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Client Name
Tank Name
Tank Location

TANK SETTLEMENT AND ROUNDNESS SURVEY REPORT

Reference: PS040000

Contents:

Survey conducted: 1st October, 2004

NATA Accredited Laboratory Number: 9475

References:
API Standard 653 Appendix B
ISO Standard 7507

Nata Signatory: Stephen Ford

For PETROSPECTION Pty Ltd
3 November, 2004

Perth WA

Introduction

Tank Name is a vertical butt welded, mild steel cylindrical tank, fitted with a coned up floor and designated for water storage. The tank has no roof and the floor has a glass reinforced plastic coating.

On behalf of our client, Client Name, we have performed a survey of the tank to provide data to assist in determining the compliance of the tank with API Standard 653 Appendix B floor and shell settlement specifications and to report on tank roundness.

The engineer on site during this survey on the 28th of October was Mr. Engineer of Client Company.

This report should be read in conjunction with API 653 Appendix B, particularly if the reader is not familiar with the Standard and the terms used in it, as some of the terms are particular to the Standard.

The API 653 Appendix B standard provides for “some judgment” by the operator in the interpretation of settlement data, particularly the determination of floor edge settlement break-over points and the nomination of statistical outlying data for shell settlement in determination of the plane of rigid tilt and the tank shell deflection.

We have exercised such judgment in good faith and provide illustrations of our workings in this report; and we have processed the data for the convenience of engineering personnel assessing the tank against the API 653B standard. The ultimate responsibility therefore lies with the engineers in accepting the information in this report and its suitability for deciding upon the condition of the tank. Consequently, we are receptive to any requests from our client to re-process the tank data in accordance with their differing interpretation of the API 653B standard.

The Standard acknowledges that the tank’s previous service history may be considered in evaluating many of the aspects of settlement.

We cannot comment whether the apparent settlement of the tank represents the as built condition or is settlement since construction. The API 653 settlement specifications assume the current condition to have developed from a purely symmetrical tank, and as such should be viewed as a worst-case evaluation.

Other than by the methods described in API Standard 653 Appendix B, we do not attempt to calculate the tank shell stresses that may be generated by tank settlement, as may be indicated by the analysis in this report, as this is beyond our field of expertise.

All dimensions are in millimeters unless specified otherwise.

Floor Survey

The tank floor of this tank has a coating of glass reinforced plastic.

During our survey, the plates were noticed to be buckled across large regions of the floor and spongy under-foot. This should be considered when evaluating the floor survey results.

During the floor survey, the floor elevations were measured at specific intervals along 24 radii positioned equidistantly around the floor perimeter.

For this report, the floor elevations are plotted in three dimensions and connected with spline curves to generate the contour map on page 5. Zero elevation corresponds with the lowest measured point on the floor.

The location and elevation of tank structures and fittings was measured during the survey for orientation with the floor survey data and to facilitate comparisons with future floor survey data (refer to the tank schematic drawing on page 23).

The contour map on page 5 shows an irregular coned up tank floor. As previously mentioned, due to plate buckling the undulations indicated on the map may not necessarily reflect the contour of the foundation.

The wire-frame drawings on page 6 provide a visual indication of the floor contour.

Localised Bottom Settlement Remote from Tank Shell

We have not identified any significant depressions or bulges in the floor remote from the tank shell, particularly any such distortions that would exceed the recommended maximum stipulated in API Standard 653 Section B.3.3.

Bottom Settlement Near Tank Shell

We have not identified any significant depressions or bulges in the floor near the tank shell that are outside the specification stipulated in API 653 Section B.3.3, as referred to by Section B.2.4.2 in addressing this form of settlement.

Floor Edge Settlement

The evaluation method for floor edge settlement described in API 653 Section B.2.3.2b requires that a straight line be extended from the “unsettled floor” along the floor, noting where the tank floor departs from the straight line (the “breakover” point) and where this extended line intersects the tank shell. The manner in which a straightedge should be applied is not specified, nor is the length of the straight line.

The method used for this report involves the creation of scaled profile drawings of floor radii, by connecting the measurement points along each radius with a spline curve. The original profile of the floor is then extrapolated and traced with a straight line to determine the edge settlement dimensions at each station (refer to the drawings on pages 8 to 11).

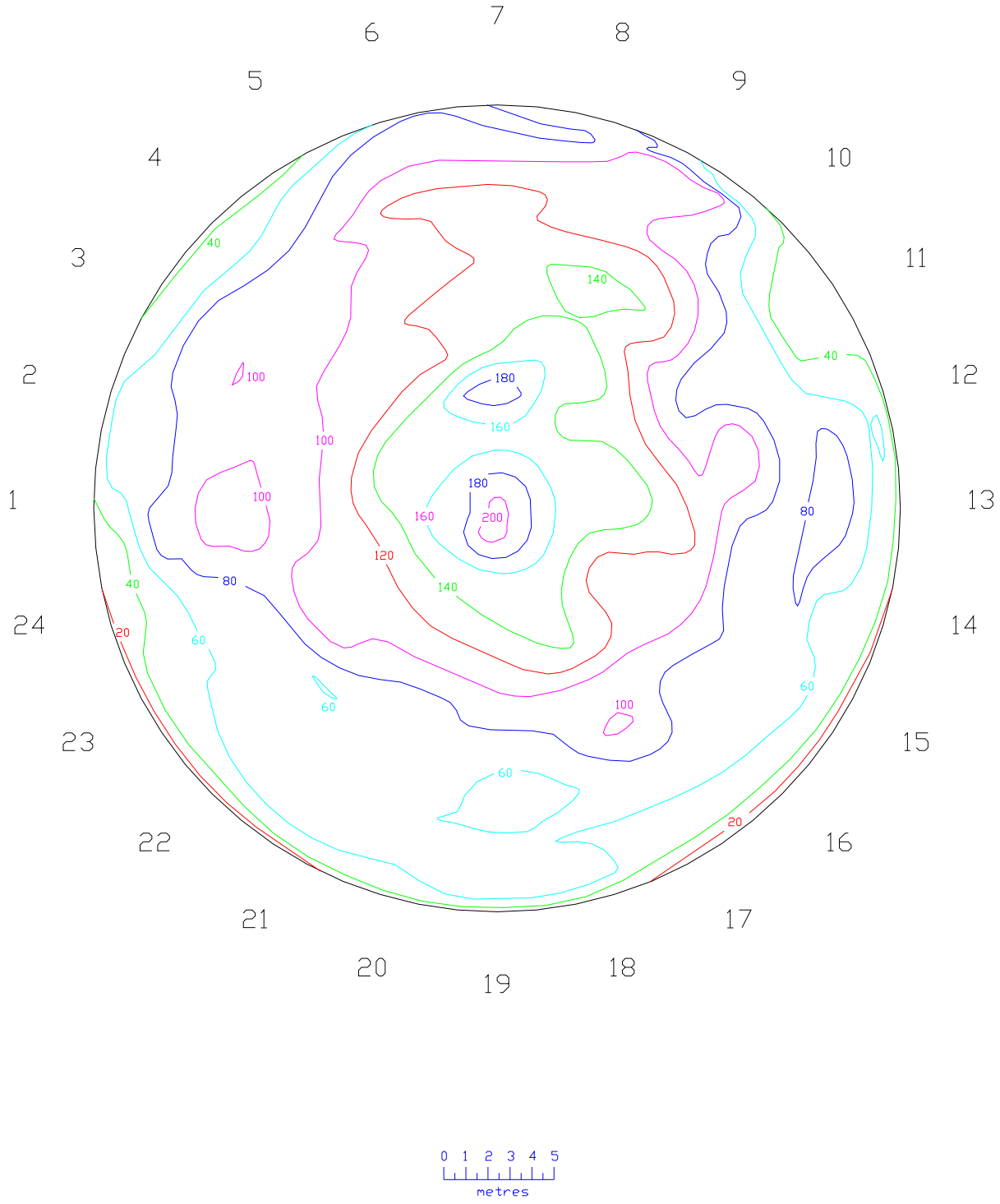
An evaluation of the floor edge settlement at each station to API 653B specification appears in the table on page 12.

We have identified floor edge settlement along the radii at 17 of the 24 measurement stations; however all the settlement is less than 75 percent of the API 653B maximum allowable specification. Above 75 percent, further analysis would be required, according to API 653B.

A table of the radial elevation optical readings is on page 13.

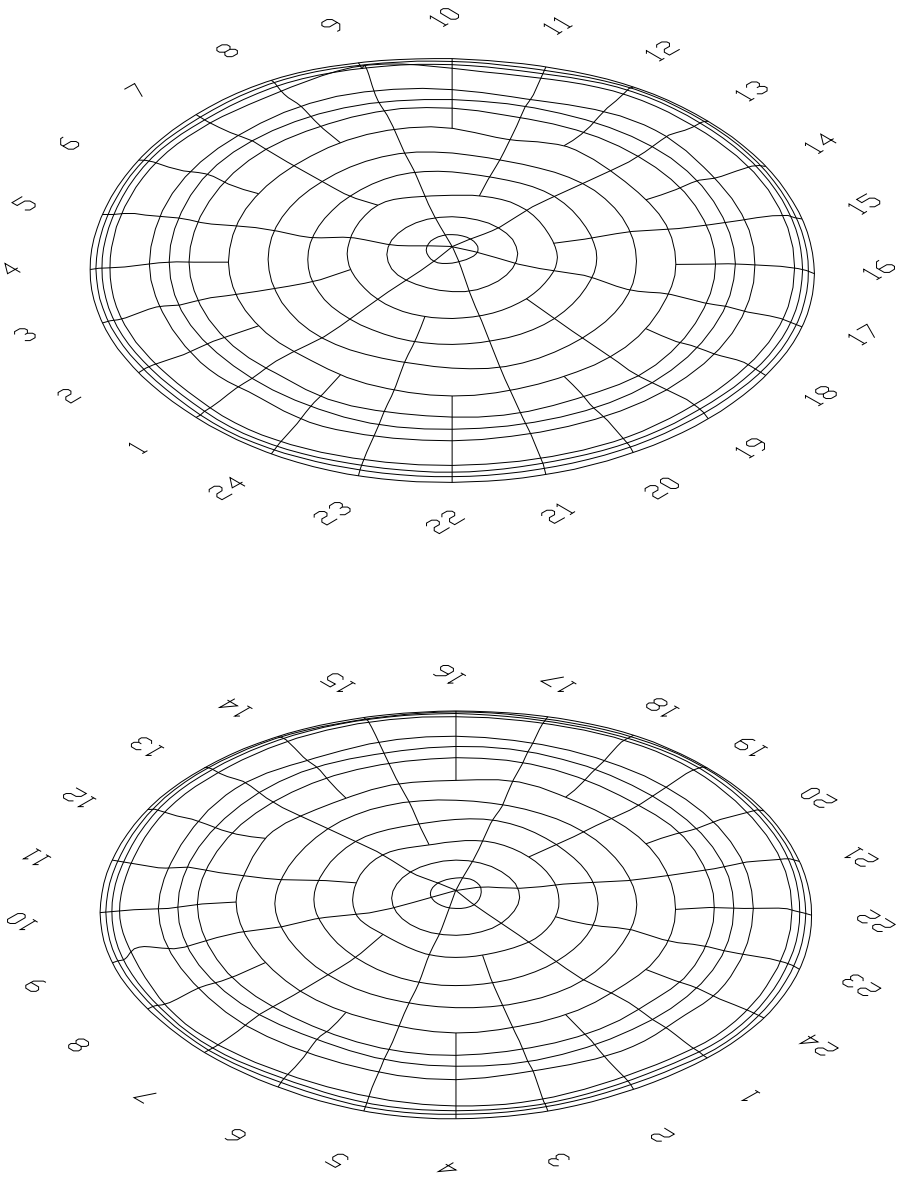
Floor weld angles are measured at the intersection of the radius line of measurement and the weld (if there are any) existing between the break-over point and the tank shell (in accordance with API 653 Figure B-12). A drawing of the floor plate layout and weld dimensions is on page 7.

Floor Contour



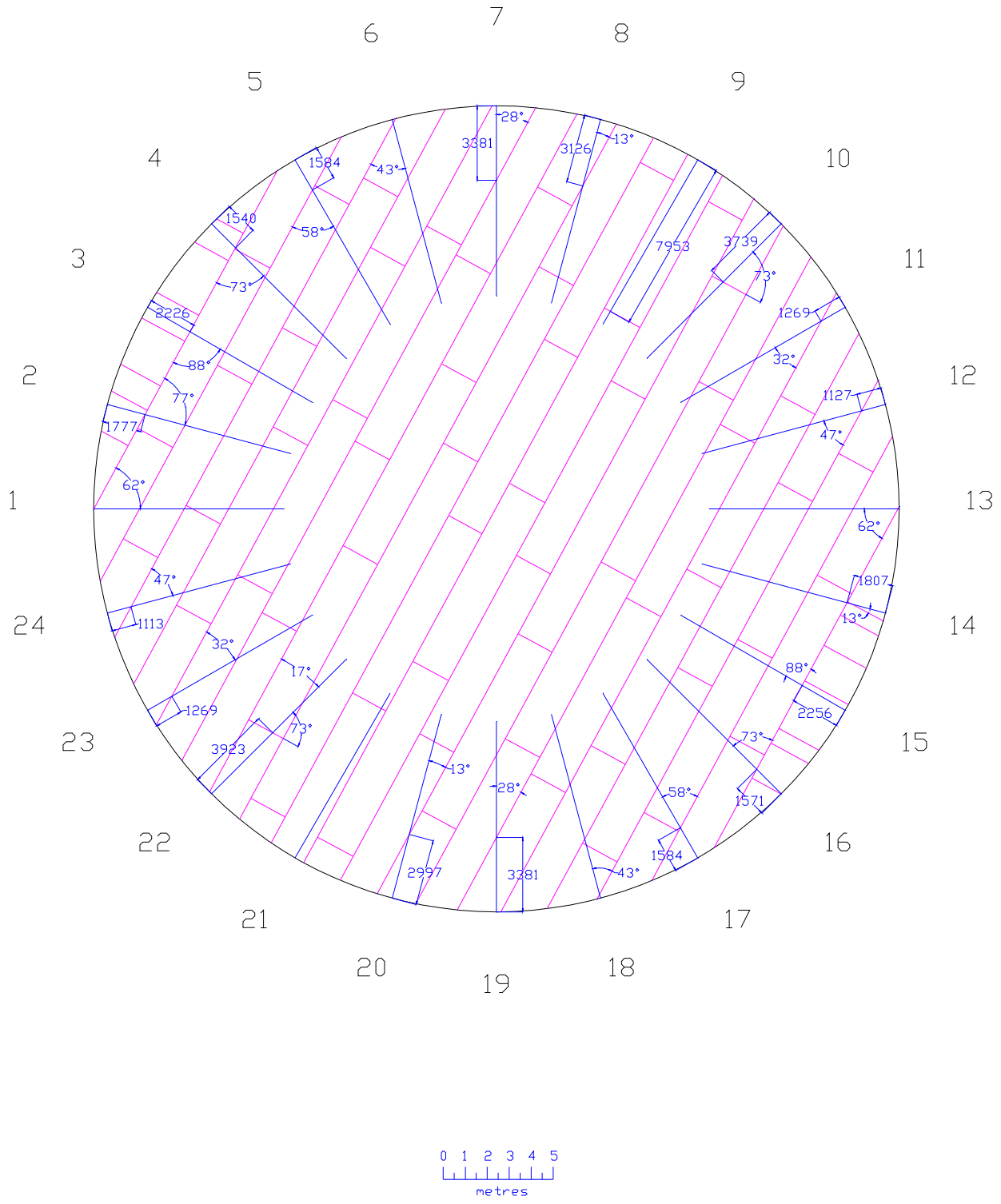
Elevation in millimeters
Zero elevation corresponds with the lowest point on the floor

Wire Frame Isometric Views

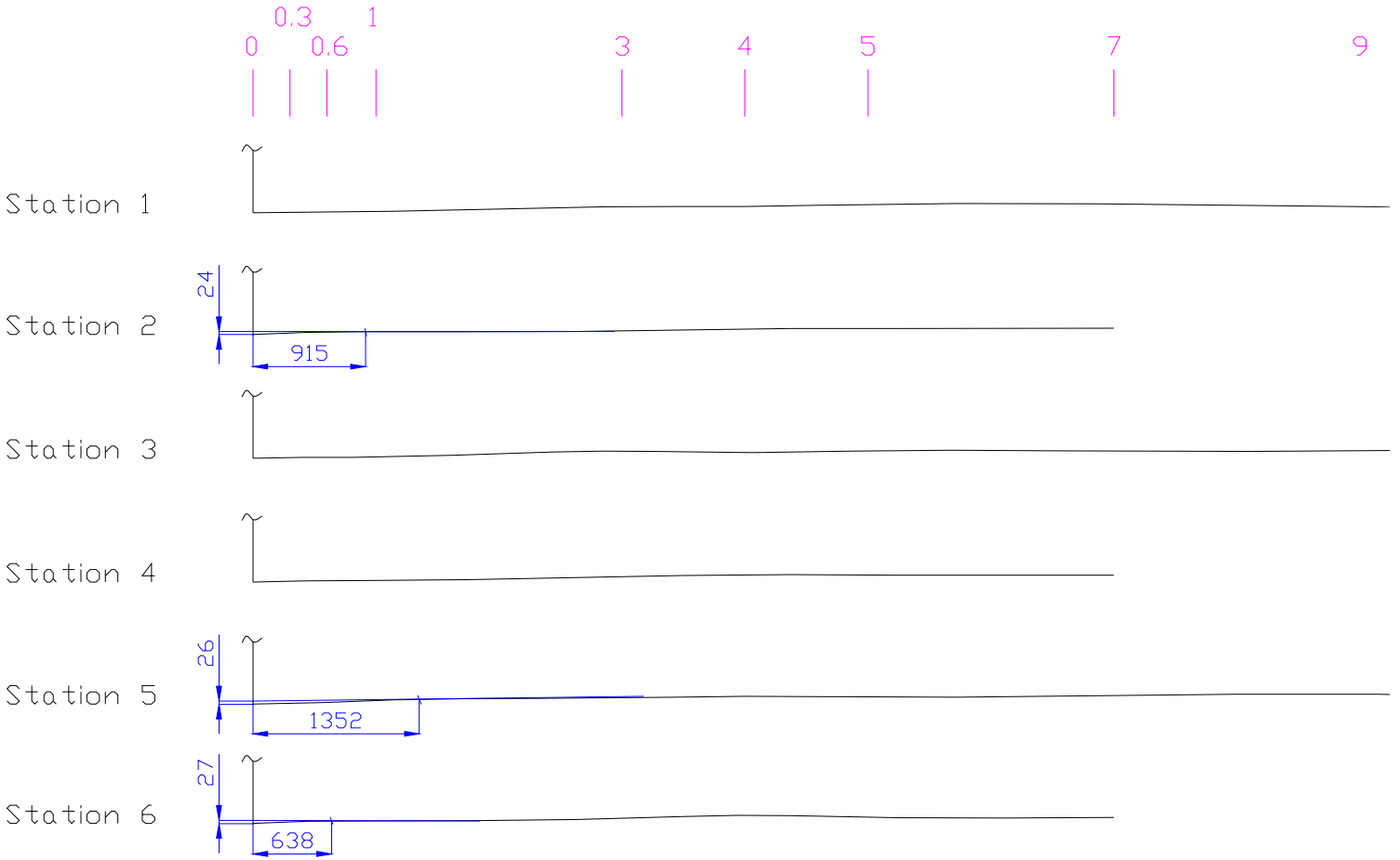


Elevations are magnified 8 times for clarity.
The contour map on the previous page is generated from the wire-frame.
The wire-frame intersections represent the measured data points

Floor Plate Layout

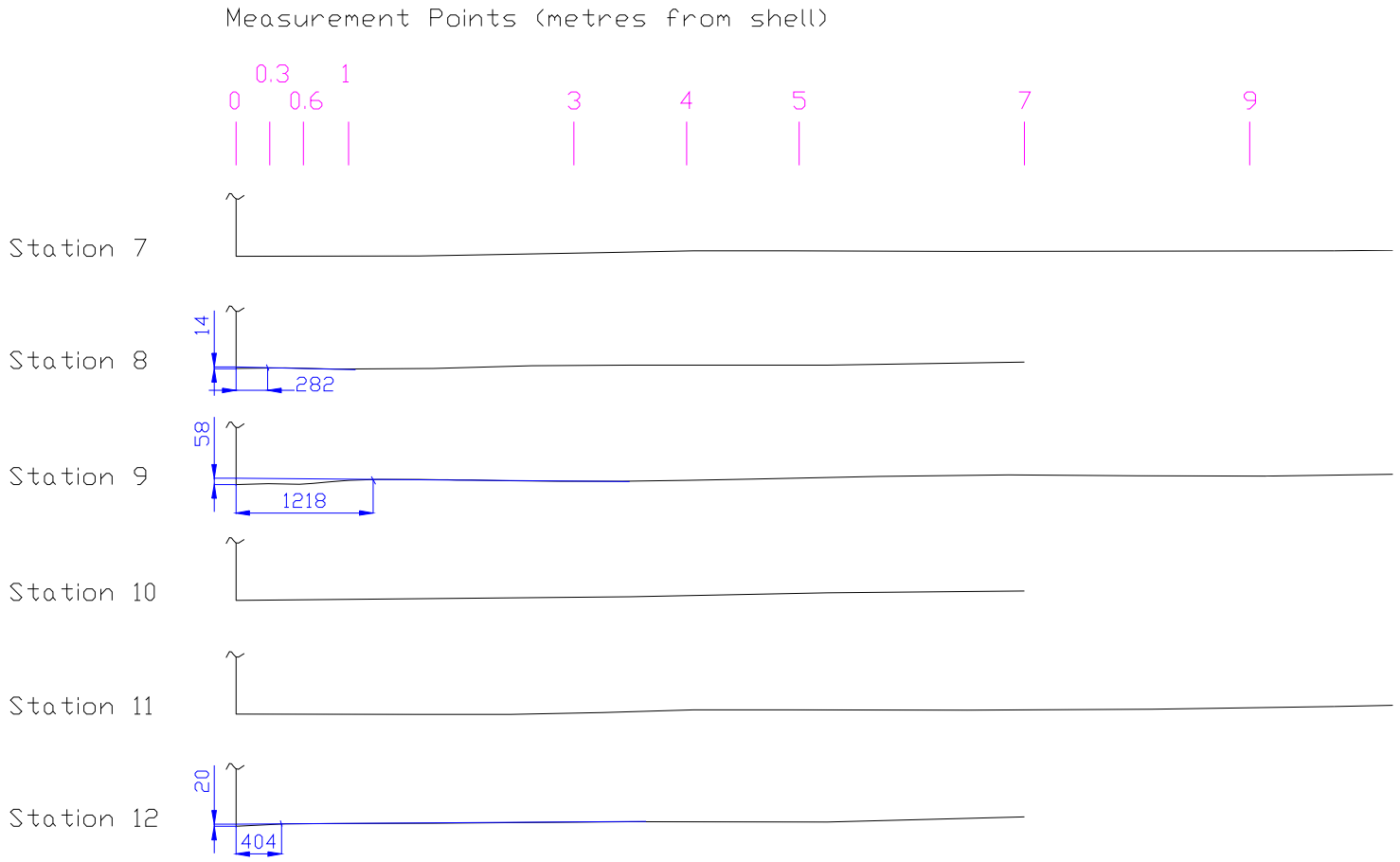


Floor Edge Settlement (API653B method)



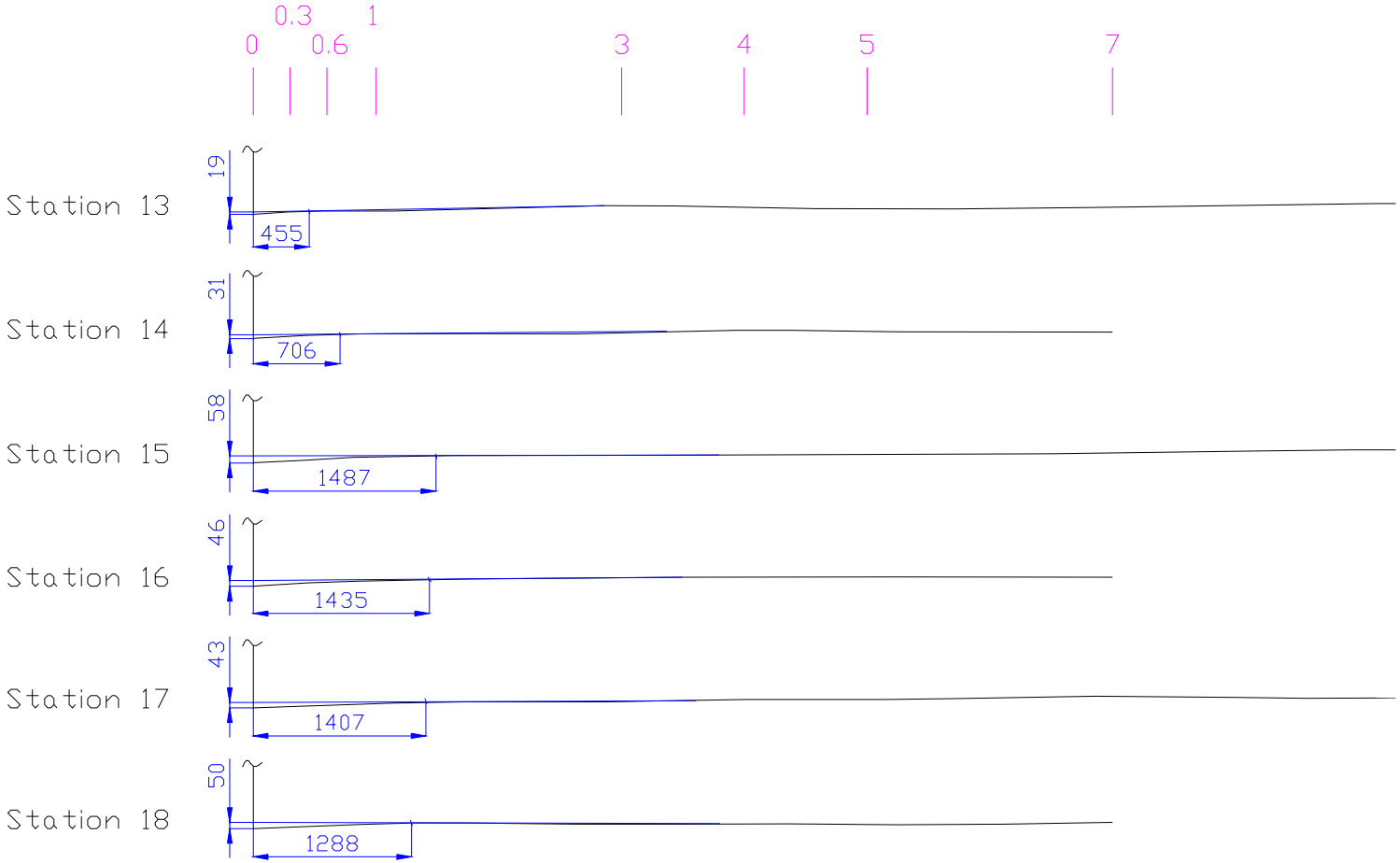
The measurement points are connected with spline curves to produce each floor profile
Dimensions in millimetres
Drawings to scale

Floor Edge Settlement (API653B method)



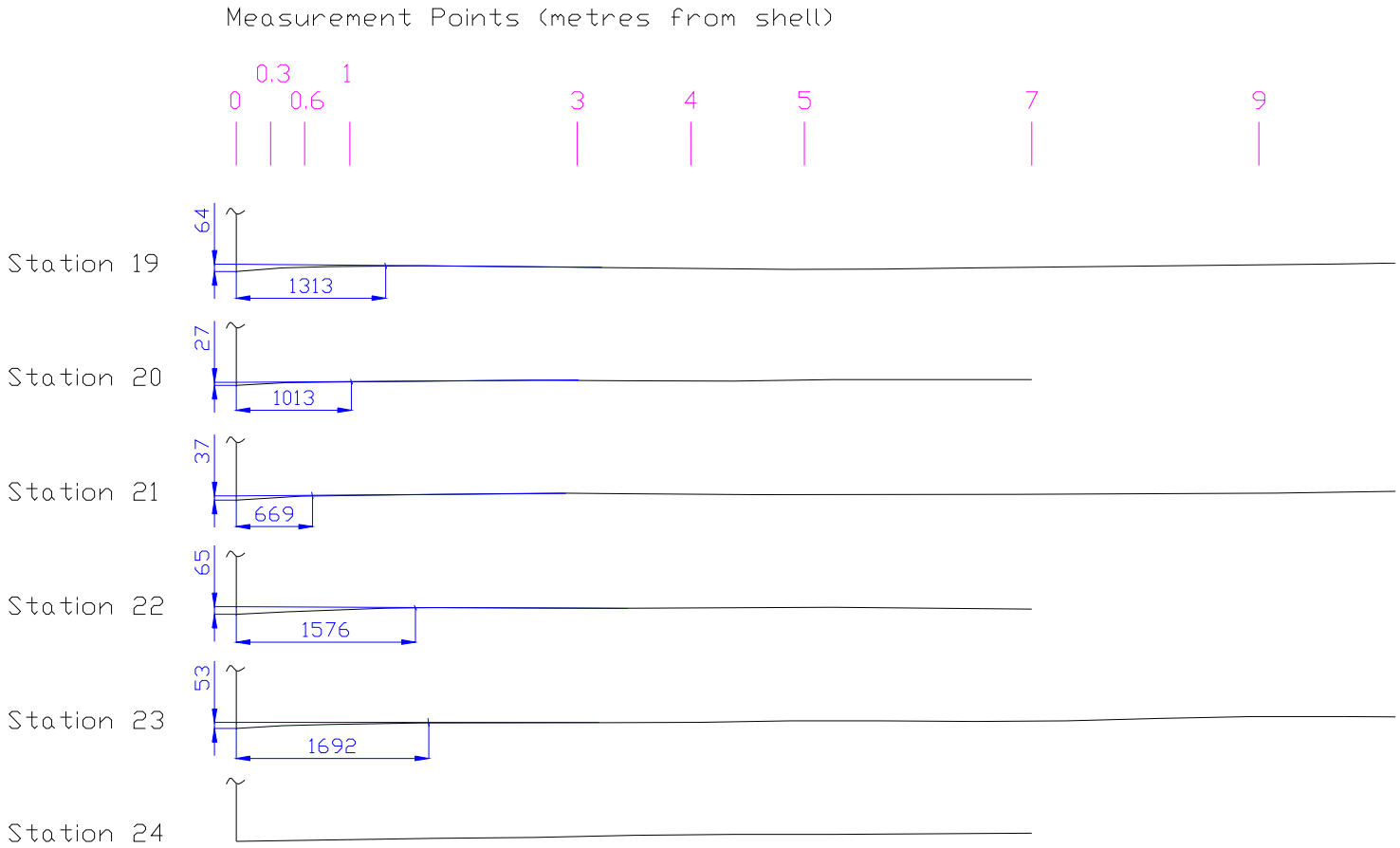
The measurement points are connected with spline curves to produce each floor profile
Dimensions in millimetres
Drawings to scale

Floor Edge Settlement (API653B method)



The measurement points are connected with spline curves to produce each floor profile
Dimensions in millimetres
Drawings to scale

Floor Edge Settlement (API653B method)



The measurement points are connected with spline curves to produce each floor profile
Dimensions in millimetres
Drawings to scale

Floor Edge Settlement Evaluation – API653B

API 653 Appendix B Floor Edge Settlement Evaluation Criteria

1. Tanks with larger edge settlements than Bew/Be/Bα are to be repaired, or have detailed analysis of the floor, and floor to shell junction.
2. Welds in tanks with settlement greater than or equal to 75% of Bew/Be/Bα and larger than 2", are to be inspected with magnetic particle or liquid penetrant examination.
3. Tanks with settlement less than 75% of Bew/Be/Bα may be returned to service.
4. An asterix preceeding an evaluation comment denotes a settlement radius that exceeds the range of the graph provided by the Standard (6 feet). The Bew/Be/Bα value reported in the table is extrapolated from the graph/s.

Tank diameter = 36.6 metres, (120.2 feet)

Station	Floor Weld Angle within Settled Area	API 653B Evaluation Method Reference	Actual Settled Area Radius R (mm)	Actual Settled Area Radius R (feet)	Max Allowable Settlement Bew/Be/Bα (inch)	Max Allowable Settlement Bew/Be/Bα (mm)	Actual Edge Settlement (mm)	Variation (mm)	Evaluation of settlement in accordance with API 653B Figures B-10, B-11 or Section B.3.4.3
1	none	B-11	0	0.00	#N/A	#N/A	0	#N/A	#N/A
2	none	B-11	915	3.00	4.67	119	24	-95	less than 75% of Be
3	none	B-11	0	0.00	#N/A	#N/A	0	#N/A	#N/A
4	none	B-11	0	0.00	#N/A	#N/A	0	#N/A	#N/A
5	none	B-11	1352	4.44	6.04	153	26	-127	less than 75% of Be
6	45°	B.3.4.3	638	2.09	3.03	77	27	-50	less than 75% of Bα
7	none	B-11	0	0.00	#N/A	#N/A	0	#N/A	#N/A
8	none	B-11	282	0.93	2.00	51	14	-37	less than 75% of Be
9	none	B-11	1218	4.00	5.65	144	58	-86	less than 75% of Be
10	none	B-11	0	0.00	#N/A	#N/A	0	#N/A	#N/A
11	none	B-11	0	0.00	#N/A	#N/A	0	#N/A	#N/A
12	none	B-11	404	1.33	2.00	51	20	-31	less than 75% of Be
13	65°	B.3.4.3	455	1.49	2.00	51	19	-32	less than 75% of Bα
14	15°	B.3.4.3	706	2.32	3.49	89	31	-58	less than 75% of Bα
15	perpendicular	B-11	1487	4.88	6.43	163	58	-105	less than 75% of Be
16	perpendicular	B-11	1435	4.71	6.28	160	46	-114	less than 75% of Be
17	none	B-11	1407	4.62	6.20	157	43	-114	less than 75% of Be
18	45°	B.3.4.3	1288	4.23	5.02	128	50	-78	less than 75% of Bα
19	30°	B.3.4.3	1313	4.31	5.33	135	64	-71	less than 75% of Bα
20	none	B-11	1013	3.32	4.99	127	27	-100	less than 75% of Be
21	none	B-11	669	2.19	3.36	85	37	-48	less than 75% of Be
22	20°	B.3.4.3	1576	5.17	6.21	158	65	-93	less than 75% of Bα
23	35°	B.3.4.3	1692	5.55	6.18	157	53	-104	less than 75% of Bα
24	none	B-11	0	0.00	#N/A	#N/A	0	#N/A	#N/A

Floor Profile Survey Data

Metres from tank shell (elevations are in millimetres)

Station	**0**	**0.3**	**0.6**	**1**	**3**	**4**	**5**	**7**	**9**	**11**	**13**	**15**	**17**	**18.3**
1	38	39	48	50	88	89	107	110	88	107	136	159	178	209
2	48	61	67	70	75	93	97	99						
3	39	47	46	48	99	85	100	97	100	107	155			
4	33	41	44	45	75	92	90	88						
5	38	46	52	67	89	102	95	109	119	111	158	148	185	209
6	66	79	86	88	107	134	117	117						
7	81	80	77	78	107	128	127	124	128	140	196			
8	87	93	88	80	118	115	115	143						
9	60	67	68	124	101	97	119	145	135	157	142	148	187	209
10	36	42	44	50	64	75	97	119						
11	28	28	27	27	34	66	64	66	81	121	146			
12	36	52	59	58	77	70	71	119						
13	29	47	54	53	99	83	71	86	113	137	157	147	185	209
14	17	36	49	57	59	84	74	69						
15	4	17	39	54	67	66	70	82	110	107	114			
16	0	20	33	45	67	76	75	73						
17	10	19	29	45	60	77	77	104	87	139	144	156	196	209
18	27	39	49	65	59	66	58	77						
19	28	54	64	74	64	57	47	68	88	112	140			
20	26	46	54	57	72	62	74	76						
21	18	39	54	58	77	68	65	68	76	106	130	149	205	209
22	14	30	38	55	68	69	74	59						
23	8	28	39	48	59	61	76	71	114	102	124			
24	16	23	28	34	56	76	76	88						

Zero elevation corresponds with the lowest measured point on the tank floor

Tank Shell Settlement

The Tank Shell Settlement graph on the following page plots the adjusted settlement, calculated using the "0 mtrs" floor profile survey data (refer to Floor Profile Survey Data Table on page 13).

This graph follows the procedure described in API Standard 653 B.2.2.4 and B.3.2 to calculate the plane of rigid tilt and the out-of-plane settlement.

The Standard gives the option to ignore any point data that do not appear to fit the initial cosine curve calculated for all points. We have achieved a correlation value of 0.74 by ignoring the data at measurement stations 10, 11, 18, 19, 20 and 21. A correlation factor of 0.9 or greater is considered a good correlation.

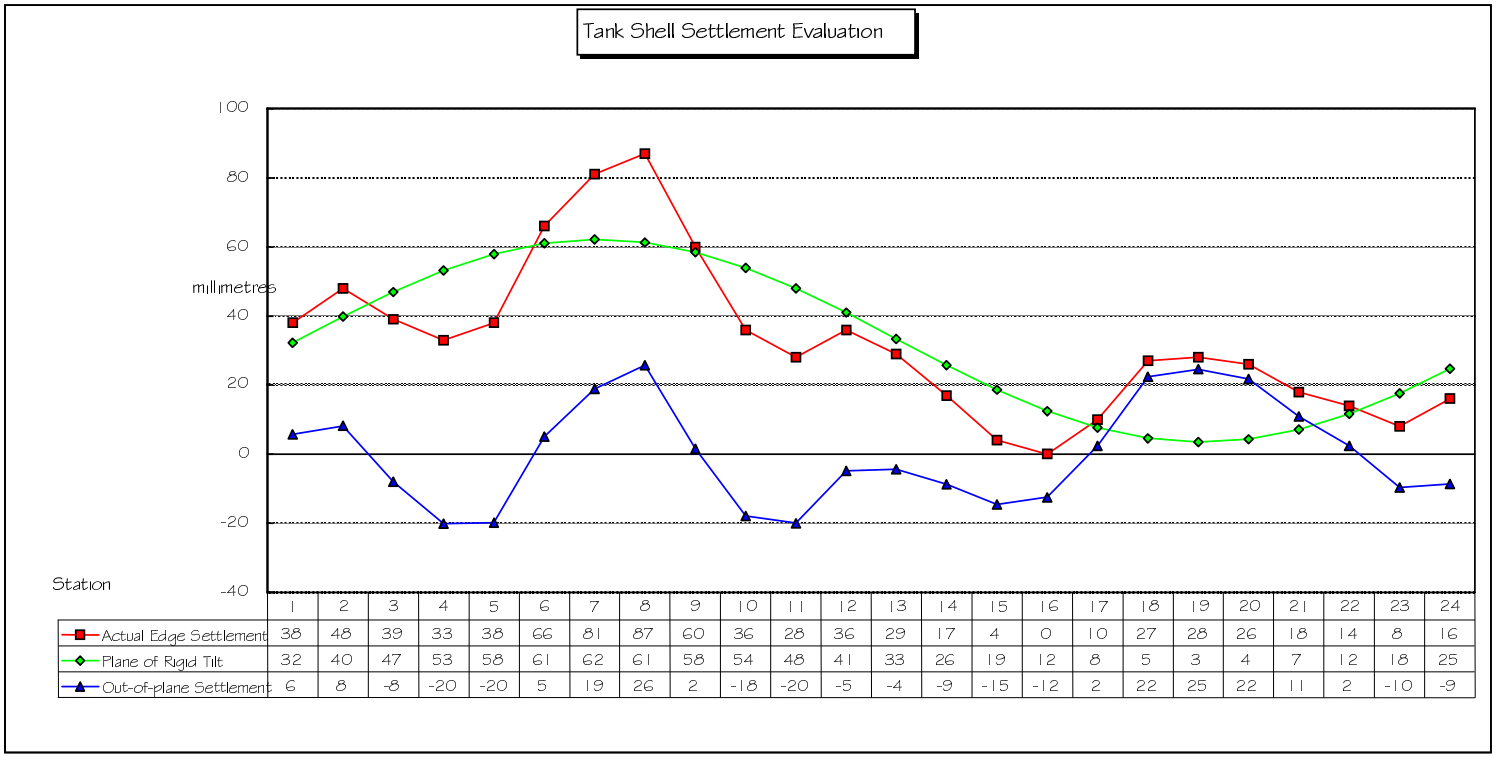
Using the out-of-plane settlement values, the out-of-plane deflection is calculated for the nominated stations (all the stations in this case) and the station having the greatest out-of-plane settlement must be included in the evaluation of out-of-plane deflection.

The maximum out-of-plane deflection at the considered measurement stations is well within the API 653B recommended limit of 24 millimetres. The maximum deflection is 16 millimetres at station 8.

The plane of rigid tilt on the graph suggests there is a maximum tilt of 59 millimetres toward measurement station 19. Note however, that the tank shell does not appear to have the same tilt – refer to the graph of tank shell verticality on page 22.

Appendix B of the API 653 Standard does not provide any criteria for floor tilt evaluation, but instead focuses on the shell settlement and deflection. Any tilt observation is obviously a static one and the data should be compared with similar data for future surveys. It may also be prudent to measure tank verticality at regular intervals to monitor tank tilt.

Client Name and Tank Number - Tank Location PS040000



Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Actual Edge Settlement	38	48	39	33	38	66	81	87	60	36	28	36	29	17	4	0	10	27	28	26	18	14	8	16
Plane of Rigid Tilt	32	40	47	53	58	61	62	61	58	54	48	41	33	26	19	12	8	5	3	4	7	12	18	25
Out-of-plane Settlement	6	8	-8	-20	-20	5	19	26	2	-18	-20	-5	-4	-9	-15	-12	2	22	25	22	11	2	-10	-9

Stations 10, 11, 18, 19, 20 & 21 ignored for the determination of the optimum cosine curve.
Optimum cosine curve (plane of rigid tilt) R^2 value = 0.74

Evaluation of Out-of-plane deflection

Selected Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Out-of-plane Deflection	6	9	-2	-6	-12	6	4	16	-2	-9	-9	7	2	1	-4	-6	-3	9	2	4	-1	2	-6	-7

API Standard 653 (B.3.2) approximation for maximum permissible out-of-plane deflection is 24 mm.
The Standard suggests further assessment or repair if the deflection exceeds the permissible value.
This evaluation is done in accordance with the notation proceeding section B.2.2.4f of API Standard 653.

Shell Roundness Survey

A survey of the tank shell was performed in accordance with ISO Standard 7507, to obtain verticality data at three heights for each strake (measured with optical equipment along 24 vertical stations around the tank exterior) and a tank reference circumference corresponding with the strake 1 upper section verticality readings.

To provide a report on the roundness of the tank shell, we have also determined the internal radii at each measurement station at 300 millimetres above the base of the tank shell.

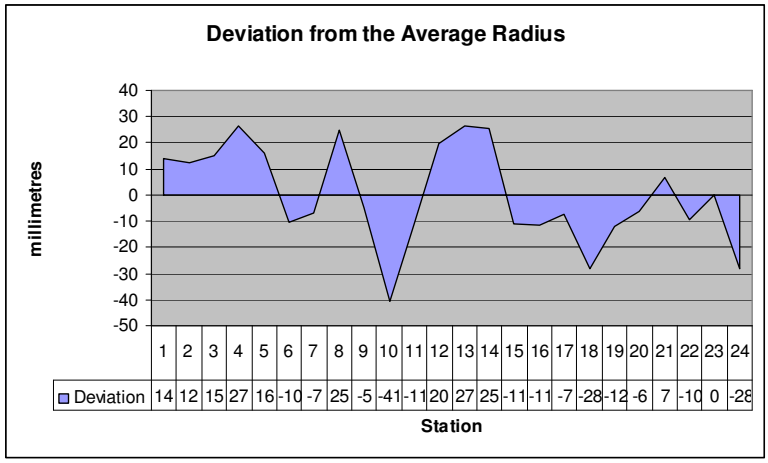
The internal radii are derived from “Disto” laser ranging (offset) measurements taken within the tank from a fixed point to each station around the upper section of strake 1. These readings are adjusted using the tank shell verticality measurements to give an equivalent reading at 300 millimetres above the tank base. The tank centroid is computed from the adjusted offsets and the radius between the centroid and each measurement station calculated, as reported in the table below.

Radii at 300mm above tank base

Station	Radius to Tank Centroid	Station	Radius to Tank Centroid	Station	Radius to Tank Centroid
1	18284	9	18303	17	18305
2	18286	10	18339	18	18326
3	18283	11	18309	19	18310
4	18272	12	18278	20	18304
5	18282	13	18272	21	18291
6	18308	14	18273	22	18308
7	18305	15	18309	23	18298
8	18273	16	18310	24	18326

The maximum radius variation at 300 millimetres above the base of the tank shell is 67 millimetres.

Following are the deviations between the average radius and the radius at each individual station:



The manufacturer of the "Disto" laser instrument specifies a minimum accuracy of ±5 millimetres and a typical accuracy of ±3 millimetres. The instrument is regularly calibrated by us against a certified tape for conformance with this specification.

For traceability to measurements taken in accordance with ISO Standard 7507 and to establish a confidence level for the reported (laser determined) radii, we provide the following comparison of radii calculated from the laser and circumference methods:

Average Radius to Centroid - laser measurements	millimetres
Average Radius at 300mm above tank base	18298.19
Radius correction to reference circumference height above tank base	-3.79
Average internal radius at reference circumference height	**18294.40**

Reference Circumference - in accordance with ISO 7507

Reference circumference	115059.00
Welds correction to circumference	-0.53
Laps correction to circumference	0.00
Corrected circumference	115058.47
Plate and paint thickness	8.00
Internal radius calculated from circumference	**18304.12**

Variation between the two internal radius determinations	**-9.73**

The following diameter information is calculated from the (laser determined) radii and verticality data for each specified strake position relative to the radii at 300 millimetres above the base of the shell.

Shell plate thickness information was measured on site using an ultrasonic thickness test meter.

Due to the position of the wind girder and the height of the upper stake (strake 4) of only 350 millimetres, it was not possible to position our equipment to measure the vertical deviations around this strake. We have, however, taken the upper readings for strake 3 at only 100 millimetres below the weld between strakes 3 and 4.

Following is a summary of the enclosed table and graphs and the measurements obtained:

Internal Diameters between Opposing Stations

Maximum diameter: 36,680 mm – middle and upper strake 3, between external stations 10 and 22.
Minimum diameter: 36,473 mm – upper strake 3, between external stations 1 and 13.

Maximum/minimum diameter variation: 207 mm.
Maximum measured variation at one level: 207 mm – strake 3 upper region.

Three Point Diameter

The three point diameter refers to the maximum circle diameter able to pass between three equidistant points around the internal surface of the tank shell, which is particularly useful for appraising floating roof clearances.

Maximum three point diameter: 36,618 mm – Strake 1 lower region, between stations 2, 10 and 18.
Minimum three point diameter: 36,502 mm – Strake 3 upper region, between stations 1, 9 and 17.

Maximum/minimum three point diameter variation: 101 mm (at any particular level) – strake 3 lower region.

Tank Radar Graph

The tank shell verticality data (refer to page 21) is processed to produce the radar graph of the tank shell stations on page 22. This graph highlights any deviation from verticality in the tank shell.

The graph for this tank shows general inward and outward distortions that have no discernable trend.

The maximum vertical variation over the height of the shell (plumbness) is 59 millimetres (inward) at external measurement station 10.

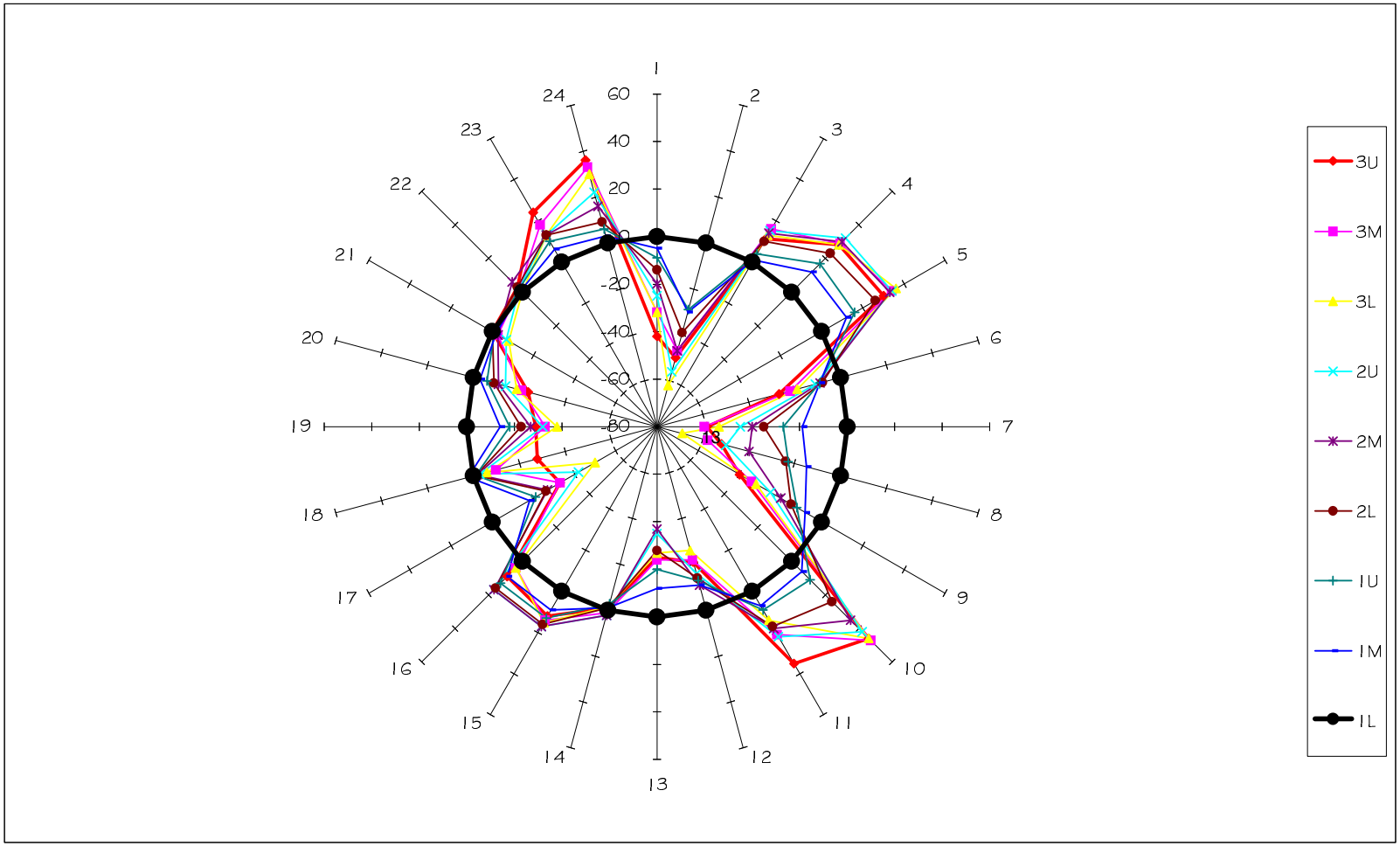
Following are the internal strake heights, calculated from external strake height measurements on the tank:

Strake	Height (mm)
1	1816
2	1460
3	2400
4	370

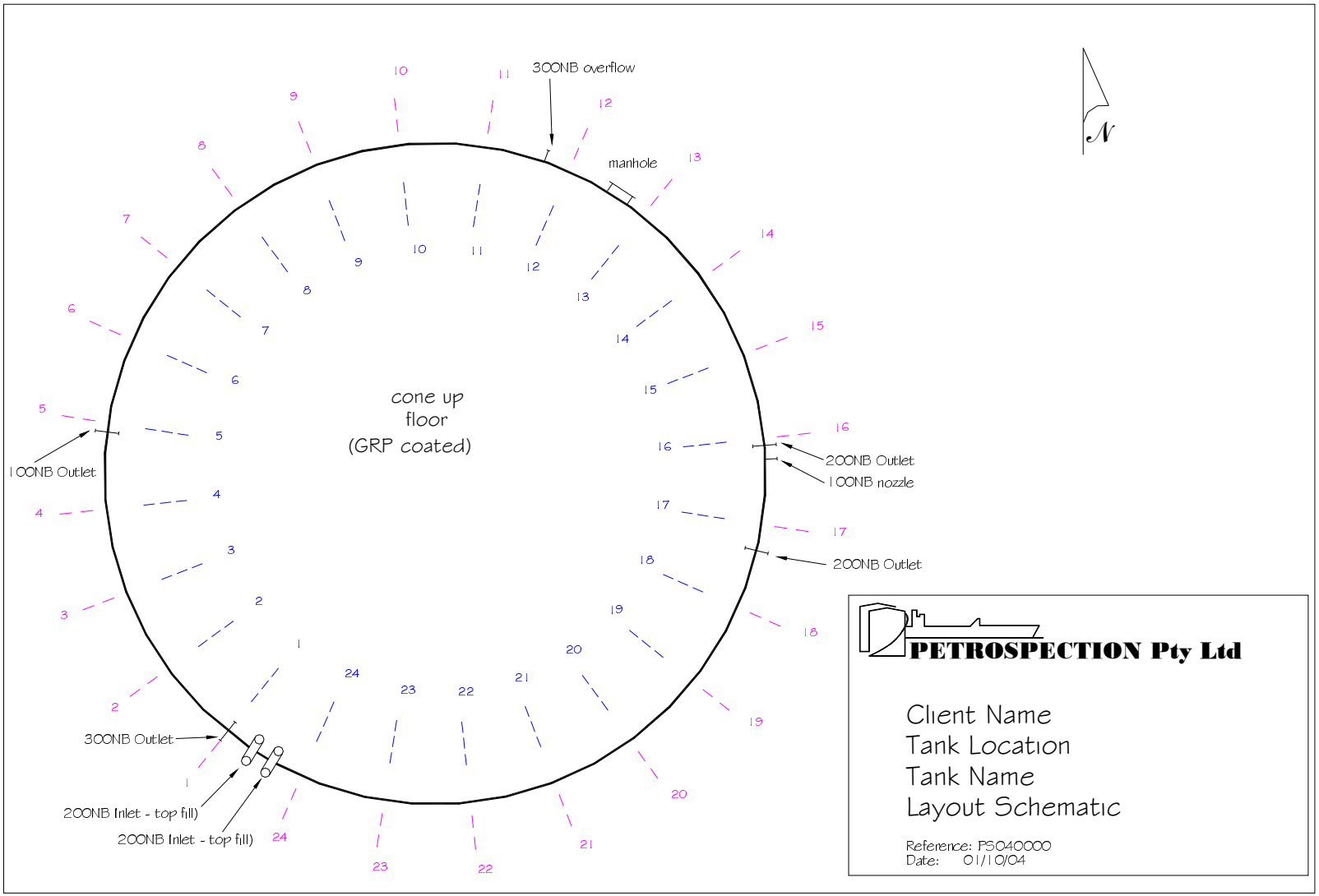
plate thickness	plate position	mm from base	INTERNAL DIAMETERS BETWEEN OPPOSING STATIONS Stations												max dia	min dia	ovality
			1/13	2/14	3/15	4/16	5/17	6/18	7/19	8/20	9/21	10/22	11/23	12/24			
8.0	1 Lower	300	36540	36543	36576	36565	36572	36619	36599	36562	36578	36631	36591	36589	36631	36540	91
8.0	1 Middle	908	36523	36512	36586	36586	36566	36612	36566	36544	36568	36638	36604	36581	36638	36512	126
8.0	1 Upper	1600	36511	36511	36593	36595	36567	36609	36554	36533	36565	36644	36610	36582	36644	36511	133
8.0	2 Lower	2066	36498	36503	36602	36604	36572	36610	36541	36529	36563	36658	36621	36584	36658	36498	160
8.0	2 Middle	2546	36483	36498	36607	36612	36578	36608	36532	36511	36555	36672	36622	36594	36672	36483	189
8.0	2 Upper	3026	36480	36489	36608	36614	36564	36605	36522	36498	36546	36675	36626	36595	36675	36480	195
8.0	3 Lower	3526	36481	36479	36604	36597	36558	36594	36507	36474	36538	36677	36618	36593	36677	36474	203
8.0	3 Middle	4476	36484	36497	36606	36598	36573	36587	36506	36483	36541	**36680**	36630	36600	36680	36483	197
8.0	3 Upper	5626	**36473**	36492	36599	36602	36569	36564	36511	36486	36538	**36680**	36650	36604	36680	36473	207
8.0	4 Lower																
8.0	4 Middle				strake 4 is only 350 mm high												
8.0	4 Upper																
Average internal diameter			36497	36503	36598	36597	36568	36601	36538	36513	36555	36661	36619	36591	36680	36473	

plate thickness	plate position	mm from base	THREE POINT DIAMETER Stations								max dia	min dia	Var
			1/9/17	2/10/18	3/11/19	4/12/20	5/13/21	6/14/22	7/15/23	8/16/24			
8.0	1 Lower	300	36579	**36618**	36586	36554	36548	36577	36592	36590	36618	36548	71
8.0	1 Middle	908	36558	36604	36582	36552	36546	36571	36590	36588	36604	36546	57
8.0	1 Upper	1600	36551	36606	36582	36552	36544	36570	36590	36588	36606	36544	61
8.0	2 Lower	2066	36542	36608	36588	36554	36546	36573	36588	36591	36608	36542	65
8.0	2 Middle	2546	36534	36609	36589	36559	36543	36576	36586	36586	36609	36534	75
8.0	2 Upper	3026	36518	36607	36589	36555	36542	36572	36582	36583	36607	36518	89
8.0	3 Lower	3526	36503	36604	36578	36542	36548	36563	36575	36567	36604	36503	101
8.0	3 Middle	4476	36513	36612	36588	36544	36552	36564	36574	36576	36612	36513	99
8.0	3 Upper	5626	**36502**	36597	36597	36542	36551	36560	36577	36586	36597	36502	95
8.0	4 Lower												
8.0	4 Middle			strake 4 is only 350 mm high									
8.0	4 Upper												
Average internal diameter			36533	36607	36587	36550	36547	36570	36584	36584	36618	36502	116

plate position	mm from base	Shell Plate Verticality Data																						
		Station																						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1 Lower	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1 Middle	908	-5	-30	1	12	12	-9	-19	-15	-8	6	7	-11	-12	-1	9	9	-18	2	-14	-3	-2	1	6	3
1 Upper	1600	-9	-29	4	17	16	-9	-27	-23	-12	11	9	-13	-20	-3	13	13	-21	-1	-18	-6	-1	2	10	6
2 Lower	2066	-14	-39	10	23	26	-8	-35	-24	-15	24	17	-14	-28	-1	16	16	-26	-1	-23	-9	0	3	13	9
2 Middle	2546	-20	-47	14	30	33	-9	-40	-40	-20	35	18	-11	-37	2	17	17	-27	-2	-27	-11	-3	6	13	16
2 Upper	3026	-25	-56	15	32	34	-11	-45	-50	-25	42	22	-16	-35	2	17	17	-42	-3	-32	-14	-7	2	13	22
3 Lower	3526	-32	-62	13	28	36	-19	-54	-69	-32	46	14	-26	-27	-2	15	4	-50	-6	-38	-19	-8	0	13	30
3 Middle	4476	-32	-47	16	29	34	-22	-60	-58	-34	47	21	-22	-24	1	14	4	-33	-10	-33	-21	-3	2	18	33
3 Upper	5626	-42	-50	11	28	30	-27	-59	-52	-40	46	35	-21	-25	-1	12	9	-33	-28	-29	-24	0	3	24	36
4 Lower																									
4 Middle		strake 4 is only 350 mm high																							
4 Upper																									



SHELL STATION RADIAL DISPLACEMENT FROM FROM BASE
Client Name Tank Name - Tank Location PS040000


300NB overflow
manhole
cone up
floor
(GRP coated)
100NB Outlet
200NB Outlet
100NB nozzle
200NB Outlet
300NB Outlet
200NB Inlet - top fill)
200NB Inlet - top fill)
N
PETROSPECTION Pty Ltd
Client Name
Tank Location
Tank Name
Layout Schematic
Reference: PS040000
Date: 01/10/04