Wave Energy Group

Fifth Year Report
Volume 2 Drawings

November 1979
LIST OF DRAWINGS

I 1001  Artists Impression
I 1002  G.A. of 10m Duck (25m wide)
I 1003  G.A. Flywheel Assembly
I 1004  G.A. Spine Joint
I 1005  Schematic of Power Cable Take-Up
I 1006  Ring Cam Pump Assembly
I 1007  Plan View Ring Cam Pump Assembly
I 1008  Hydraulic System Schematic
I 1011  Schematic Flow Diagram - Spine Joint Control
I 1013  Proposed Construction Site
I 1014  G.A. Mooring System

F 73101  Variable Axial Pump/Motor with Computing Auto Control

L 2001  Spine Design - bending moments vs strain
L 2002  Spine Design - concrete stress vs strain
L 2003  Spine Design - prestressing steel stress vs strain
L 2004  Spine Design - S-N diagram for plain concrete
L 2005  Spine Design - S-N diagram for prestressing steel
L 2006  Spine Design - bending movement and joint angles on wave height distribution diagram

L 2011  G.A. Spine
L 2012  Details of Spine
L 2021  G.A. 10 m Concrete Duck
L 2022  G.A. 10 m all Steel Duck
L 2023  Design Calculations - 10 m Concrete Duck
L 2024  Design Calculations - 10 m Steel Duck
L 2025  Comparison between a 10 m and 12 m Concrete Duck
L 2026  Details of Concrete Body of Duck
L 2031  G.A. of Casting Yard and Assembly Area
OUTLINE OF POWER MODULE: SUMP

1. HYDRAULIC MOTOR
   - P.S. - 2000
   - SPEED - 1500 RPM

2. HORIZONTAL MOUNTING
   - SUPPORT BASED ON "Spherical Plain Bearings"
   - SUPPORT BASED ON "FLYWHEEL SUPPORT STATURE"

3. TIP SPEED - 30 m/s

G.A FLYWHEEL ASSEMBLY

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PLATE MOUNTED TO GYRO ASSEMBLY

CAM RING INNER FACE

CAM RING OUTER FACE

D' PLATE MOUNTED TO OIL RING MAIN

DISPLACED SPHERICAL CENTRE

LOW PRESSURE OIL RING MAIN

HIGH PRESSURE OIL RING MAIN

DO NOT SCALE THIS DRAWING

POWER MODULE SHELL

PUMPS P3248

PUMPS P3248
PILOT CONTROLLED NON-RETURN VALVE

PRIMARY HYDRAULIC RING CAM CYLINDER

RING CAM

PRIMARY HYDRAULIC RING CAM CYLINDER

SUMP PUMP

207 BAR (CONSTANT)

POWER TO GENERATOR

EXCESS POWER TO FLYWHEEL

HYDRAULIC MOTOR

FLYWHEEL

HYDRAULIC MOTOR

HYDRAULIC MOTOR

GENERATOR

SUMP
NOTE:
The curve represents the short-term stress-strain relationship for 50 N/mm² concrete (SPHO)

CONCRETE STRESS RANGE FOR
M = 20 x 10⁶ N/mm²
T.m. = 11.0 N/mm

CONCRETE STRESS RANGE FOR
M = 30 x 10³ N/mm²
T.m. = 17.3 N/mm²
NOTE:

THIS CURVE REPRESENTS THE STRESS STRAIN RELATIONSHIP FOR 18 mm 276FORM STRAND (BRIDON WIRE LIMITED).

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Drawing Title:  -- SPINE DESIGN --
PRESTRESSING STEEL STRESS vs. STRAIN

Project No: PAD 100

Drawn: CJB  Date: oct 79
Rev: L  Date: 2003

LOAD P (Kn)
STRESS σ (N/mm²)

ULTIMATE LOAD 360 Kn. (1700 N/mm²)

STEEL STRESS RANGE 1085
FOR M=20 x 10⁶ Tm=0.3 N/mm²

STEEL STRESS RANGE 1121
FOR M=30 x 10⁶ Tm=157 N/mm²

TENSILE STRAIN εₜ
NOTE:
The S-N curves shown have been taken from Abeles Symposium 'Fatigue of Concrete' (ACI Publication SP-41, Sect SP41-1, Fig. 2 p.10)

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Project No: PAD 100  L  2004

Drawing Title: — SPINE DESIGN —
S-N Diagram for Plain Concrete

Scale: 1:20

Drawn: GJB  Date: OCT 79

Checked: Date:
The S-N curves shown relate to 18mm of 'DYFORM' strand and have been obtained from information supplied by Braidon Wire Limited.

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--- SPINE DESIGN ---
S-N DIAGRAM FOR PRESTRESSING STEEL

AVERAGE OF CYCLES TO FAILURE, N

Note:

10
10^2
10^3
10^4
10^5
10^6
10^7
10^8

STRESS RANGE S
(as a proportion of ultimate)

10
0.8
0.6
0.4
0.2

slope of curves estimated

\( \sigma_{\text{max}} \)

0.8

30 \times 10^6 \text{ Nm}

bending moment

20 \times 10^6 \text{ Nm}

bending moment
WATER LEVEL = .,. ,
flange providing restraint against horizontal movement of duck.

SECTION A-A
SCALE 1:100

SECTION B-B
SCALE 1:100
(DETAILS OF HOOKES JOINT OMMITTED FOR CLARITY)

SECTION C-C
SCALE 1:100

PLAN VIEW OF ZIG-ZAG ARRANGEMENT
FOR DUCK STRING
SCALE 1:1500
PRESTRESSING DUCT

DETAILS OF MALE END
SCALE 1:100

DETAILS AT CENTRE OF SPINE
SCALE 1:100

DETAILS OF FEMALE END
SCALE 1:100

TYPICAL DETAIL OF SPINE WALL
SCALE 1:20

NOTE:
Reinforcement in diaphragms to be 1/16 at 200 mm intervals, both faces.

7-strand S.C.O. multigrip anchor

7-mm strands grouted into duct.

TYPICAL DETAIL OF SPINE WALL
SCALE 1:20

NOTE:
Reinforcement in diaphragms to be 1/16 at 200 mm intervals, both faces.

S.C.O. multigrip 7-strand anchorage system
anchorage at 282 BC round complete perimeter of spine.

PRESTRESSING TENDONS are 18 mm dia. 7-wire dyform strands.

ELEVATION X—X
SCALE 1:5

NOTE:
Prestressing tendons are 18 mm dia. 7-wire dyform strands.

ELEVATION Y—Y
SCALE 1:5

NOTE:
Prestressing tendons are 18 mm dia. 7-wire dyform strands.

40 mm dia. Macalloy bolts in pairs at 282 BC

ends of prestressing strands
wedges (in three pieces)
Macalloy bolts

NOTE:
Prestressing tendons are 18 mm dia. 7-wire dyform strands.
**Structural Details**

- **Connections**
- **Cable Duct** contains seawater.
- **Diaphragms** filled with fresh water containing anti-corrosion inhibitors.
- Solid concrete diaphragms 2 1/2' thick at each end 3/4' thick.

**ISOMETRIC VIEW**

**Mechanical Components**

**Notes:**
1. Concrete to be Grade 50 lightweight concrete using lightweight aggregate & normal sand.
2. Steel to be Grade 93.
3. Diaphragm segments to be prestressed.
4. All steel to be Grade 93.
5. End diaphragms removed to show voided construction.

**CONSTRUCTION DETAILS**

- **Box Beam**
- **Concrete Body**
- **Steel Beak**
- **Rubber Diaphragm**
- **Cable Reel**
- **Longitudinal Toli**
- **Steel Pipe** 3" thick.
- **Steel Shell** 3/16" thick.
- **Diaphragms** 2 1/2' thick.
- **Conc...
END PLATE REMOVED TO SHOW BUOYANCY CHAMBERS AND PRESSURE VESSEL

STEEL SECTION

9.8m DIAMETER PRESTRESSED CONCRETE SPINE

BUOYANCY CHAMBERS-STEEL PIPES FILLET WELDED TO 16mm THICK DIAPHRAGM WALLS

CONSTRUCTION

DUCK HELD TO SPINE BY 200mm WIDE STEEL BELT OF BOX-GIRDER CONSTRUCTION—TWO PER DUCK

NOTES
1. DUCK IS BASED ON THE 10m MODEL
2. STATIC FRESH WATER TO CONTAIN A FLUID OR FLUIDS SUITABLE FOR PREVENTION OF CORROSION AND FREEZING.
3. STEEL TO BE GRADE 43
NOTES

1. Concrete to be grade 50 lightweight concrete using light aggregate and natural sand fines and having a minimum cement content of 480 kg per m³, and a maximum saturated density of 19 kN per m³.

2. Fresh water to contain corrosion and freezing inhibitors.

3. All steel to be grade 43 except for mechanical items.

QUANTITIES PER DUCK

1. Steel in generators + gyroscopes 130 tonne
2. Steel plate in pressure vessel 91 tonne
3. 3 steel pipes in beak 13 tonne
4. Steel plate in beak shell diaphragm + ribs 63 tonne
5. Reinforcing steel at 120 kg per m³ cube 41 tonne
6. Prestressing steel: 21 cables, each having
   5° 1.8 mm Ø, 
   2133 m of 18 mm strand
7. Concrete: 337 m³ lightweight + 30 m³ dense (for ballast)
8. Fresh water + corrosion inhibitor 125 tonne

ITEMS & TONNE DESCRIPTION

<table>
<thead>
<tr>
<th>ITEMS</th>
<th>TONNE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buoyancy</td>
<td>-1169</td>
<td>Submerged volume = 45.722 x 25 x 1143 m³</td>
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</table>
| Steel    | +211  | 4% gyroscopes at 2.5T = 100
        |       | 2% gyroscopes at 10T = 20
        |       | 4.8 m O.D. pressure vessel with 22mm walls
        |       | 50mm end plates + 1.5T vessel stiffeners, ribs
        |       | 15x13 @ 0.16 at 1.8 at 1.31 |
|          | +50   | Piping 2 at 820 x 8 thick |
|          |       | 1 at 950 x 9 thick 8/3 |
|          |       | BEAK SHELL AND STIFFENERS |
|          |       | 2.5x20x0.1x.64 | 3.7 |
|          | +14.3 | STEEL DIAPHRAGM at = 80 |
|          |       | (33)x 4.9 @ .16x .4 @ 18 |
|          |       | ENCLOSED FRESH WATER |
|          |       | 4.98x25 | 1.0 + 1.8T |
|          |       | 1.58 |
|          |       | 6.896 | 5.198 |
| Concrete | +127  | DIAPHRAGMS 6.000 thick |
|          |       | 2 internal each end |
|          |       | 27.75x2.4x1.1136 |
|          |       | REMAINING BODY 22.6 m |
|          |       | 11.98x22.6x1.08 @1.61T |
|          | +514  | 3.628 | 2.929 |
|          |       | 3.389 | 2.541 |
| Electric | +11   | CONCENTRIC CYLINDERS |
|          |       | 133x2.4x12x10x10 @1.1T |
| Cable    |       | 6.328 | 0.403 |
| Reel     |       | 6.328 | 3.830 |
| Ballast  | 93    | TO BE POSITIONED TO ACHIEVE THE CORRECT FLOATING ATTITUDE |
|          |       | 6.328 | 3.977 |
| Weight   | +1322 | NOTE COF 20° BELOW 4 |
|          |       | 4.986 | 3.503 |
| Submerged |      | 52.593 = 25 x 1.005 |
|          |       | 5.014 | 3.977 |

A Scale Corrected from 1.75

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Design Calculations for 10m Concrete Duck

Project No: PAD 100

Scale: 3:200
Loads in Metric Tonnes: PAC - 06/99
NOTES

1. STEEL TO BE GRADE 43, EXCEPT MECHANICAL ITEMS.
2. STATIC FRESH WATER TO CONTAIN CORROSION 4 FREEZING INHIBITORS
3. B = CENTRE OF BUOYANCY G = CENTRE OF GRAVITY
   [AT 4.998, 3.003]
NOTES
1. THERE IS NO ALLOWANCE IN CONCRETE WEIGHTS FOR ANY DIAPHRAGMS.
2. INDICATIONS ARE THAT ALLOWING FOR DIAPHRAGMS, AT LEAST A 60% VOID RATIO WOULD BE REQUIRED FOR A VIALBE DUCK DESIGN.
3. THIS DRAWING IS FOR HUB DEPTH = 0.65 x DIAMETER AT 27.962°; LATEST REQUIREMENTS ARE FOR HUB DEPTH = 0.65 x DIAMETER AT 37°.
TYPICAL SECTION OF DUCK ASSEMBLY
SCALE 1:100

position of intermediate diaphragms to be determined by layout of gyroscopes in power module.

DETAIL SECTION OF CONCRETE BODY
SCALE 1:50

Attachment points for steel beak to concrete body

DETAILS OF CONCRETE BODY OF DUCK

SECTION A—A
SCALE 1:100

SECTION C—C (THROUGH INTERMEDIATE DIAPHRAGM)
SCALE 1:50
Dock gates

Gantry for positioning duck retaining straps

Duck with slight negative buoyancy is winched up onto floating spine beam

3200t capacity 'syncrolift' or similar ship lift

Assembly basin

SECTION C-C

150t capacity gantry

500t capacity 'syncrolift' or similar ship lift

Assembly and stressing beds

SECTION B-B

300m approx

UNIT FOR ROTATING SEGMENTS

SECTION A-A

Traversing pit

Steel beam positioned and concrete segments attached, mechanical installation

Casting beds for duck segments

Gantry rails

Gantry for lifting and transporting segments

3no spine buffer stores and electrical installation beds

3no lines of 7 casting beds

Transfer platform winched sideways on skates

Traversing track for rotating unit

Plan View of Casting Beds and Assembly Areas

Metres: 0 10 20 30 40 50 60 70 80 90 100