Underwater Circular Curve Implementation for Offshore Pipe-line Installation

Case Study: South Pars Phase 12 Pipeline Snake-lay Operation (5378)

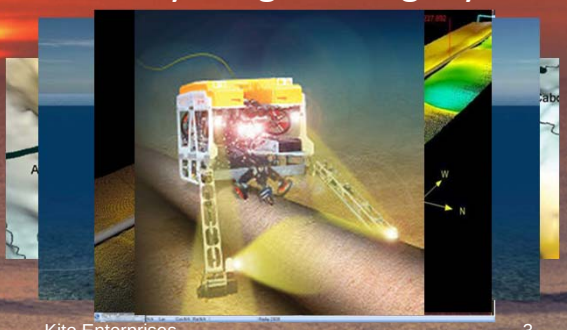
By:
Kamyar Shojaee
Kito Enterprises Company, UAE

What is Offshore Pipe-Laying?

A three minutes movie

What Surveyors do in this industry?

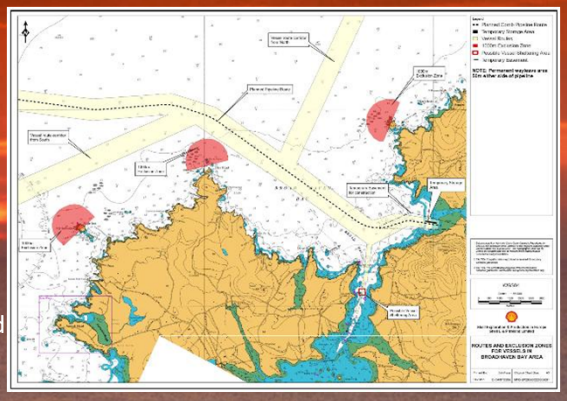
- Pre-Engineering Survey
- Pre-Lay Survey
- Positioning services on Lay-barge during lay
- Post Survey
- As-Built Survey



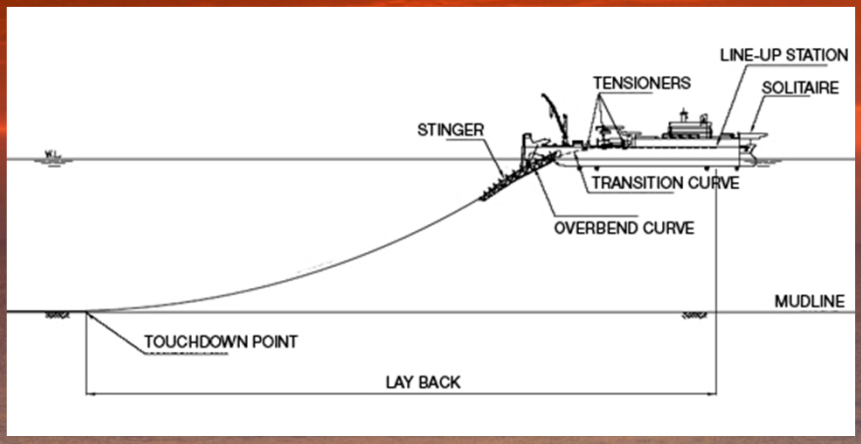
Pipe-line Routes

Routes are designed based on:

- •Topography of the seabed
- •Seabed Hazards and debris
- •Seabed layers and Soil characteristics
- •Type of materials which is going to be transferred by pipeline



Definitions



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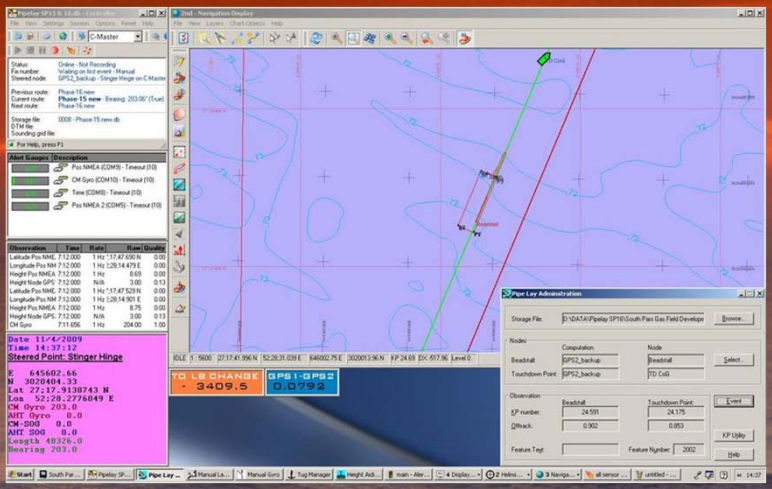
What Surveyors Provide on Lay Barge



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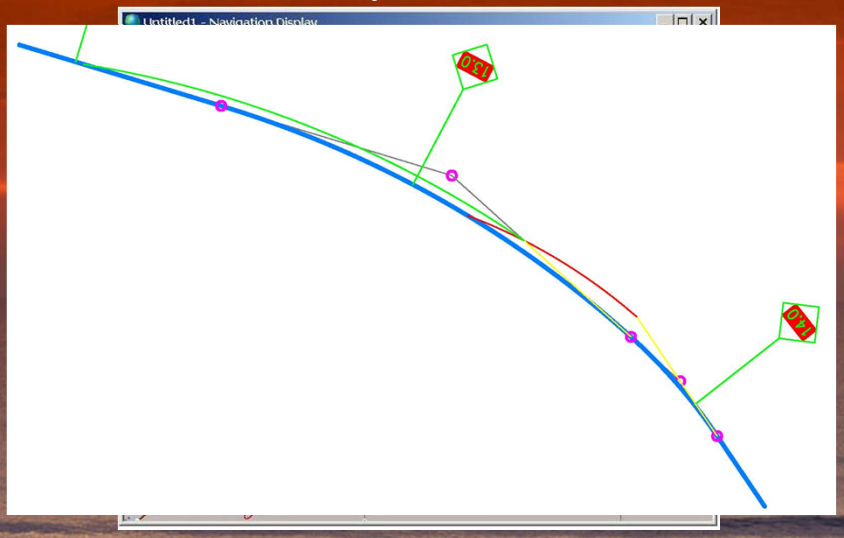
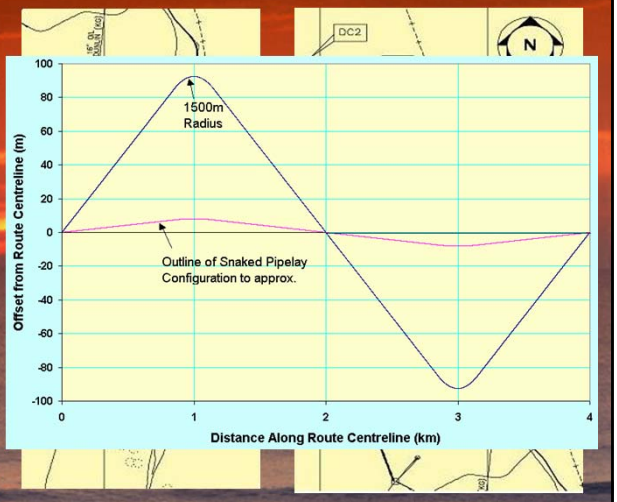
Curve Implementation

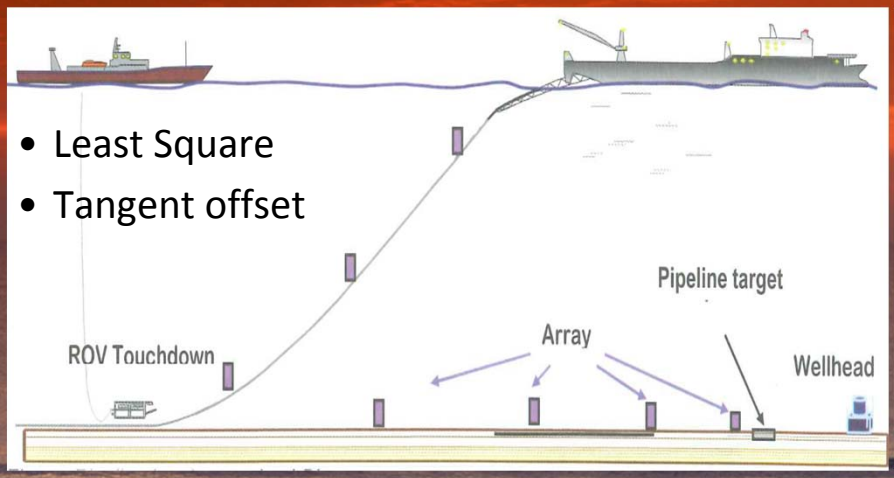


Snake-Lay

- High temperature material transfer
  - It may buckle the pipe longitudinally due to expansion
  - Wet buckle may happen during the commissioning



Online Curve Radius Monitoring



- Least Square
- Tangent offset

Least Square Method

Feasibility Study

$$A = \begin{bmatrix} 2x_1 & 2y_1 & -1 \\ 2x_2 & 2y_2 & -1 \\ \vdots & \vdots & \vdots \\ 2x_i & 2y_i & -1 \end{bmatrix}$$

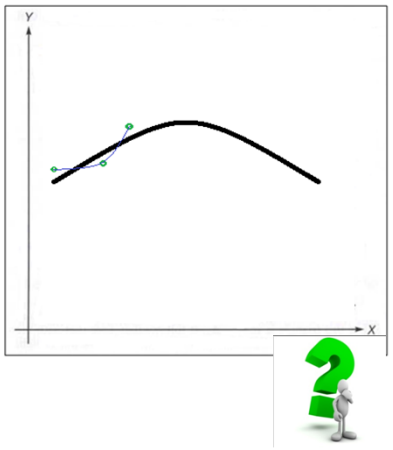
$$X = \begin{bmatrix} X_o \\ Y_o \\ f \end{bmatrix} \qquad L = \begin{bmatrix} x_1^2 + y_1^2 \\ x_2^2 + y_2^2 \\ \vdots \\ x_i^2 + y_i^2 \end{bmatrix}$$

$$R = \sqrt{X_o^2 + Y_o^2 - f}$$

The observation equation and solution is as below:

$$AX = L + V$$

$$X = (A^T A)^{-1} A^T L$$



Least Square Method

Comparison of two survey

Comparison of two sets of as-built survey with least square method

ROV fixes - First Try		
Easting	Northing	Bias
638860.95	2951054.29	-0.19
638858.81	2951046.17	-0.99
638858.89	2951036.25	-0.08
638857.30	2951025.33	0.11
638854.95	2951016.42	-0.99
638854.83	2951006.61	0.29
638853.15	2950996.63	0.10
638851.92	2950986.73	0.42
638849.88	2950975.95	0.10
638848.17	2950966.08	0.07
638847.58	2950957.12	1.13
638844.17	2950947.31	-0.47
638842.82	2950937.38	0.07
638840.92	2950927.56	0.12
638838.48	2950917.58	-0.30
638836.67	2950907.93	-0.04
638834.41	2950898.00	-0.14
638832.64	2950888.27	0.29
638829.98	2950878.47	-0.10
638827.58	2950868.68	-0.16
638827.55	2950867.90	0.03

ROV fixes - Second Try		
Easting	Northing	Bias
638860.95	2951054.29	-0.19
638859.81	2951046.17	0.00
638858.89	2951036.25	-0.08
638857.30	2951025.33	0.11
638855.95	2951016.42	0.00
638854.83	2951006.61	0.29
638855.15	2950996.63	0.16
638852.92	2950986.73	1.41
638849.88	2950974.95	0.21
638849.17	2950967.08	0.95
638848.58	2950958.12	2.01
638843.17	2950947.31	-1.46
638842.82	2950937.38	0.07
638840.92	2950927.56	0.12
638838.48	2950917.58	-0.30
638836.67	2950907.93	-0.04
638834.41	2950898.00	-0.14
638832.64	2950886.27	0.51
638829.98	2950878.47	-0.10
638827.58	2950868.68	-0.16
638827.55	2950867.90	0.03

Least Squar Result - First Try

Center of Curve		Radius
E	637672.8	1192.913
N	2951169	

Deviation		
Center		Radius
E	302.034	-306.754
N	-55.4549	

Least Squar Result - Second Try

Center of Curve		Radius
E	637912.2	950.9521
N	2951129	

Deviation		
Center		Radius
E	541.4124	-548.715
N	-95.2832	

Tangent Offset

Circular Curve Layout by Tangent Offset

(TD) and tangent offset (TO) can be calculated as below:

$$TD = c\cos\delta$$

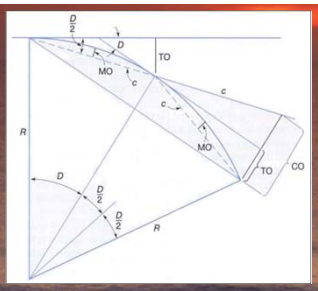
$$TO = c\sin\delta$$

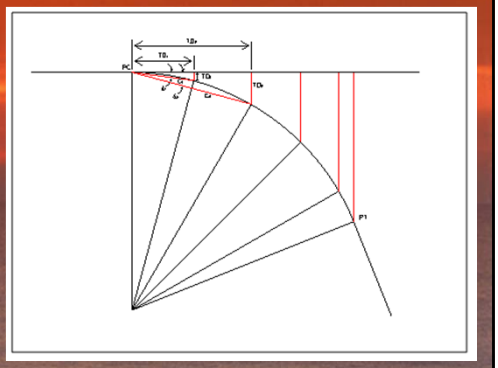
Where δ angle ($D/2$ in figure) or deflection angle can be calculated by:

$$\delta = \frac{L}{2R}$$

And chord (c) formula is:

$$c = 2R\sin\delta$$

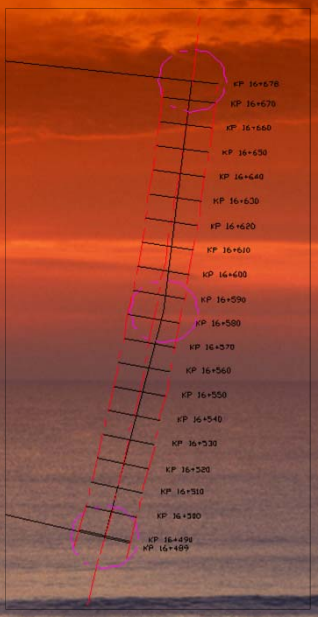




Tangent Offset

Circular Curve Stationing and Staking

- Staking in the underwater operation is not going to be a real wooden or metal stakes which are stubbed on the sea bottom.
- The virtual staking will be done in online survey software and the positioning of the stakes will be fixed by "*Go Go*" method using DGPS and USBL.



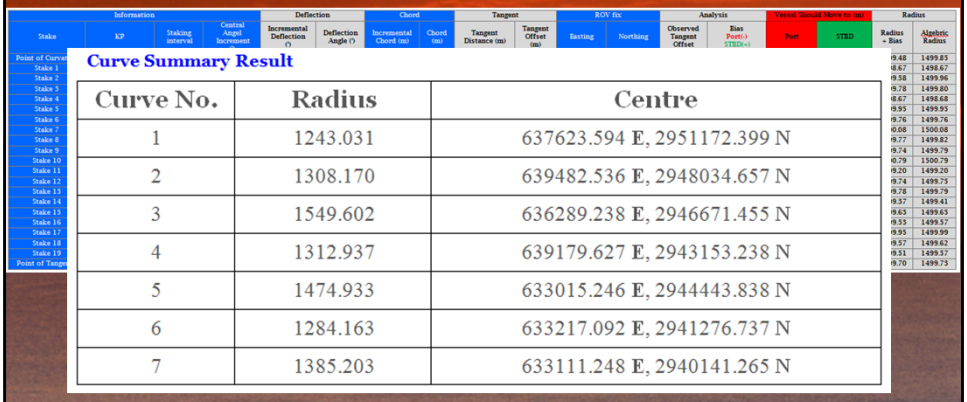
Tangent Offset

Implementation in Operational mode

- **The curves will be staked** by KPs and the related parameters will be calculated
- **ROV fixes will be taken** in pre-designed stakes as the laying is going on.
- ROV fixes (Easting and Northing) will be entered into the related **calculation sheets** and the real tangent offset and biases will be calculated
- **The biases will be transmitted** on line via radio signals to the pipe-layer barge for DP operators' action.
- The next additional **movement of the barge** will be done based on the survey data to either port side or starboard side.
- The **actual radius of the curve** will be calculated as it is being expanded by more pulls based on tangent offsets. It helps to control the curve to stay in the corridor and given tolerances.

Tangent Offset

Results

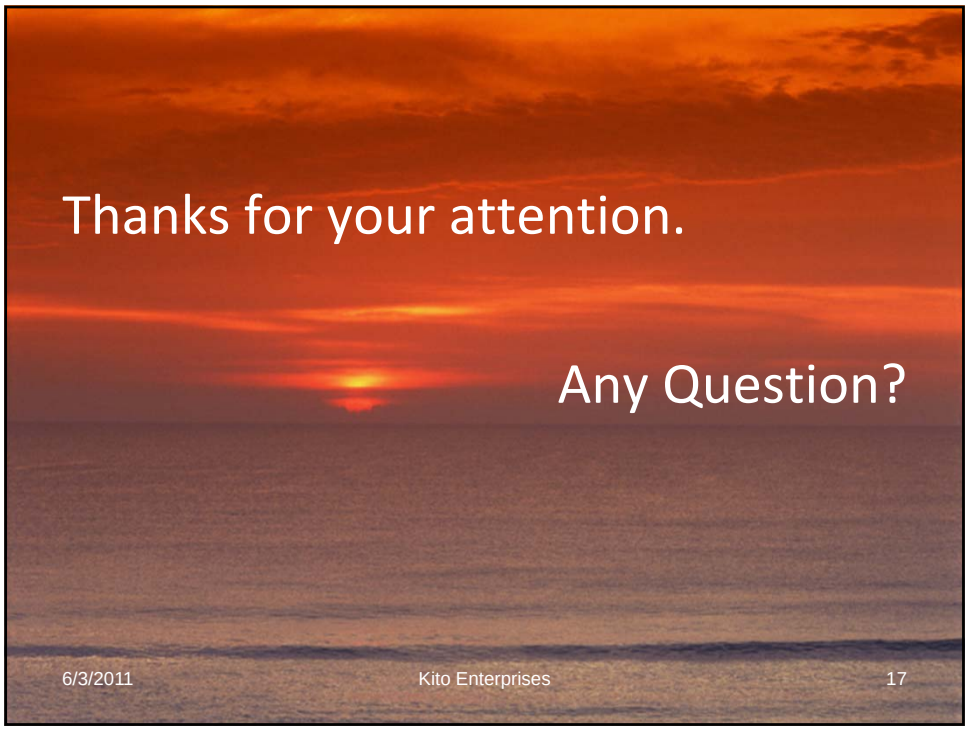


Curve Summary Result

Curve No.	Radius	Centre
1	1243.031	637623.594 E, 2951172.399 N
2	1308.170	639482.536 E, 2948034.657 N
3	1549.602	636289.238 E, 2946671.455 N
4	1312.937	639179.627 E, 2943153.238 N
5	1474.933	633015.246 E, 2944443.838 N
6	1284.163	633217.092 E, 2941276.737 N
7	1385.203	633111.248 E, 2940141.265 N

Conclusion

- LS method Does work for the curves which has implemented in order to find the radius of the curve
- TO is the best option to monitor the radius of curve during implementation of curve
- Once the pipeline was laid on the pre-designed route an As-Built survey could be done and the radius can be calculated by LS method


Thanks for your attention.
Any Question?
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