx. 20 miles.

Due to short time available we kindly ask you to confirm your attendance by telex or by telephone, please ask for Miss Janet Visser.

It will be a great pleasure to have you as our guests on February 22, 1979.

Yours faithfully

VEROLME ENGINEERING COMPANY
IJSSELMONDE B.V.

Encl. 3 x
Hydroblok Hammer
Type: HBM-4000
Standard

Main Specifications.

CAPACITY

Guaranteed NET driving energy
160 tm.
200 000 ft lb

RATED driving energy approx.
232 tm.
1 700 000 ft lb

Bufferforce min.
1600 t.
3 300 kips

max.
4000 t.
8 800 kips

Number of blows/min.
40-70

Power (installed)
4400 hp.

Magnitude of total soilresistance the hammer can overcome during driving
7200 t.
16 000 kips

WEIGHTS

Dropweight
93 t.
205 000 lbs

Hammer (incl. dropweight, excl. anvil, pile sleeve and ballast)
186 t.
411 000 lbs

Anvil
15 t.
33 000 lbs

Pile sleeve
21 t.
46 000 lbs

Under water ballast
38 t.
84 000 lbs

Max. pile size (without adaptor)
2134 mm. O.D.

Dimensions in mm. Subject to modifications.
PROGRAM HBM 4000 DEMONSTRATION


09.15 hrs  Guests assemble in front of Rotterdam Hilton Hotel.
           Boarding buses.

09.30 hrs  Buses leaving.

10.00 hrs  Arrival at Motel "Papendrecht" -
           Restaurant "De Staatse Schans"

10.00 - 12.00 hrs  Coffee.
                   Briefings by Dr. J.W. Jansz, managing director
                   Hollandsche Beton Groep, Research and
                   Development.

12.00 hrs  Departure for Test Site.

12.30 - 13.30 hrs  Demonstration of HBM 4000 piledriving system.

13.30 hrs  Departure for Motel "Papendrecht" -
           Restaurant "De Staatse Schans"

14.00 - 16.00 hrs  Cocktails.
                   Cold Buffet.

16.00 hrs  Departure for Rotterdam Hilton.
           Informal discussion.
PROGRAM

Demonstration of Hydroblok HBM 4000 Piledriving Hammer

Thursday, February 22, 1979

09.15 hrs  Guests assemble in front of Rotterdam Hilton Hotel
           Boarding Buses

09.30 hrs  Buses leaving

10.00 hrs  Arrival at Motel "Papendrecht", Restaurant "De Staatse Schans"
           Participants with own transportation join the group

10.00 - 12.00 hrs  Coffee
           Introduction by Messrs Verolme Engineering Company
           Briefings by Dr. J.W. Jansz, Managing Director HBG, Research and Development and by Messrs Netherlands Offshore Company
           Questions

12.00 hrs  Departure for Test Site

12.30 - 13.30 hrs  Demonstration of HBM 4000 Piledriving System

13.30 hrs  Departure for Motel "Papendrecht", Restaurant "De Staatse Schans"

14.00 - 16.00 hrs  Cocktails
           Cold Buffet

16.00 hrs  Departure for Rotterdam Hilton
           Informal discussions
<table>
<thead>
<tr>
<th>Client</th>
<th>Year</th>
<th>Project Location</th>
<th>above/under water</th>
<th>Water-depth</th>
<th>Hammer</th>
<th>Piles</th>
<th>Penetration</th>
<th>Soil</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pélchiney</td>
<td>1970</td>
<td>Flushing NL</td>
<td>above</td>
<td>-</td>
<td>H.B.M.14</td>
<td>concrete</td>
<td>34 m</td>
<td>clay, sand</td>
<td>HBM</td>
</tr>
<tr>
<td>Publ.W.Rdm</td>
<td>1971/72</td>
<td>Europort NL</td>
<td>above</td>
<td>-</td>
<td>H.B.M.850</td>
<td>concrete 59.45 cm</td>
<td>34 m</td>
<td>sand</td>
<td>HBM</td>
</tr>
<tr>
<td>Min.Publ.W.</td>
<td>1973</td>
<td>Zealand, NL</td>
<td>above</td>
<td>-</td>
<td>H.B.M.850</td>
<td>200 steel piles, dia 106 cm</td>
<td>12 m</td>
<td>clay, sand</td>
<td>HBM</td>
</tr>
<tr>
<td>Shell Oil Comp.</td>
<td>1974</td>
<td>Gulf of Mexico Marsh Island Block 130</td>
<td>under</td>
<td>217 ft (66m)</td>
<td>H.B.M.500</td>
<td>1 steel pile 24&quot; dia, 1&quot; w.t.</td>
<td>350 ft. (160m)</td>
<td>stiff clay, silts</td>
<td>McDermott HBM</td>
</tr>
<tr>
<td>Min.Publ. Works</td>
<td>1974/75</td>
<td>Eastern Schelde River NL</td>
<td>under</td>
<td>10 m</td>
<td>H.B.M.500</td>
<td>Various tests a.o. underwater compaction</td>
<td>--</td>
<td>--</td>
<td>HBM</td>
</tr>
<tr>
<td>Publ.W.Adm</td>
<td>1974/75</td>
<td>Amsterdam, NL</td>
<td>above</td>
<td>--</td>
<td>H.B.M.500</td>
<td>950 steel piles box type</td>
<td>25-36 m</td>
<td>peat, sand</td>
<td>HBM</td>
</tr>
<tr>
<td>Greater London Barrier Council</td>
<td>1974/76</td>
<td>Thames Barrier U.K.</td>
<td>above</td>
<td>--</td>
<td>H.B.M.850</td>
<td>Steel profiles Larsen 6 and PSP 8005</td>
<td>15-20 m</td>
<td>peat, sand, clay, chalk</td>
<td>HBM</td>
</tr>
<tr>
<td>Publ.W.Rdm</td>
<td>1976</td>
<td>Rotterdam, NL</td>
<td>above</td>
<td>--</td>
<td>H.B.M.500</td>
<td>Steel sheet piles</td>
<td>--</td>
<td>peat, clay, sand</td>
<td>HBM</td>
</tr>
<tr>
<td>Occidental of Scotland Inc.</td>
<td>1976</td>
<td>Claymore field, North Sea</td>
<td>above</td>
<td>360 ft.</td>
<td>H.B.M.3000</td>
<td>4 steel piles dia 48&quot; 24 steel piles dia 60&quot; batter 10.7:1</td>
<td>150 ft.</td>
<td>clay, sand-layers</td>
<td>Neth.Offsh Comp.NOC.</td>
</tr>
<tr>
<td>Kellog's</td>
<td>1977</td>
<td>Cork, Dublin Ireland</td>
<td>above</td>
<td>12 m</td>
<td>H.B.M.850</td>
<td>400 steel piles 24&quot;</td>
<td>15-18 m</td>
<td>sand, weathered rock</td>
<td>HBM</td>
</tr>
<tr>
<td>Company</td>
<td>Year</td>
<td>Location</td>
<td>Depth</td>
<td>Diameter</td>
<td>Material</td>
<td>Length</td>
<td>Soil</td>
<td>Contractor</td>
<td></td>
</tr>
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</tr>
<tr>
<td>Placid Intl. Oil Ltd.</td>
<td>1977</td>
<td>Platform L10/D North Sea, Dutch Sector</td>
<td>above</td>
<td>90 ft</td>
<td>HBM 3000</td>
<td>4 steel piles dia 42&quot;, 1.5&quot; wt batter 7:1:1</td>
<td>177 ft 53 m</td>
<td>sand</td>
<td>Neth. Offshore CoNOC.</td>
</tr>
<tr>
<td>Pennzoil Ned. Comp.</td>
<td>1977</td>
<td>Platform K13/c North Sea, Dutch Sector</td>
<td>above</td>
<td>90 ft</td>
<td>HBM 3000</td>
<td>4 steel piles dia 42&quot;, batter 5.6:1</td>
<td>190 ft 58 m</td>
<td>sand</td>
<td>Neth. Offshore CoNOC.</td>
</tr>
<tr>
<td>Placid Intl. Oil Ltd.</td>
<td>1977</td>
<td>Platform L10/E North Sea, Dutch Sector</td>
<td>above</td>
<td>90 ft</td>
<td>HBM 3000</td>
<td>4 steel piles dia 42&quot;, 1S/1.75&quot; wt batter 7:1:1</td>
<td>176 ft 50 m</td>
<td>sand</td>
<td>Neth. Offshore CoNOC.</td>
</tr>
<tr>
<td>Shell Oil Comp.</td>
<td>1977</td>
<td>Cognac Field, Gulf of Mexico</td>
<td>under</td>
<td>1050 ft 300 m</td>
<td>HBM 3000A</td>
<td>24 steel piles, dia 84&quot;, 2&quot; w.t., L 625 ft 190 m</td>
<td>490 ft 150 m</td>
<td>soft clay</td>
<td>McDermott Hydrobl Unit.</td>
</tr>
<tr>
<td>Single Buoy Moorings Inc (SBM)</td>
<td>1977</td>
<td>Pulay Field South Chinese Sea</td>
<td>under</td>
<td>60 m</td>
<td>HBM 500</td>
<td>6 steel piles dia 24/48&quot;, w.t. 1.5/1.25&quot; L 98 ft 30 m</td>
<td>76 ft 23.2 m</td>
<td>very stiff clay</td>
<td>Hydrobl Unit</td>
</tr>
<tr>
<td>Min.Publ. Works</td>
<td>1977/79</td>
<td>Gouda Tunnel NL</td>
<td>under</td>
<td>2-16 m</td>
<td>HBM 500</td>
<td>2800 concrete piles sq. 40 cm</td>
<td>14-15 m</td>
<td>sand</td>
<td>HBM</td>
</tr>
<tr>
<td>Min.Publ. Works</td>
<td>1978</td>
<td>Gouda Tunnel, NL</td>
<td>above</td>
<td>--</td>
<td>HBM 500</td>
<td>400 concrete piles sq. 40 cm</td>
<td>17 m</td>
<td>peat, sand</td>
<td>HBM</td>
</tr>
<tr>
<td>Occidental Oil</td>
<td>1978</td>
<td>Piper field, North Sea, British sector</td>
<td>under</td>
<td>150 m</td>
<td>HBM 1500</td>
<td>8 steel anchor-piles dia, 60&quot; L 94 ft.</td>
<td>100 ft 30 m</td>
<td>soft to stiff clay</td>
<td>Hydrobl Unit</td>
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<tr>
<td>Petroland BV</td>
<td>1978</td>
<td>Platform L7BB North Sea, Dutch sector</td>
<td>above</td>
<td>--</td>
<td>HBM 3000</td>
<td>4 steel piles, dia 42&quot;, w.t. 2/2.5&quot;</td>
<td>191 ft 58 m</td>
<td>sand</td>
<td>Neth. Offshore CoNOC.</td>
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<tr>
<td>Electr. Comp. Denmark</td>
<td>1978</td>
<td>Asnaes, DK</td>
<td>above</td>
<td>18-20m</td>
<td>HBM 500</td>
<td>24 steel piles dia 24&quot;</td>
<td>12-15 m</td>
<td>clay, sand</td>
<td>HBM</td>
</tr>
<tr>
<td>Philipp Holzmann Germany</td>
<td>1978</td>
<td>Hamburg Harbour Germany</td>
<td>under</td>
<td>6 m</td>
<td>HBM 500</td>
<td>120 steel HPiles</td>
<td>sand/gravel</td>
<td>HBM</td>
<td></td>
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<tr>
<td></td>
<td>Electr.Com., Denmark</td>
<td>1979*</td>
<td>Asnaes, DK</td>
<td>18-20m</td>
<td>HEM 500</td>
<td>340 piles, dia 24&quot;</td>
<td>12-15 m</td>
<td>clay, sand</td>
<td>HEM</td>
</tr>
<tr>
<td>---</td>
<td>---------------------</td>
<td>------</td>
<td>-----------</td>
<td>--------</td>
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<td>24.</td>
<td>Min.Publ. Works</td>
<td>1979*</td>
<td>Eastern Schelde river NL.</td>
<td>above</td>
<td>15-30m</td>
<td>HEM 1500</td>
<td>47 piles, dia 48&quot;</td>
<td>30 m</td>
<td>sand</td>
</tr>
</tbody>
</table>

* to be executed
EXPERIENCE

WITH

HBM HYDROBLOK HAMMERS
<table>
<thead>
<tr>
<th>Client</th>
<th>Project</th>
<th>Period</th>
<th>Number of piles and sizes</th>
<th>Wall Thickness</th>
<th>Penetration</th>
<th>Soil Condition</th>
<th>Pile Batter</th>
<th>Actual Driving Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOC</td>
<td>Testdriving on-shore in Holland</td>
<td>1974</td>
<td>1x84 in diam.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Nil</td>
<td>+20 hr</td>
</tr>
<tr>
<td>AMOCO UK</td>
<td>Montrose platform North Sea U.K.</td>
<td>July 1975</td>
<td>28x48 in diam.</td>
<td>2.0 in</td>
<td>-</td>
<td>hammer on standby only</td>
<td>Nil</td>
<td></td>
</tr>
<tr>
<td>Occidental of Scotland Inc.</td>
<td>Claymore platform North Sea U.K. Sector</td>
<td>July 1976</td>
<td>2x48 in diam.</td>
<td>2.0 in</td>
<td>46 meter</td>
<td>Alternate Clay and Sand Layers</td>
<td>10.7:1</td>
<td>14.6 hr</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>19x60 in diam.</td>
<td>(150 feet)</td>
<td></td>
<td></td>
<td>10.0:1</td>
<td>7.1:1</td>
</tr>
<tr>
<td>Placid International Oil Ltd.</td>
<td>Platform L10/D North Sea Dutch Sector</td>
<td>May 1977</td>
<td>4x42 in diam.</td>
<td>1.5 in</td>
<td>53 meter</td>
<td>Sand</td>
<td>10.0:1</td>
<td>6.2 hr</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(175 feet)</td>
<td></td>
<td></td>
<td>7.1:1</td>
<td></td>
</tr>
<tr>
<td>Pennzoil Nederland Company</td>
<td>Platform K13/C North Sea, Dutch Sector</td>
<td>July 1977</td>
<td>4x42 in diam.</td>
<td>1.25/2.125 in</td>
<td>58 meter</td>
<td>Sand</td>
<td>8.0:1</td>
<td>4.4 hr</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(190 feet)</td>
<td></td>
<td></td>
<td>5.6:1</td>
<td></td>
</tr>
<tr>
<td>Placid International Oil Ltd.</td>
<td>Platform L10/E North Sea, Dutch Sector</td>
<td>Sept.1977</td>
<td>4x42 in diam.</td>
<td>1.5/1.75 in</td>
<td>54 meter</td>
<td>Sand</td>
<td>10.0:1</td>
<td>5.7 hr</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(176 feet)</td>
<td></td>
<td></td>
<td>7.1:1</td>
<td></td>
</tr>
<tr>
<td>Petroland B.V.</td>
<td>Platform L7BB North Sea, Dutch Sector</td>
<td>Sept.1978</td>
<td>4x42 in diam.</td>
<td>2.0/2.5 in</td>
<td>58 meter</td>
<td>Sand</td>
<td>5.6:1</td>
<td>2.8 hr</td>
</tr>
</tbody>
</table>

TOTAL: + 154 hr
Piledrivers at jobsite:

Installation vessels/barges:

Piles driven to final penetration by different hammer types:

Hammer problems:

At end of pile driving 4 out of 5 hammers were unuseable, one HBM 3000 finished the driving job!
### HEAVY PILE DRIVERS

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>MRBS 8000</th>
<th>HEM 3000A (3000)</th>
<th>MRBS 12500</th>
<th>HEM 4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. rated energy</td>
<td>867.960 ft/lbs 120.000 mkg</td>
<td>1.100.000 (774.000) ft/lbs 157.000 (107.000) mkg</td>
<td>1.582.220 ft/lbs 218.750 mkg</td>
<td>1.700.000 ft/lbs 232.000 mkg</td>
</tr>
<tr>
<td>Net driving energy</td>
<td>781.165 ft/lbs 108.000 mkg</td>
<td>795.600 (542.000) ft/lbs 110.000 (75.000) mkg</td>
<td>1.424.000 ft/lbs 196.875 mkg</td>
<td>1.157.000 ft/lbs 160.000 mkg</td>
</tr>
<tr>
<td>Weight</td>
<td>277 ton</td>
<td>188 (175) ton</td>
<td>385 ton</td>
<td>226 ton</td>
</tr>
<tr>
<td>Blows per minute</td>
<td>38 bl/min</td>
<td>70 bl/min</td>
<td>36 bl/min</td>
<td>70 bl/min</td>
</tr>
<tr>
<td>Driving capacity (en/t.unit)</td>
<td>4.104.000 mkg/min</td>
<td>7.700.000 (5.250.000) mkg/min</td>
<td>7.087.500 mkg/min</td>
<td>11.200.000 mkg/min</td>
</tr>
</tbody>
</table>

*Information drawn from manufacturer's sales brochures*
HBM-4000 TYPE HYDROBLOK HAMMER
UNDER DURATION TEST, SLIEDRECHT 1979.

Today, February 22, 1979 you will see a more than life-size test site. The most powerful hammer in the world, driving an 84 inch pile to a penetration of more than 230 ft.

WHY ALL THIS EFFORT?

We have three goals in mind, viz.:

1) It must be proved to the client, in this case The Netherlands Offshore Company, that their hammers can meet the guaranteed performance specifications over an extended period of time.

2) The Hydroblok organization wants to check its design calculations and to calibrate its design techniques for future developments.

3) This opportunity is utilized to gather information of a more general nature about the interactive behaviour of the total hammer-pile-soil system.

1) Performance

The test has clearly shown that this huge hammer really will do the job it was designed for. But what do we really mean by performance? The hammer must generate energy, necessary to achieve penetration, to achieve plastic deformation of the soil. The pile transports the energy from the hammer to the soil.

The only meaningful yardstick to measure the energy is the kinetic energy of the ram immediately before it hits the anvil:

\[ E = \frac{1}{2} Mv^2. \]

The mass \( M \) is known from calculations, and more accurate also from the fabricators weighing procedure sheet.

The impact velocity \( v \) is measured and visualized at the operators console. In our case the velocity is determined by the time delay \( t \) between two adjacent points that are passed by the ram. (Incidentally also the rebound velocity is indicated by the same means). The velocity indicator is carefully checked and calibrated and it is a standard built-in piece of equipment in every Hydroblok hammer.

Does the pile accept all that energy from the hammer? It depends on the relative properties of the combination of pile and hammer. At a certain impact velocity \( v \) a given pile can only absorb a certain force per time-span and the excess force is bounced back into the hammer, and is therefore lost to the driving process. Here the adjustable Hydroblok buffer-force comes into the picture.

The operator can regulate the impact force during driving independently from the energy. Conventional hammers allow such a force-adjustment only by adapting (i.e. reducing) the energy. This unique feature allows the energy to be temporarily stored in order to stretch the blow over a
longer period of time by merely adjusting the bufferforce, constantly working with the same optimum energy level of each hammerblow. This in fact is the key to fast driving, as has been proved in many offshore operations where short driving times have amazed so many.

During testing various bufferforces and impact velocities were used. The impact-force diagrams have also been measured to check the diagrams calculated with the PILEWAVE-computerprogram.

The HBM-4000 delivers more than its guaranteed kinetic energy of 120 000 lb.ft. (160 tfm) at buffer forces varying from 2500 tonforce to 4000 tonforce.

2 Design Check.
The built-in buffer protects the hammer from excessive stress and strain. At moment of impact shock-waves start to travel not only in the pile, but also in the hammer. Now peakforces are controlled by the buffer and consequently kept within acceptable limits. This makes it possible to design the various hammer parts properly on fatigue. Extensive stress and strain calculations have been performed, both statically (figure 1) and dynamically (figure 2 and 3), the latter being based on known impact speeds of the various colliding hammer-parts. Test measurements during actual piledriving have proved that these complex calculations correctly assess what happens in practice. Therefore we can be sure that the hammer is designed as a reliable tool, suitable to be used underwater during longer periods.

3 Hammer-pile-soil behaviour.
Extensive tests and measurements have been performed to determine stresses and accelerations at the top and near the toe of the pile. Soil investigation has been carried out before driving. During driving pore pressures and total soil pressures were recorded. This part of the test gathers information of a more general interest. It has been made possible through the generous support and participation of a broad international forum:

Amoco U.K. Exploration Company
Britisch Petroleum Trading Ltd.
Det Norske Veritas
Delft Soil Mechanics Laboratory
Groupe Elf-Aquitaine
Hollandsche Beton Groep
Industriële Raad voor de Oceanologie
Institut Français du Pétrole
Lloyd's Register of Shipping
Marathon Oil Company
Netherlands Offshore Company

---
hollandsche beton maatschappij bv
p.o.box 82 - rijswijk - the netherlands.
and pore pressure and total pressure measurements were made by Building Research Establishment.

Much valuable information has been gathered and the final report will be issued to the sponsors before 1 March 1979.

Now that the "WHY?" has been clarified it is time to tell something about "WHAT" you will see at the testsite. We refer to figure 4. At the site there already was available an 84 inch vertical pile (1) in fig. 4), which was used to test previous hammers. This time the test procedure called for a batter pile 7 on 1. (2) in fig. 4). During driving the inclination increased to 5 on 1 due to deformations in the soil. The inclined testpile is closed at its toe and the outer diameter is 84 inch, wall thickness 1.25 inch. During driving the pile was supported in the beginning by the means of brackets A and B connected to the vertical pile. Brackets A) and B) are removable and they were taken away and replaced again as the driving procedure progressed and successive add-ons were welded. The total length now is 71 m (235 ft.) The 7 m deep hole (3) in fig. 4) is protected by steel-piling. It can be emptied by pumping out water and it has been utilized for welding operations and it allows the hammer to drive the pile a further 5 m below ground level should that be necessary. The first 9 m of Soil consist of peat, then up to 40 m layers of clay with medium dense sands. From 40 m to 70 m we find dense sands and below 70 m clay with dispersed sand layers. A blowcount graph is added to this information-package as fig. 5.

Finally a number of maximum values are given that have been reached at any time during the testing program of some 33 hours of driving, though not all in combination. (catalog values between brackets)

| Net impact energy of ram (\(\frac{1}{2}mV^2\)) | ton.meter | 190 | (160) |
| Bufferforce maximum | tonf | 4000 | (4000) |
| | kips | 8800 | (8800) |
| Maximum blowcount | per 25 cm | 40.000 |
| | per foot | 49.000 |
| Hours effective driving | hammer 4001 | 23 hrs. 17 min. |
| on testpile (15 Febr.79) | hammer 4002 | 11 hrs. 7 min. |
Three-dimensional finite element model representing the ram of Hydroblok hammer HBM 4000. Calculations provide stress and strain in each part of the ram under various static conditions.
wedge-shaped part is \( \frac{1}{32} \) of ram cylinder

\[ \text{impactspeed of impact head onto bottom side of ram cylinder is 4.5 m/s} \]

Figure 2: Three-dimensional finite element model representing the ram of a Hydroblok hammer HBM 4000. The model includes next to stress-strain relations also mass; it is suited to perform dynamic calculations.
Figure 3: Typical result of dynamic calculation with the model shown in figure 5. All heavily loaded parts of a Hydroblok hammer are calculated in a similar way.
SLIEDRECHT PILE TEST 1978-1979

HYDROBLOK HAMMER HBM 4000

GROUND LEVEL

PEAT

- 9M.

SAND
SILT CLAY

BATTER STARTED 7:1
HOW 5:1

- 40M.

PLEISTOCENE
DENSE SANDS

- 70M.

CLAY WITH
SAND LAYERS

PILES 1 AND 2
84" O.D. - 1 ¼" W.T.
CLOSED BOTTOMS

FIG. 4

Hollandsche Beton Maatschappij BV
P.O. Box 82 - Rijswijk - The Netherlands

9.04.71
FEBR. 1979
Fig. 5.

Sliedrecht, pile test 30, 31-Oct. 1978

Penetration between (m)

Blowcount (bl/v, 25 m)

100  200

1 2 3 4 5 6 7 8 9 10 11

17 hour stop

35 hour stop

15 hour stop


Pile measurements.
SITUATION ON TEST-SITE

1st HYDROBLOK HAMMER TYPE HBM 4000 SUCCESSFULLY TESTED DURING A PERIOD OF 24 DRIVING HOURS

2nd HYDROBLOK HAMMER TYPE HBM 4000 ON BATTER TEST PILE Ø84"

VERTICAL PILE
HYDRAULIC HOSES

CRANE

PILESECTION Ø84"

TEMPORARY RECEPTION HALL

POWERPACK

GANGWAY

PONTOON

hollandsche beton maatschappij bv
p.o.box 82 - rijswijk - the netherlands.

9.04.71

FEBR. 1979
<table>
<thead>
<tr>
<th>Display B</th>
<th>Net Impact Energy of ram HBM 4000</th>
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<tbody>
<tr>
<td>ms</td>
<td>km</td>
</tr>
<tr>
<td>8.4</td>
<td>2007</td>
</tr>
<tr>
<td>8.5</td>
<td>1946</td>
</tr>
<tr>
<td>8.6</td>
<td>1885</td>
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<td>8.8</td>
<td>1826</td>
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<tr>
<td>8.9</td>
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</tr>
<tr>
<td>13.4</td>
<td>760</td>
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<td>722</td>
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<tr>
<td>14.1</td>
<td>686</td>
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</tbody>
</table>

A = BUFFERFORCE IN METRIC TONS
B = TIMESPAN \( \downarrow \) OVER SAME DISTANCE
C = TIMESPAN \( \uparrow \)
BLOWS PER MINUTE = \( \frac{60}{D} \)
THE PUPPET SYSTEM
OPERATIONAL IN 1978
PUPPET SYSTEM

HOISTROPE

PUPPET EYES

HYDROBLOK HAMMER

GUIDELINES

PILE

MUDLINE

PUPPET WEIGHT
SITUATION PIPER-FIELD
NORTH-SEA 1978

PENDANT BUOY

PENDANT WIRE

MUDLINE

RETRIEVAL BUOY

ANCHORCHAIN

PILE 60"(0.3 L=94FT

146 M (480FT)

110 FT
HYDROBLOK HAMMER

FOLLOWER

PILE
MINIMUM SPACING OF 8 4" PILES AROUND LEG OF JACKET WHEN USING A HYDROBLOK HAMMER TYPE HBM 4000
MINIMUM SPACING OF 84" PILES AROUND LEG OF JACKET WHEN USING A HYDROBLOK HAMMER (HBM 4000-SLIM TYPE)

MINIMUM CLEARANCE

820
820
300
300

R = 6387

5'PILE 84" [2134]

HBM 4000-SLIM TYPE

MINIMUM SPACING

2355

MINIMUM CLEARANCE

Hollandsche beton maatschappij bv
p.o.box 82 - rijswijk - the netherlands.

9.04.71
FEBR. 1979
Piled Anchor Point (PAP) System with self-equalizing force distribution for Tension Leg Platforms.

Hydroblok hammer driving

anchor cable, checked before submersion and coiled.

pile gimbal.
anchor plate.
base frame.

The base frame primarily serves the purpose to stabilize the anchor piles before they are driven. The anchor plate carries the anchor cable(s); the anchor cable-connection can be carefully checked and the cable is coiled before submersion. The anchor piles are driven, and a certain difference in the levels of the gimbals is acceptable. Pulling the anchor cable(s) makes the anchor plate match all gimbals, evenly distributing the anchor force to all (maximum 3) piles. The base frame from this moment on has no function anymore, as far as vertical anchor forces are concerned. Pinning the base frame firmly to the seafloor with separate piles makes horizontal components of the anchor force not work any more on the vertical anchor piles. Because of the nature in which TLP-anchor piles are cyclicly loaded, separation of horizontal and vertical force components can be advantageous.
THE PUPPET SYSTEMS

The Puppet Systems are Hydroblok's newest methods which make it possible to drive piles insupportedly. In such cases there is nothing to hold the pile upright during the first stage of its installation.

Two variations were developed (figure 1):

Number 1: A method which uses only lateral soil resistance for stabilization.

Number 2: A method where an element is added for self-stabilization, the so-called Puppet Weight.

A standard Hydroblok hammer is the integral part of the Puppet System. During driving a Hydroblok hammer sits freely on top of the pile, while the hoist is kept slack.

The sleeve guides the hammer perfectly onto the pile. This specific feature in combination with the underwater driving capability each Hydroblok hammer basically possesses, provides the elements for the Puppet System.

Puppet System method number 1 that uses lateral soil resistance only was recently described in detail (reference 1). Puppet system method number 2 will be published soon. (references 2 and 3). A short outline will be given here.

The soil-independent Puppet System number 2 (figure 1) requires two puppet-weight-guidelines, running down from the vessel, passing through the puppet-eyes, to the Puppet Weight. The latter is simply a mass, loosely slipped around the pile at a low level, thus producing a tension force in the puppet-weight-guidelines. A component of this tension force acts onto the puppet-eyes, thus stabilizing pile and hammer within certain limits which will be explained hereafter.

A puppet System operation mainly starts with the temporary connection of pile and hammer into one unit. There must be some sort of a hoist (e.g. drillstring) to lower the unit. Figure 2, stage 1, shows the pile shortly before it will touch the sea floor. Because of current-action the pile toe will not remain vertically beneath the vessel, but will deviate a certain distance $q_1$ (landing distance): 

$$q_1 = F_D \left( \frac{h-l_0}{G_1+G_2+G_3} + \frac{l_0(l_0-l_1)}{G_1(l_0-l_1)+G_2(l_0-l_2)+G_3(l_0-l_3)} \right)$$  \hspace{1cm} (1)
FD represents the resultant of all current forces on the system acting at a distance $l_D$ above the pile toe. Further symbols will be clear from figures 1, 2 and 3. The corresponding pile angle $\alpha_1$ (landing angle):

$$\alpha_1 = \frac{F_D(l_0-l_D)}{G_1(l_0-l_1) + G_2(l_0-l_2) + G_3(l_0-l_3)}$$

To make the calculations in a conservative manner, a possible position change $\Delta q$ of the vessel will be assumed to occur in the time-split between touch-down and the beginning of the pile's self-penetration (stage 3). This results in a horizontal distance $q_s$ (stabbing distance) between pile toe and vessel, with corresponding pile angle $\alpha$ (stabbing angle):

$$q_s = q_1 + \Delta q$$

$$\alpha_s = \frac{G_3 l_0 (G_1 + G_2 + G_3) - F_D l_D (h-l_0)}{h l_0 (G_1 + G_2 + G_3) - (G_1 l_1 + G_2 l_2 + G_3 l_3) (h-l_0)}$$

The position change $\Delta q$ can occur in all possible directions; it depends on the numerical value of current velocity and position change which position change represents the worst case.

Stage 3 (figure 2) shows the pile after being stabbed and the hoist is fully slackened off. The tension forces in the puppet-weight-guidelines now stabilize the system in such a way that the pile will be kept in its (stable) equilibrium position with a slight deviation from the vertical because of currents and distance $q$. The system may now undergo various position changes $\Delta q$.

Before piledriving starts the vessel may change its position to obtain a vertical position of the pile (stage 4) or if required a better one.

When the pile's position is within the required limits, the hammer will be started to operate while the Puppet Weight keeps pile and hammer upright. No dangerous shocks can be transferred into the hoist, nor in the puppet-weight-guidelines because of the slack in the hoist and the loosely guidance of the Puppet Weight around the pile. After some hammer blows the pile has penetrated the soil far enough to remain in its upright position, even without the Puppet Weight.

Figure 3 shows how the mechanical system works. For simplicity sake in first instance the following is assumed: (1) no friction between the puppet-weight-guidelines and the puppet-eyes, nor between the Puppet Weight and the pile; hence, the hoist force $T$ is equal to $G_3 \cos \alpha$; (2) the vessel remains exactly vertically above the vessel (no position change of the vessel); (3) no currents, thus $F_D=0$; (4) the Puppet Weight remains at a constant level above the sea floor, thus distance $l_3$ is constant and independently of pile angle $\alpha$.

Suppose the system to be out of balance; let $M_q$ be the moment of forces directed towards a positive value of $\alpha$, relative to the toe.
side of the pile. From statics it follows (figure 3):

\[ M_\alpha = (G_1 l_1 + G_2 l_2 + G_3 l_3) \sin \alpha + 
- G_3 l_0 \sin(\alpha - \beta) \cos \alpha \]

where \( \beta = \arctan(-\frac{l_0 \sin \alpha}{h - l_0 \cos \alpha}) \)

(5)

For a sufficient large value of \( G_3 \) (which means a sufficient heavy Puppet Weight), this curve is similar to the curves shown in figure 4 (however, symmetrical with respect to the vertical axis).

The system is in equilibrium in the positions EP and UEP, where \( M_\alpha = 0 \). Position EP is the only stable Equilibrium Position; where in this symplification \( \alpha = 0 \). Positions UEP are Unstable Equilibrium Positions. The only relevant question in this stage is whether the stable Equilibrium Position EP exists or not. From mechanics (reference 4) it follows that the system remains stable as long as \( \frac{dM_\alpha}{d\alpha} < 0 \), where \( M_\alpha \) is the moment of forces directed towards a positive value of \( \alpha \).

Derivation and linearization (small values of \( \alpha \)) of equation (5) gives for the equilibrium position where \( M_\alpha = 0 \) and \( \alpha = 0 \):

\[ \frac{dM_\alpha}{d\alpha} = (G_1 l_1 + G_2 l_2 + G_3 l_3) \alpha - \frac{G_3 l_0 h}{h - l_0} \]

(6)

Hence, the equilibrium position where \( \alpha = 0 \) is stable if:

\[ G_3 > \frac{(G_1 l_1 + G_2 l_2)(1 - l_0/h)}{l_0 - l_3(1 - l_0/h)} \]

(7)

This simple equation specifies the minimum required Puppet Weight to make the system self-stabilizing. Because of the simplifications mentioned earlier in this paragraph, this equation may only be used to assess an approximation of the required Puppet Weight; a full analysis taking into account all mentioned aspects will answer the question wether a given Puppet Weight stabilizes the system properly.

In appendix A the moment of forces \( M_\alpha \) has been derived, taking into account friction forces in the system, position changes of the vessel, currents and changes of \( l_3 \) due to a pile angle \( \alpha \). Figure 4 shows the moment of forces \( M_\alpha \) for a certain example (not specified further in this paper). When the friction forces in the system are taken into account there are two curves; one because of a downward movement of the vessel and a second one for an upward movement. In this graph the points EP, UEP, RS and URS are the important ones. Point EP is the only (stable) Equilibrium Position of the system, because of \( \frac{dM_\alpha}{d\alpha} < 0 \).

A small deviation of the system away from this position will
always cause a moment $M_\alpha$ that will direct the system back towards position EP.

Points UEP are Unstable Equilibrium Positions of the system; these points have no practical value. Points RS are to be looked upon as Re-Stab positions.

If for some reason pile angle $\alpha$ would reach one of these positions, the system will not regain automatically its (stable) equilibrium position EP when the vessel moves upwardly at that same moment; the pile must be lifted and be re-stabbed again. Does the vessel show a downward movement at that particular moment, re-stabbing could theoretically be put off until the system reaches point URS, being an Utmost Re-Stab position. In practice, however, only the position EP and RS are of interest. The other points (UEP and URS) therefore will not be considered any further in this paper.

A computer program is available to assess the points EP, RS and URS. Appendix B shows a Puppet System Analysis Sheet, available to be filled in.

**NOMENCLATURE**

\begin{align*}
\phi_i &= \text{friction coefficient between puppet-eyes and puppet-weight-guidelines} \\
\phi_3 &= \text{friction coefficient between Puppet Weight and pile} \\
F_D &= \text{resultant of drag forces on pile and hammer} \\
G_1 &= \text{weight of hammer in water} \\
G_2 &= \text{weight of pile in water} \\
G_3 &= \text{weight of Puppet Weight in water} \\
h &= \text{water depth} \\
l_0 &= \text{height of puppet-eyes} \\
l_1 &= \text{height of hammer's centre of gravity} \\
l_2 &= \text{height of pile's centre of gravity} \\
l_3 &= \text{height of Puppet Weight's centre of gravity for } \alpha = 0 \\
l_p &= \text{height of point of action of } F_D \\
\Delta l_3 &= \text{increase of } l_3 \text{ (appendix A)} \\
M_\alpha &= \text{moment of forces directed towards a positive value of } \alpha \text{ and relative to the toe side of the pile} \\
q &= \text{horizontal distance between pile toe and vessel} \\
\Delta q &= \text{increase of } q \text{ due to a position change of the vessel} \\
q_1 &= \text{ } q \text{ at pile landing (just before touch-down)} \\
q_s &= \text{ } q \text{ just before pile stabbing}
\end{align*}
\[ T = \text{total of forces in puppet-weight-guidelines} \]
\[ W_1 = \text{friction force due to } f_1 \]
\[ W_3 = \text{friction force due to } f_3 \]
\[ \alpha = \text{pile angle measured from the vertical} \]
\[ \alpha_1 = \alpha \text{ at pile landing (just before touch-down)} \]
\[ \alpha_s = \alpha \text{ just before pile stabbing} \]
\[ \beta = \text{angle of puppet-weight-guidelines, measured from the vertical} \]

REFERENCES


(3) JANSZ, J.W. and BROCKHOFF, H.S.T. "A simple Way to Drive Free-Standing Subsea Anchor Piles", to be presented at Offshore Technology Conference, 1979, OTC 3439

METHOD 1

Figure 1: The Puppet Systems

METHOD 2
Stage 1: Pile, hammer and Puppet Weight just before landing on sea floor.

Stage 2: Touch-down of pile toe; a position change of the vessel is assumed.

Stage 3: Hoist slackened off while Puppet Weight stabilizes pile and hammer.

Stage 4: Vessel changes position to obtain a vertical pile position; hammer starts operating.

Figure 2: Operation of the soil-independent Puppet System Number 2.
**Figure 3A: Friction forces**

\[ N_1 = 2T \cdot \sin \frac{\alpha}{2} \]

\[ W_1 = f_1 \cdot N_1 \]

\[ N_3 = G_3 \cdot \sin \alpha \]

\[ W_3 = f_3 \cdot N_3 \]

\[ G_3 \cdot \cos \alpha \]

**Figure 3: Mechanical system of Puppet System Number 3**
downward movement of the vessel

upward movement of the vessel

EP = (stable) Equilibrium Position
UEP = Unstable Equilibrium Position
RS = Re-Stab position
URS = Ultimate Re-Stab position

Figure 4: Puppet System Number 2, moment $M_\alpha$ versus pile angle $\alpha$ for certain example
MOMENT OF FORCES FOR PUPPET SYSTEM NUMBER 2

See figure 3. Let $M_\alpha$ be the moment of forces directed towards a positive value of $\alpha$ and relative to the pile toe. From statics it follows:

$$M_\alpha = \{G_1.l_1 + G_2.l_2 + G_3(l_3 + \Delta l_3)\} \sin \alpha +$$

$$- F_D.l_D - T.l_0.\sin(\alpha-\beta) \quad (B1)$$

where: $\Delta l_3 = l_0 - h + \frac{h-l_0.\cos \alpha}{\cos \beta}$

and: $\beta = \arctan\left(\frac{a-l_0.\sin \alpha}{h-l_0.\cos \alpha}\right)$

From figure 3A:

$$W_1 = \pm 2f_1.T.\sin h|\alpha| \quad (B2)$$

$$W_3 = \pm f_3.G_3.\sin|\alpha| \quad (B3)$$

From equilibrium of forces in the puppet-weight-guidelines:

$$T = G_3.\cos \alpha + W_1 + W_3 \quad (B4)$$

$W_1$, $W_3$ and $T$ can be eliminated from the four equations (B1), (B2), (B3) and (B4); further substitution of $\Delta l_3$ leads to $M_\alpha$ as a function of known parameters and pile angle $\alpha$:

$$M_\alpha = G_1.l_1 + G_2.l_2 - F_D.l_D +$$

$$+ G_3\{(l_3+l_0-h + \frac{h-l_0.\cos \alpha}{\cos \beta}) \sin \alpha +$$

$$- G_3.l_0\left(\frac{\cos \alpha \pm f_3.\sin|\alpha|}{1-(\pm 2f_1.\sin|\alpha|)}\right) \sin(\alpha-\beta) \quad (B5)$$

where: $\beta = \arctan\left(\frac{a-l_0.\sin \alpha}{h-l_0.\cos \alpha}\right)$

The sign in these equations to be chosen positive for an upward movement of the vessel and negative for a downward one.
# PUPPET SYSTEM ANALYSIS SHEET

## INPUT

<table>
<thead>
<tr>
<th>Sea</th>
<th>Water depth [ ]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current at hammer level at touch down [ ]</td>
</tr>
<tr>
<td></td>
<td>Current at surface [ ]</td>
</tr>
<tr>
<td></td>
<td>Current near sea-bottom [ ]</td>
</tr>
</tbody>
</table>

- **Vessel**
  - Type (e.g. barge, drillship)
  - Positioning method (e.g. anchors, dynamically)
  - Expected position changes of vessel [ ]

- **Pile**
  - Steel, circular cross section, hollow, open-ended:
    - Outside diameter [ ]
    - Wall thickness [ ]
    - Length [ ]
  - Other types:
    - Type (e.g. square, circular, two parts)
    - Length [ ]
    - Weight above water [ ]
    - Water displacement [ ]
    - Frontal area (for current forces) [ ]

- **Hammer**
  - Please circle appropriate type:
    - HBM 500/HBM 900/HBM 1500/HBM 3000A/HBM 4000

## RESULTS

**Puppet Weight:** steel, weight above water [ ]

<table>
<thead>
<tr>
<th>Pile landing distance ( q_p ) m</th>
<th>upstream position change</th>
<th>downstream position change</th>
<th>position change perpendicular to current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pile landing angle ( \alpha_p ) deg</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>Pile stabbing distance ( q_s ) m</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>Pile stabbing angle ( \alpha_s ) deg</td>
<td>deg</td>
<td>deg</td>
<td>deg</td>
</tr>
<tr>
<td>Equilibrium Position EP deg</td>
<td>deg</td>
<td>deg</td>
<td>deg</td>
</tr>
<tr>
<td>Re-Stab positions RS deg</td>
<td>deg</td>
<td>deg</td>
<td>deg</td>
</tr>
<tr>
<td>Ultimate Re-Stab positions URS deg</td>
<td>deg</td>
<td>deg</td>
<td>deg</td>
</tr>
<tr>
<td>Smallest angle between EP and RS deg</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Computer run nr:** [ ]

**Executed by:** [ ]

**Verified by:** [ ]

---

*hydroblok* hollandsche beton maatschappij bv

p.o.box 82 - rjswijk - the netherlands
HYDROBLOK references:


(3) JANSZ, J.W. "Underwater Piledriver for 1000-ft Depth", Ocean Engineering, 1975, November 15, pp. 68-76


(6) JANSZ, J.W. "North Sea Pile Driving Experience With a Hydraulic Hammer", Offshore Technology Conference 1977, OTC 2840

(7) HUSSEN, K. van "Submarine Piledriving for Deepwater Installations", Ocean Resources Engineering, September 1977, pp. 60-65

(8) McNALLY, R. "Extending the Limits of Platform Technology", Ocean Resources Engineering, November 1977, pp. 4-10


(10) "Cognac Launch Technology An Offshore Landmark", Offshore Engineer, October 1978, pp. 18-20


(12) "Controlled Hydraulic Piledriving". Consulting Engineer, January 1979, pp 48-52


(14) JANSZ, J.W. and BROCKHOFF, H.S.T. "A simple Way to Drive Free-Standing Subsea Anchor Piles", to be presented at Offshore Technology Conference, 1979 OTC 3439

(15) JANSZ, J.W. "Underwater Piledriving; Todays Experience and What is About to Come", to be presented at Second International Conference on Behaviour of Offshore Structures, August 1979
Note: Only proven conceptions are proposed herein.
INTRODUCTION

PART 1

THIS SET OF SKETCHES INDICATES THE ALTERNATIVE POSSIBILITIES OF HYDROBLOK HANDLING

CONTENTS

- SITUATION
- EXTENDER
- CONNECTION BETWEEN PILE, EXTENDER AND HYDROBLOK HAMMER
- HYDROBLOK DRIVING UNDERWATER, USING THE HAMMERCASING AS A DIVING BELL
- HOSE HANDLING
- YOKE FRAME FUNCTION
- WEIGHTS
- REELS (FOR HOSES AND ELECTRIC CABLE)

SHEET

- S1
- 31.32
- 31.34
- 41
- H1-H6
- Y1-Y4
- W1
- 81-83

SHEET S1 INDICATES THE SITUATION AS WE ASSUMED
ALL BASIC ITEMS FOR HYDROBLOK DRIVING ARE INDICATED
ITEMS INDICATED BY A QUESTION MARK ARE SUBJECT TO DISCUSSION

PART 2

Sheets 0400.00 - 130 UPTO AND INCL 152

GENERAL PILE - AND HAMMER HANDLING

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SITUATION BROWN & ROOT
VEROLME ENGINEERING COMPANY PROJECT: 79083

POWERPACK
VESSEL Z

REELS

CONNECTION BETWEEN REELS AND POWER PACK
HYDRAULIC HOSES AND ELECTRIC CABLE
[FOR HOSE HANDLING SEE SHEET 41.46]

HATCH?
[SEE SHEET NG]

Yoke Frame?
[SEE SHEET Y1.74]

HOSE GUIDE?

CONNECTION BETWEEN PILE AND HAMMER?
[SEE SHEET C1.66]

EXTENDER?
[SEE SHEET E1.62]

MUDLINE

INITIAL PENETRATION

SHEET: S1

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HYDROBLOK DRIVING SYSTEMS USING THE EXTENDER

---

HYDROBLOK HAMMER

---

STRUCTURE

---

EXTENDER

---

STRUCTURE

---

HYDROBLOK HAMMER

---

PILE

---

PILE TOP ABOVE STRUCTURE

---

PILE TOP INSIDE STRUCTURE

---

PILE TOP ABOVE MUDLINE

---

PILE TOP BELOW MUDLINE

---

SEE ALSO SHEET E2

---

SHEET E1
HYDROBLOK DRIVING SYSTEMS: WITH/WITHOUT THE USE OF THE EXTENDER

HYDROBLOK HAMMER RETRIEVED AFTER DRIVING

EXTENDER

STRUCTURE

PILES DRIVEN TO FINAL PENETRATION

SHEET: E2
HOW TO CONNECT PILE, EXTENDER AND HYDROBLOK HAMMER

SUCH CONNECTIONS CAN BE USED WHEN HYDROBLOK HAMMER, EXTENER AND/OR PILE ARE JOINTLY LOWERED TO SEAFLOOR

NO CONNECTION

CONNECTION BY LOCKING PIN OR SHEARPin (DIVERLESS DISCONNECTING)

SHEET: C1
CHAIN CONNECTION BETWEEN PILE, EXTENDER AND HYDROBLOK HAMMER.

NO CONNECTION

CONNECTION BY CHAINS
AFTER DRIVING DISCONNECTION OF CHAINS
[BY DIVERS?]
- Locking pins released [remotely controlled]
- Hydrobloc hammer lifted from pile top

Retrieving of hammer without pile or extender
HYDROBLOK HAMMER SITS FREELY ON TOP OF PILE
- PILE SUPPORTS HAMMER
- LOCKING PINS [GRIPPING] ARE FREE OF THE PILE

SITUATION AFTER STABBING: READY FOR DRIVING
LOCKING PINS IN PILE SLEEVE

- PILE IS SUPPORTED BY THE LOCKING PINS
- ANVIL RESTING ON PILE SLEEVE
- GAP BETWEEN RAM AND ANVIL
- GAP BETWEEN ANVIL AND PILE TOP

SITUATION DURING LOWERING TO SEAFLOOR

SHEET: C5

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SHEAR PIN CONNECTION BETWEEN EXTENDER AND PILE

SHEAR PIN WITHSTANDS ALL FORCES DURING HANDLING

SHEAR PIN SHEARED OFF AFTER FIRST BLOW OF HYDROBLOK HAMMER
HYDROBLOK DRIVING UNDERWATER, USING THE HAMMERCASING AS A DIVING BELL

AIR SUPPLY HOSE
WATERSURFACE

HAMMER CASING

RAM CYLINDER

ALL STEEL ANVIL

PILE

MUDLINE

SHEET: G1

HYDROBLOK

0400.00.109
APRIL 79
HYDROBLOK DRIVING ABOVE WATER

HOIST
SLING SLACKED OFF
BEFORE DRIVING CAN
START [YOKE FRAME
FUNCTION]
HYDROBLOK HAMMER

PILE
SLING KEPT SLACK
DURING DRIVING
[YOKE FRAME FUNCTION]

HOSES TO
POWERPACK

PILE DRIVEN TO
FINAL PENETRATION

SHEET: H1

APRIL 75
UNDERWATER DRIVING WITH FIXED HOSELENGTH

POWERPACK

VEssel

HOIST

Hose Loop

Hose Guide

Mudline

Pile driven to Z

Final Penetration

SHEET: H2
UNDERWATER DRIVING WITH VARIABLE HOSELENGTH PAID OUT

NOTE: DEPTH MEASURING PROVISIONS FOR HOSE REEL CONTROL ARE NOT INDICATED.
Hose Handling and 'Yoke Frame' Function Combined

[Vessel] -> [Constant Tension Reel] -> [Heave]

- Hoses Under Constant Tension
- Hoist
- Hoses Fixed to Yoke Frame (for swivel see also Sheet H9)
- Hoses Loopwise
- Yoke Frame (Type A)
- Hydroblok Hammer
- Pile
- Mudline

Sheet: H4

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Hose handling and 'Yoke Frame-Function' Combined

- Hoist
- Reel or Guideswage
- Vessel
- Ball Valve
- Swivel
- Telescoping Unit 'Yoke Frame-Function' Type 3
- Hoses
- Guide
- Hydroblok Hammer

Sheet: H5

Hydroblok
PROVISIONS TO AVOID HOSE-OR CABLE DAMAGE IN ROUGH WATER.

(TO AVOID THE 'HOSE BUNDLE' TO TANGLE IT HAS TO BE GUIDED OR KEPT UNDER CONSTANT TENSION, DEPENDING ON AMBIENT FORCES A COMBINATION OF BOTH MAY BE NECESSARY. CONSTANT TENSION IS ALSO NECESSARY WHEN IT IS DIFFICULT TO CONTROL THE SIMULTANEOUS PAYOUT OF THE SEPARATE REELS.)

TO REEL TO CONSTANT TENSION REELS SLACKENED HOIST

RIGID HOIST [E.G. PIPE]

Hose guide, connected to hoist, allowing free passage of hoses and cable.

LOOPWISE TO HYDROBLOK HAMMER

STRAIGHT TO YOKE FRAME OR OTHER SIMILAR MEMBER

Sheet: H6
UNDERWATER DRIVING OFFSHORE BASICALLY REQUIRES THE 'YOKE FRAME FUNCTION'

TYPE A = REAL YOKE FRAME

VEssel

MASS_SYSTEM A

STROKE

HYDROBLOK HAMMER

MASS_SYSTEM B

PILE

MUDLINE

SHEET: Y1

HYDROBLOK

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TYPE B: CENTRAL TELESCOPING UNIT

VESSEL

HARV

SHOIST

MASS. SYSTEM A

TELESCOPING UNIT

STROKE

HYDROBLOK HAMMER

MASS. SYSTEM B

PILE

MUDLINE

SHEET: Y2

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TYPE C: SLACKED HOIST

VESSEL

HOIST

MASS. SYSTEM A

HYDROBLOK HAMMER

MASS. SYSTEM B

PILE

MUDLINE

SHEET: Y3
HANDLING PROPERTIES OF THE 3 TYPES OF 'YOKE FRAME - FUNCTIONS'

**TYPE: A**
- Hoist
- Stroke: 15'
- Yoke Frame
- Sling
- Spile

**TYPE: B**
- Hoist:
- Stroke: 15'
- Telescoping Unit
- Yoke Frame
- Sling
- Spile

**TYPE: C**
- Hoist
- Stroke: 15'
- Sling
- Spile

YOKE FRAME MUST BE RETRACTED AND LOCKED

NO SPECIAL REQUIREMENT

NO SPECIAL REQUIREMENT

FOR HOSE CONNECTIONS SEE SHEET

SHEET: Y4
WEIGHTS OF HYDROBLOK HAMMER HBM 3000A INCLUDING 'YOKER FRAME' FUNCTION

WEIGHT IN AIR [METRIC TON]

**TYPE - A:**
- HAMMER + YOKE FRAME: 225 TON
- BALLAST FOR UNDERWATER USE: 16 TON
- TOTAL: 241 TON

**TYPE - B:**
- HAMMER + CENTRAL TELESCOPING UNIT: 164 TON
- BALLAST FOR UNDERWATER USE: 22 TON
- TOTAL: 216 TON

**TYPE - C:**
- HAMMER: 188 TON
- BALLAST FOR UNDERWATER USE: 25 TON
- TOTAL: 213 TON

**NOTE:**
Buoyancy of the hammer in water 73 TON

TOTAL WEIGHT IN WATER [METRIC TON]

**TYPE - A:** 168 TON
**TYPE - B:** 143 TON
**TYPE - C:** 140 TON

SUBJECT TO MODIFICATION
HOSE REEL FOR HOSE 4" I.D. [OIL SUPPLY AND RETURN]

STANDARD FOR 900 FT. HOSE

18' [5400 MM]

67" [1700 MM]

BALL VALVE SWIVEL

HYDRAULIC MOTORS

HYDRAULIC POWER UNIT

TO HAMMERS

TO POWERPACK

12' [3600 MM]

WEIGHT EXCL. HOSE 60000 LBS (27 T)

OPTIONAL GUIDE SHEAVE AND SPOOLING DEVICE

SPOOLING DEVICE

[TRAVELLING] GUIDE SHEAVE

TO HAMMER

SHEET: R1
Hose Reel for Hose 1/4" I.D. [Buffer and Air Hose, Continuous Length]

Standard for 900 FT Hose

48" 1200MM

130" 3300MM

Swivel Ball Valve

Hydraulic Motor

Hydraulic Power Unit

To Powerpack

To Hammer

Weight Excl. Hose 1300 lbs (6T)

Optional Guide Sheave and Spooling Device

Spooling Device

[Travelling] Guide Sheave

To Hammer

Sheet: R2

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ELECTRIC CABLE REEL

STANDARD FOR 900FT HOSE 67"

106" (2700MM)

SLIPPING

TO POWERPACK

HYDRAULIC MOTOR

HYDRAULIC POWER UNIT

75" (1850MM)

WEIGHT EXCL. CABLE 1000 LBS [ST.]

OPTIONAL GUIDESHEAVE
AND SPOOLING DEVICE

SPOOLING DEVICE

[TRAVELLING] GUIDE SHEAVE

TO HAMMER 2

SHEET: R3

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TRANSPORTATION OF PILES

PILE FLOATED TO LOCATION [IN CALM WATER]

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TRANSPORTATION OF PILES

PILES LOADED ON BARGE

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PILE SUPPORTED IN OUTRIGGER, HYDROBLOK HAMMER LIFTED ON TOP OF PILE.
HYDROBLOK HAMMER CONNECTED TO PILE

HYDROBLOK HAMMER
HAMMER-PILE CONNECTION
OUTRIGGER

PILE

hydroblok
HYDROBLOK HAMMER AND PILE LOWERED JOINTLY UNDER WATER
STABBING SYSTEM WITH GUIDELINES
PILE AND HYDROBLOK HAMMER JOINTLY LOWERED

GUIDE LINES
(CONSTANT TENSION)

HOISTROPE

GUIDE

HYDROBLOK HAMMER

PILE

SOFT LINE
TO BE CONNECTED AND/OR DISCONNECTED BY DIVERS

SLEEVE

MUDLINE

STRUCTURE

THIS SYSTEM DOES NOT REQUIRE AN ACCURATE POSITIONING SYSTEM OF THE VESSEL
NOTE: HOSE HANDLING NOT INDICATED

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0400.00.137
RELANDING OF HYDROBLOK HAMMER

GUIDELINES
(CONSTANT TENSION)

PILE

SLEEVE

MUDLINE

STRUCTURE
SITUATION DURING DRIVING

GUIDELINES (CONSTANT TENSION)

HOIST

SLING SLACKED OFF

GUIDES

HYDROBLOK HAMMER

PILE

SLEEVE

MUDLINE

STRUCTURE
GUIDELINE REPLACEMENT SYSTEM

PILE TO BE STABBED

SOFT LINE

GUIDE LINES

REMOVABLE GUIDELINE STATIONING

STRUCTURE

MUDLINE

PILE TO BE STABBED

SOFT LINE

GUIDE LINES

GUIDELINE STATIONING REMOVED

STRUCTURE

PILE DRIVEN

MUDLINE
STABBING WITHOUT GUIDELINES
PILE AND HYDROBLOK HAMMER JOINTLY LOWERED

NOTE: ANTI-ROTATION PROVISIONS AND HOSE HANDLING NOT INDICATED

THIS SYSTEM CAN BE USED WHEN THE VESSEL AND/OR HOIST HAS A GOOD MANOEUVRABILITY.
THE TV-CAMERA WATCHES THE MOVEMENT OF THE PILE-TIP IN RESPECT OF THE STRUCTURE
RELANDING OF HYDROBLOK HAMMER

HYDROBLOK

HANGER

R.C.V.

PILE

SLEEVE

MUDLINE

STRUCTURE
T.V. CAMERA SYSTEM RUNNING ALONG GUIDELINES

DETAIL ACC. P

HOIST AND ELECTRIC CABLE

GUIDE LINES

GUIDE FRAME

CAMERA

GUIDELINES S CONSTANT TENSION

T.V. CAMERA [SEE DETAIL]

BALLAST BLOCK

STRUCTURE

MUDLINE

hydrobloc

APRIL '79
RCV-225: A Production, Field Proven Remote Controlled Vehicle System

FEATURES:
- Low light level, long distance TV viewing
- Precise RCV control for close up inspection
- Fast, safe system set-up and deployment
OPEN CATCH TO AVOID DAMAGE TO A STRUCTURE WHEN STABBING WITHOUT GUIDELINES

PILE LOWERED EXCENTRICALLY IN RESPECT OF SLEEVE PILE. BY MANOEUVRING IN X, Y AND Z DIRECTION THE PILE IS STABBED INTO THE GUIDEBELL

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0400.00.145
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ELEVATOR SYSTEM DESIGN PHILOSOPHY

VESEL

GUIDELINES

ELEVATOR LINES

LARGE MISALIGNMENT

SMALL MISALIGNMENT

ELEVATOR

S'PILE

STRUCTURE

MUDLINE

S'PILE

STRUCTURE
PILE, HANGING FROM ELEVATOR, STABBED INTO A STRUCTURE
Lowering Hydroblok Hammer to Pile Top Using the Elevator Lines as Guidelines
HAMMER LANDED ON TOP OF PILE
SITUATION DURING DRIVING

VESSLE

HOIST
ELEVATOR LINES

SLING SLACKED OFF
GUIDE
HYDROBLOK HAMMER
GUIDE
ELEVATOR

PILE

STRUCTURE

MUDLINE
PILE DRIVEN TO FINAL PENETRATION
HAMMER RETRIEVED
ELEVATOR REMOTELY UNLOCKED AND RETRIEVED

VEssel

ELEVATOR LINES

ELEVATOR

STRUCTURE

MUDLINE

PILE

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