

STRIDE PROJECT – Steel Risers in Deepwater Environments – Recent Highlights

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Introduction

In recent years the focus of this joint industry project has been towards steel simple catenary risers (SCR's), of welded construction, typically in water depths over 3000 ft. As more of these risers are deployed worldwide, STRIDE has moved from feasibility and primary design aspects, towards design refinement and development economics. 2H Offshore Engineering are the initiator and Lead Engineering Contractor for the project.

This paper presents information relating to three activities conducted in recent times within the STRIDE JIP:

1. Large scale test programme simulating the touch down area of a steel SCR at a tidal harbour location, simulating riser motions, looking at trenching effects and riser/seabed interaction.
2. Vortex induced vibration (VIV) monitoring of the gas export SCR at Allegheny, a mini TLP at which currents were logged up to 2 knots
3. Tow tank tests looking at VIV on a model SCR, 12.5m long, and subject to current from different incident directions.

1. SCR-Seabed Interaction

This activity relates to a significant area of uncertainty within SCR design – how the dynamic SCR interacts with the seabed. Deepwater seabeds are usually very fine and soft clay. ROV videos of installed SCR's show significant seabed trenching in the dynamic riser area, often 4 to 5 ft deep, sometimes with back-fill. In April 2000 a test programme was set up to look at whether riser seabed interaction might produce localised stress hot-spots due to soil suction or trench interaction.

The riser simulated is shown in Figure 1 – a spar SCR in 1000m water depth. FEA analysis was used to predict riser motions at the touchdown area due to environmental loading on the spar (ignoring soil suction). Then a second analysis model was set up of a cut-down riser that could be more easily simulated on test – Figure 2 – and the input motions at the top end were adjusted to produce riser motions at the seabed similar to the full-scale case.

A tidal harbour location was found in the west of England that had seabed properties similar to the deepwater Gulf of Mexico, and this allowed the cut-down model to be set up – Figure 3. An actuator unit at the top end – Figure 4 – provided the required motions simulating spar drift and wave motions. Strain gauges along the riser recorded the local bending moment for different actuator motions – Figure 2.

Over a period of about a month, different tests were performed on the cut-down SCR, at low tide and high tide, and simulating the different wave and drift motions for the full scale riser. Figure 5 shows strain gauge readings from a spar fast drift simulation, as might be seen from a failed spar mooring line in a storm. Some of the strain gauge positions show a non-smooth transition from the starting bending moment (spar at “near” position) to the final (“far” position). There is a suction “peak” in evidence, (actually an inverted peak here, relates to a sag-type bending moment on the riser). This peak is made clearer when the riser is laid down again at exactly the same rate – the lift shows the peak, the laydown does not, and this adds confidence to the conclusion that this is a soil suction effect. Figure 6 shows this comparison for some of the strain gauge positions.

It seems that as the riser is lifted from the seabed, a suction peak races along the riser at ~1 m/s as the soil-riser suction causes a local tightening in the radius of curvature. This peak grows and fades as it passes along the riser. Figure 7 shows an example of this. For this test the top of the pipe was below the mudline and the trench had been backfilled by hand with seabed material to simulate trenches seen offshore. The test then simulated the fast drift as before, and the strain gauge with the highest peak is plotted.

Towards the end of the test programme, tests were also conducted on a simulated rigid seabed, by actuating the riser on top of a steel walkway placed on the harbour floor under the riser. These tests did not show the suction peak identified in Figure 7. Figure 8 shows bending moment traces from strain-gauges at different riser positions along the test pipe. It can be seen that the lift and lay-down strain gauge curves are almost identical. This indicates that the suction peaks seen on other tests were due to soil suction, and not a result of the actuation system or hysteresis/inertia effects.

Work is ongoing within STRIDE phase 4 analysing the data from these experiments. Further tests are being conducted using seabed soil from the harbour on small scale rigs at 2H and NGI Oslo, pushing riser sections of different diameters into the soil to compare uplift and lateral resistance.

2. Allegheny Monitoring Programme

The Allegheny TLP gas export riser presented an excellent opportunity to fit motion loggers onto an SCR likely to see vortex induced vibration (VIV) due to ocean currents. No data was publicly available of this nature, with VIV prediction codes largely relying on data from vertical risers. The riser is welded steel construction, 12-3/4” OD in 3,255 ft water depth in the Gulf of Mexico. The top 580 ft has a helical strake VIV suppression system, designed to reduce VIV but not expected to eliminate it.

Twelve 2H data-loggers were fitted during riser installation in August 1999 as shown in Figures 9 and 10. The loggers are configured to allow attachment and removal by ROV, and are stand alone units with onboard memory and power. The loggers measured triaxial linear acceleration for 20 minutes every 6 hours until the memory was full in January 2000. During the logging period, a significant eddy current event occurred producing currents near to 2 knots at Allegheny – Figures 11 and 12.

Figure 13 shows a response summary over the logging period. The riser response has been classified into the following four classes:

- <C1> small amplitude response;
- <C2> vessel motion induced response;
- <C3> VIV induced response;
- <C4> "mixed" response.

In general, the riser VIV response can be seen to correlate with the higher and more unidirectional current velocities.

Significant back-analysis and code benchmarking has now been performed on the measured data. It seems that the Allegheny SCR was subject to VIV response, but the measured VIV response was less than has been predicted by available VIV software, both in terms of response amplitude and occurrence. The reasons for this are still under investigation. Current considerations are:

- The strake system may be better at suppressing VIV than was expected
- Due to their shape, SCR's have their own preferred planes of modal vibration. If the current direction is not orthogonal to these, the SCR plane may fight the VIV direction, and suppress VIV.
- Variation in current direction through the water column may cause a damping effect.

Within STRIDE Phase 4, further work is proceeding on this activity:

- Program benchmarking by 5 VIV code suppliers
- Analysis of the Allegheny TLP motions during the monitoring period
- Analysis of a second monitoring campaign at Allegheny, March 2000 to July 2000

3. The Effect of Current Direction on SCR VIV

This issue was raised by some of the results of the Allegheny monitoring programme. SCR's differ from vertical risers because their deflected shape will tend to fix their VIV response to in-riser-plane and out-of-riser-plane. If the incident current is at an angle to these two preferred vibration planes, it is likely that VIV will not occur according to classical understanding. In addition, all

currently available VIV analysis programs predict separately the in-plane and out-of-plane VIV.

The effect of current direction on SCR VIV was investigated in September 2001 using tow tank facilities at Marintek in Norway. The model parameters were as follows:

Riser model	-	brass tube, 12.5m long x 14mm dia
Top angle	-	30° to vertical
Bottom angle	-	5° to horizontal
Tow speed range	-	0.12 to 0.34 m/s, 12 increments
Reynolds Number	-	1,400 to 3,900
Angles to current	-	0, 30, 60, 90, 120, 150, 180 degrees
VIV modes predicted	-	4-6
Instrumentation	-	biaxial accelerometers at 10 positions spaced Along the riser, forces at riser ends, current meter

The experiments were carried out in the sub-critical Reynolds region, which removes the complications and uncertainties of testing across the critical Reynolds region. Whilst the Reynolds number is relatively low, the drag coefficient curve is fairly flat throughout this sub-critical Reynolds region, and the model response should give a good indication of offshore SCR response in sub-critical flows. The lower velocities were necessary to avoid excessive riser shape deflection due to drag.

The model formed a free hanging catenary that was towed at different angles in a tow tank (Figures 14, 15).

Vibration response was monitored using in-plane and out-of-plane accelerometers at 10 positions along the model's length. These were hardwired, routing wiring through the centre of the pipe, to a logging console sampling at 100 Hz. Video was used to assist in determination of mode numbers and VIV amplitudes.

The test programme was completed just recently in September 2001. All runs were successful, and data appears to be excellent. Results and conclusions from the tests are still under consideration at the time of writing.

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STRIDE Lead Engineering Contractor: 2H Offshore Engineering

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STRIDE Programme Manager: Offshore Technology Management

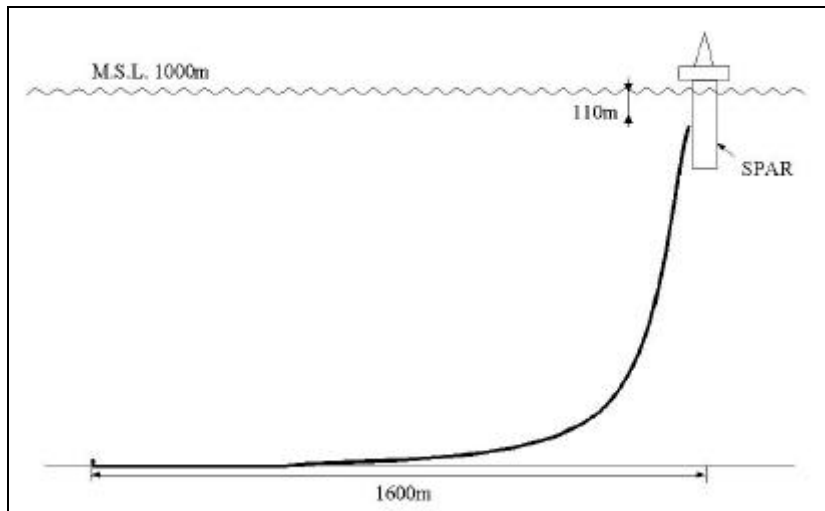


Figure 1 – Full Scale Riser Configuration

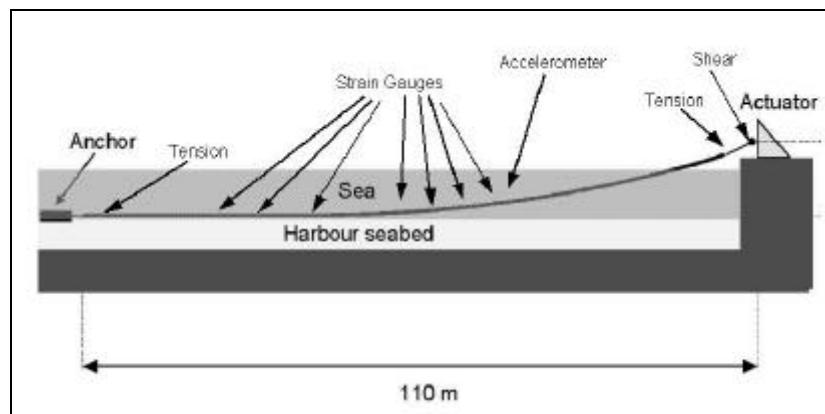


Figure 2 – Harbour Test Set-Up Schematic



Figure 3 – Harbour Test Site at Low Tide

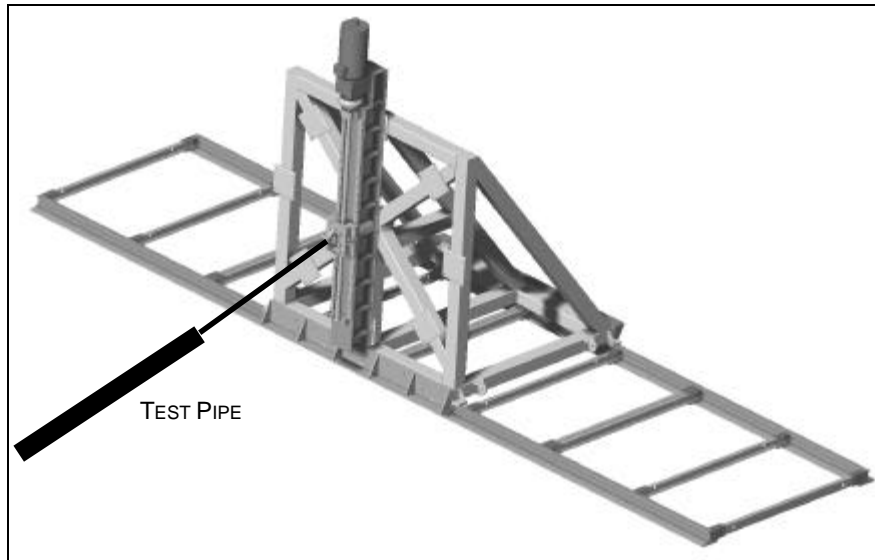


Figure 4 – Actuator Unit and Rails

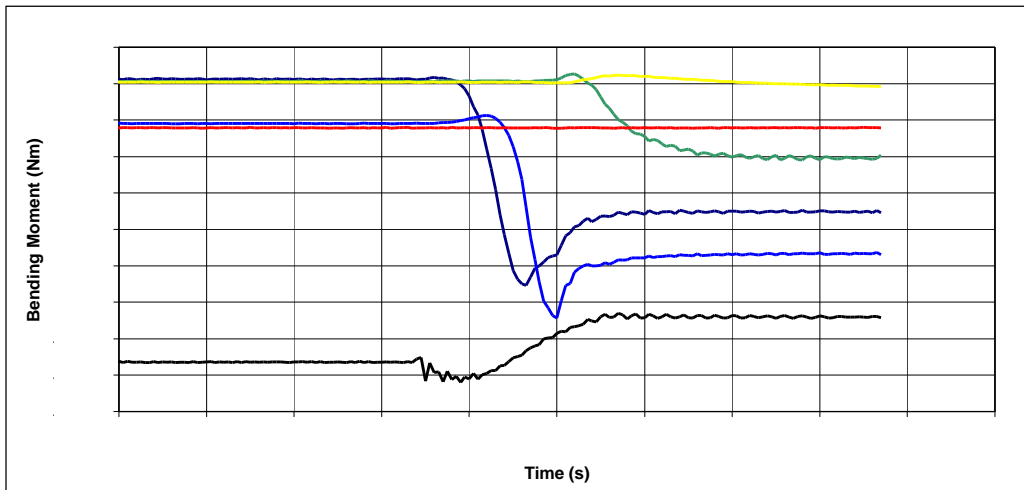


Figure 5 – Bending Strain at Different Riser Positions During a Drift Simulation

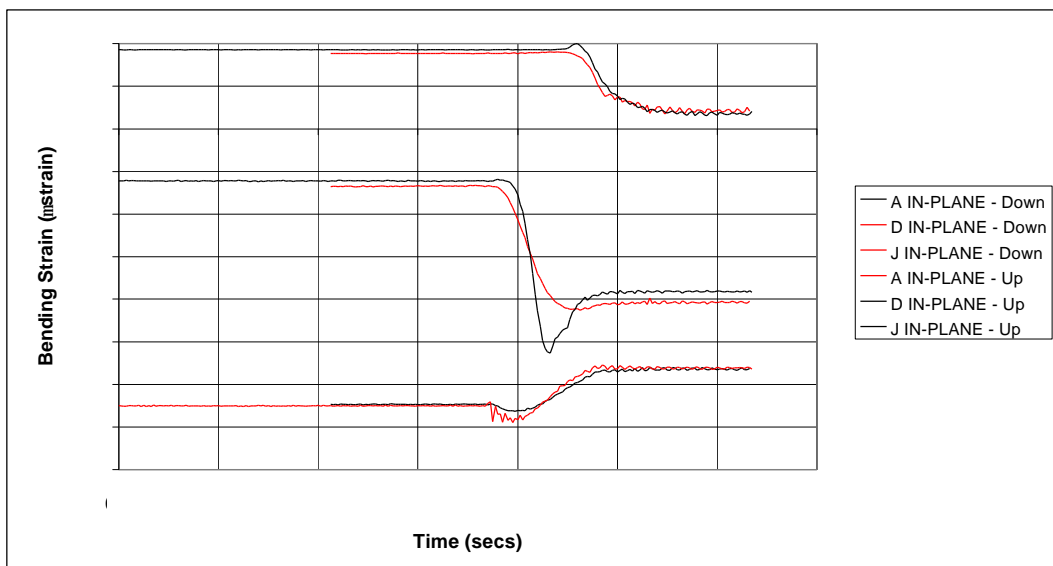


Figure 6 – Comparing Near-Far and Far-Near Bending Traces

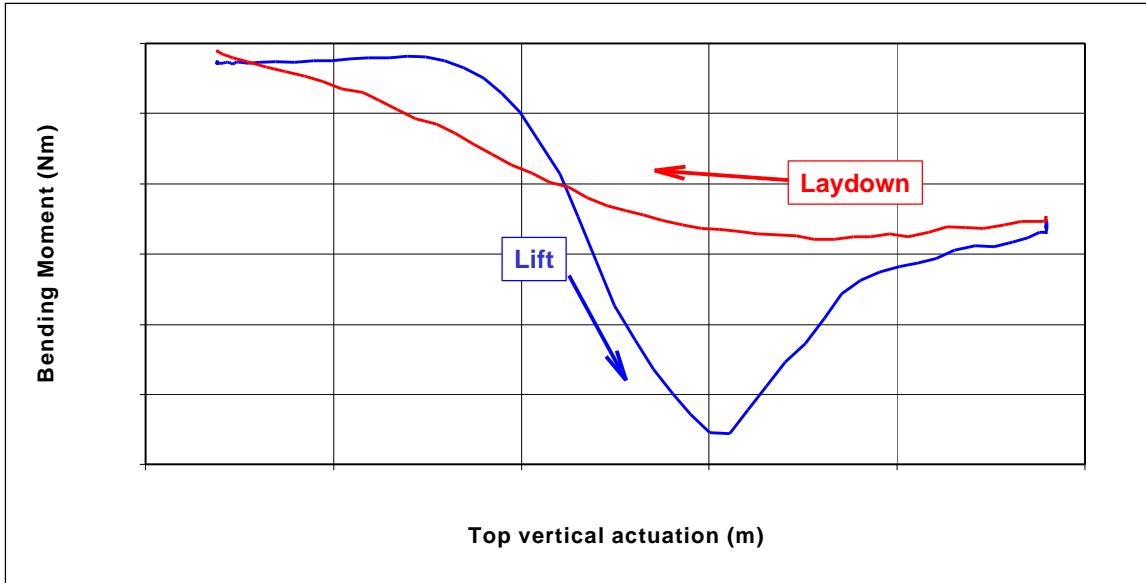
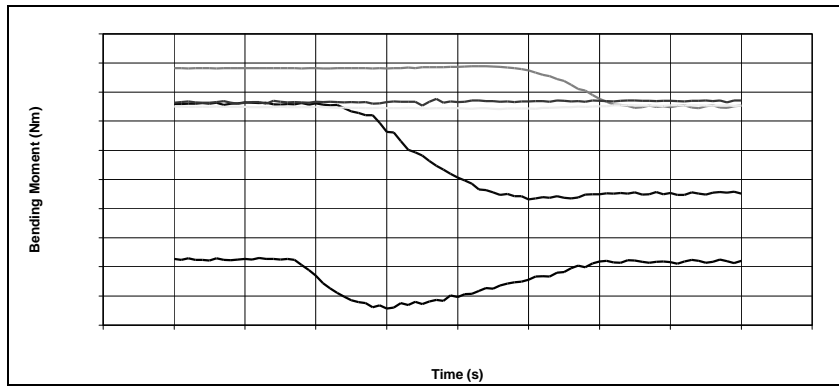
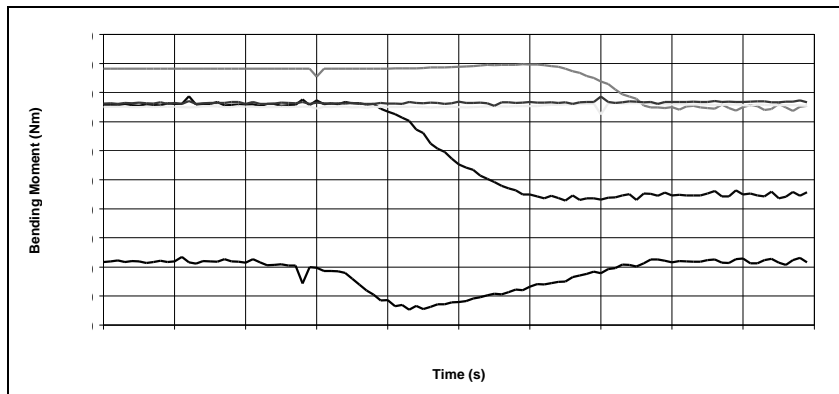


Figure 7 – Suction Peak for Fast Drift Case



(a) Lift (Near to Far)



(b) Laydown (Far to Near)

Fig. 8 – Strain Gauge Data from Rigid Surface Tests

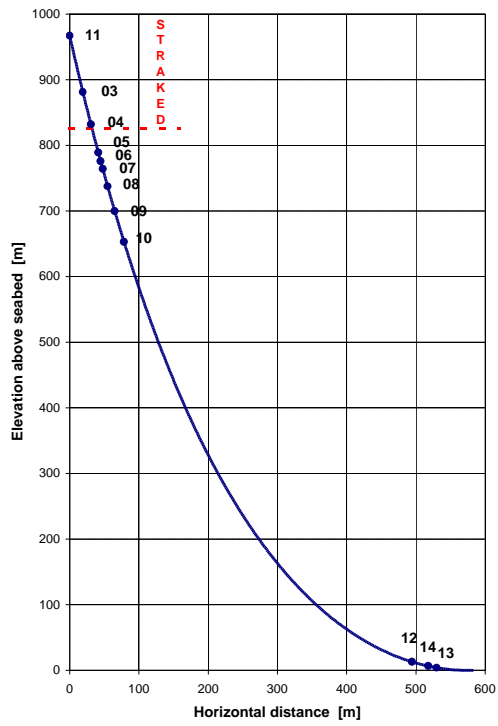


Figure 9 - Data Logger Positions along the Allegheny Gas Export Line



Figure 10 - 2H Accelerometer on the Allegheny SCR

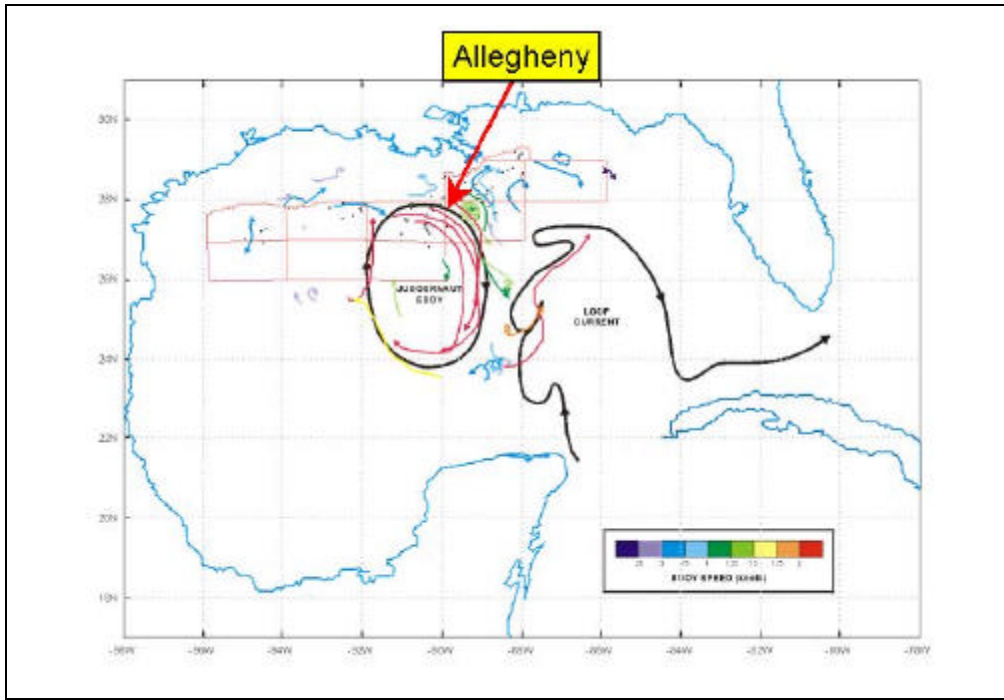


Figure 11 – Eddy “Juggernaut”

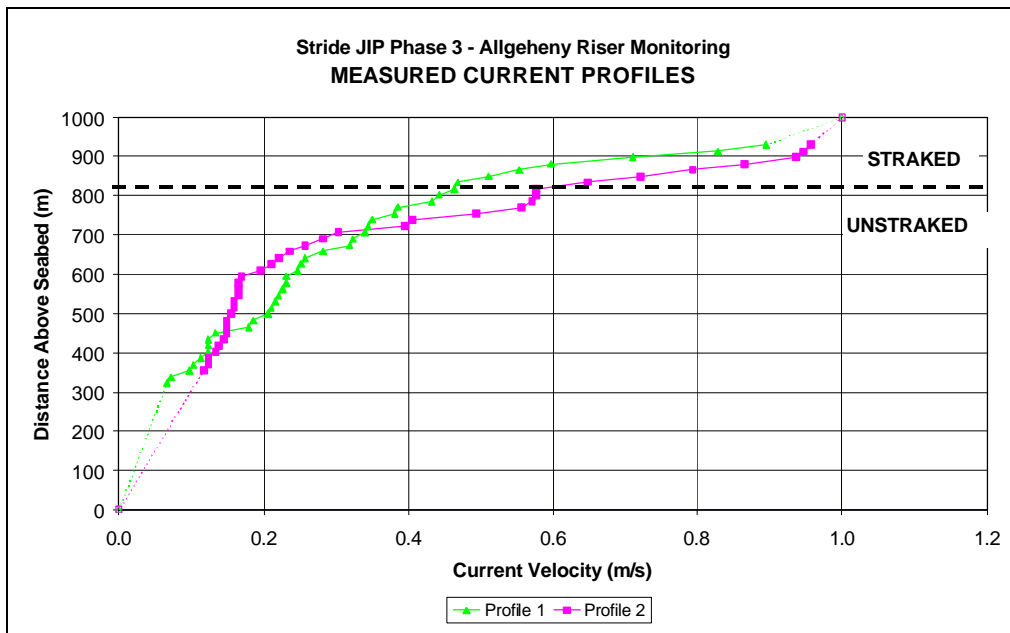


Figure 12 – Measured Currents

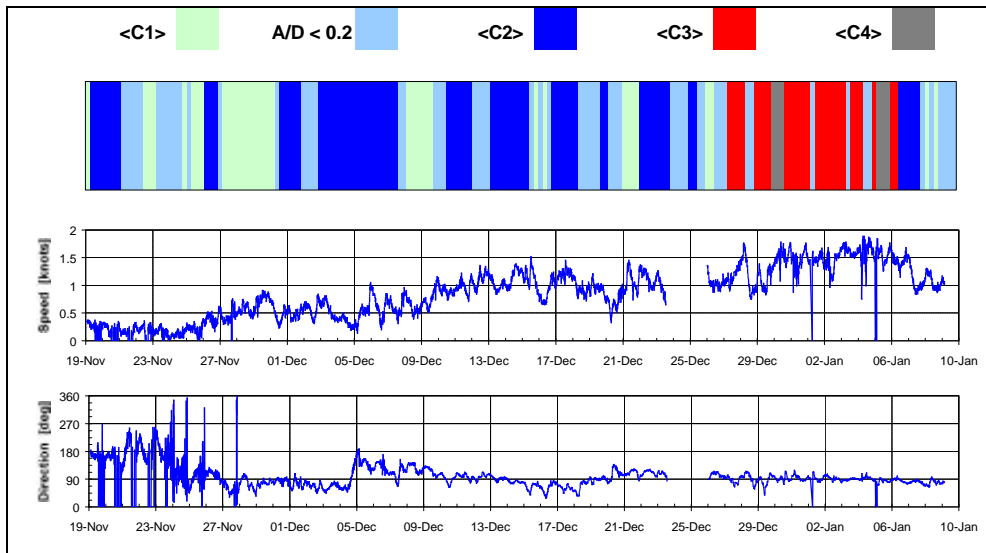


Figure 13 - Response Classification Summary

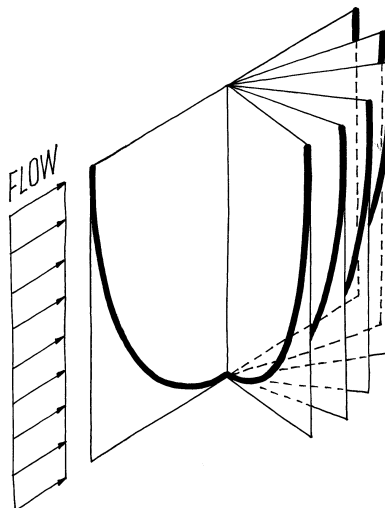


Figure 14 – SCR Presents Different Angles to Currents

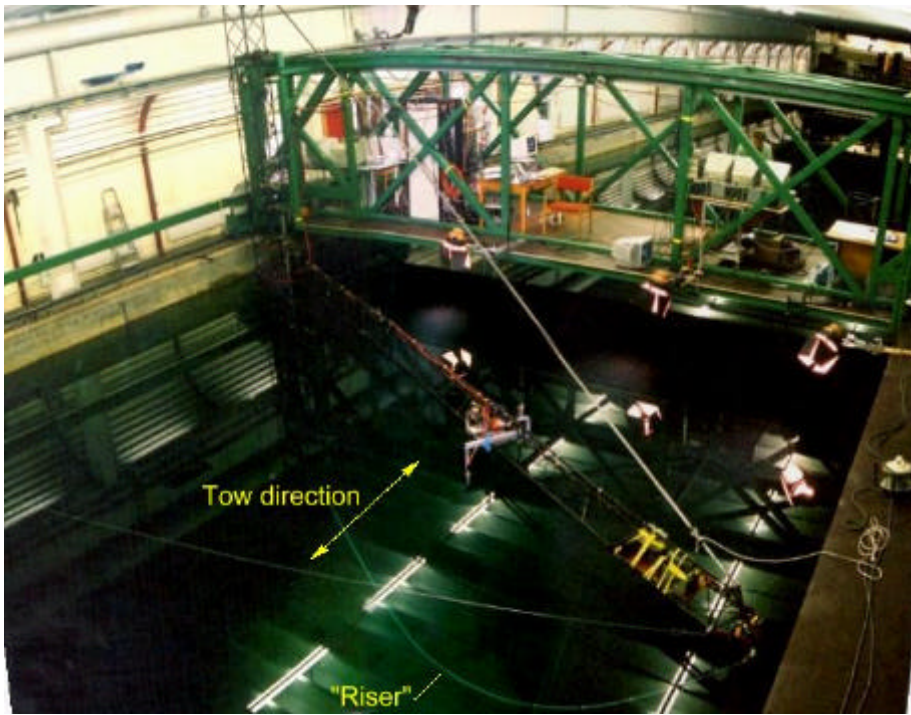


Figure 15 – Tow Tank Setup