



**V-STARS S8 & PRO-SPOT Demonstration
Measurement Report for**

**Korea Hydro & Nuclear Power Co. Ltd (KHNP)
Yonggwang Nuclear Power Division
Jeonnam, Korea**



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Object Measured

Three items were measured as part of the V-STARS demonstration and PRO-SPOT demonstration. The first object was a large turbine. The second was a small semi-cylindrical mould. The last was the mating turbine casing for the turbine measured. The turbine is shown on the cover of this report. The second object is shown in the adjacent image. The turbine casing is shown below.



The primary objective of these measurements was to demonstrate how objects can be measured using V-STARS and PRO-SPOT. To do this, the objects were targeted and measured.

Equipment Used

1. V-STARS S8 INCA3 Camera (INCA3 camera shown in image below)
2. PRO-SPOT target projector
3. AutoBar
4. Coded targets
5. Single dot targets and strip tape
6. Edge Targets
7. Scale Bars



Measurement 1 - Turbine

Objectives

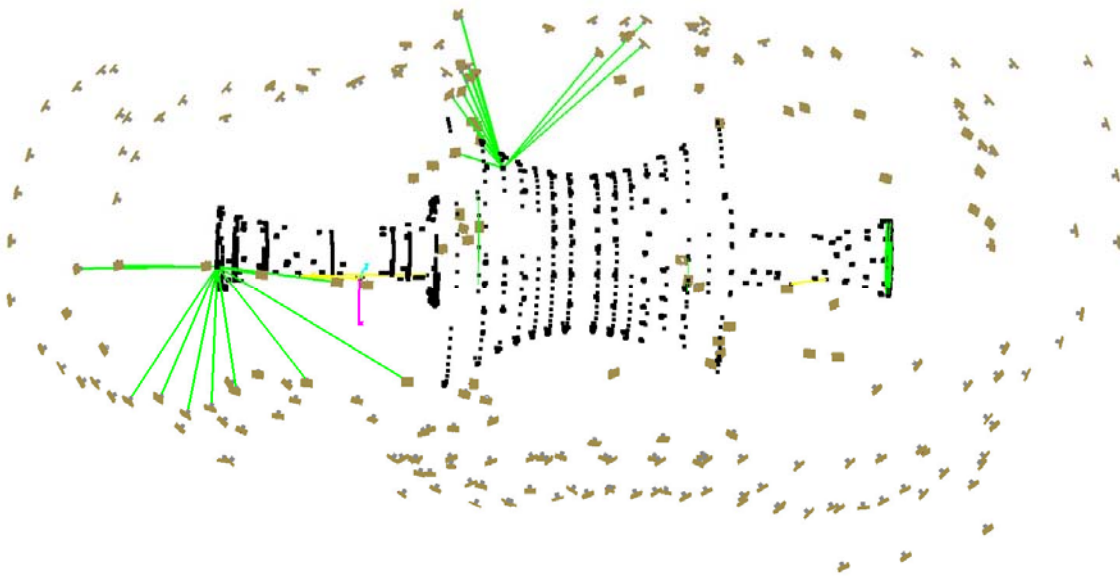
1. Demonstrate INCA3 camera use
2. Determine location of center points on turbine
3. Determine end planes
4. Determine length of turbine
5. Determine separation between two blades

Targeting

1. AutoBar for initial coordinate system
2. Reference coded targets to tie photography together
3. Single dot targets on key planes and circles.
4. Edge targets to measure distance between blades
5. Scale bar points to scale measurement.

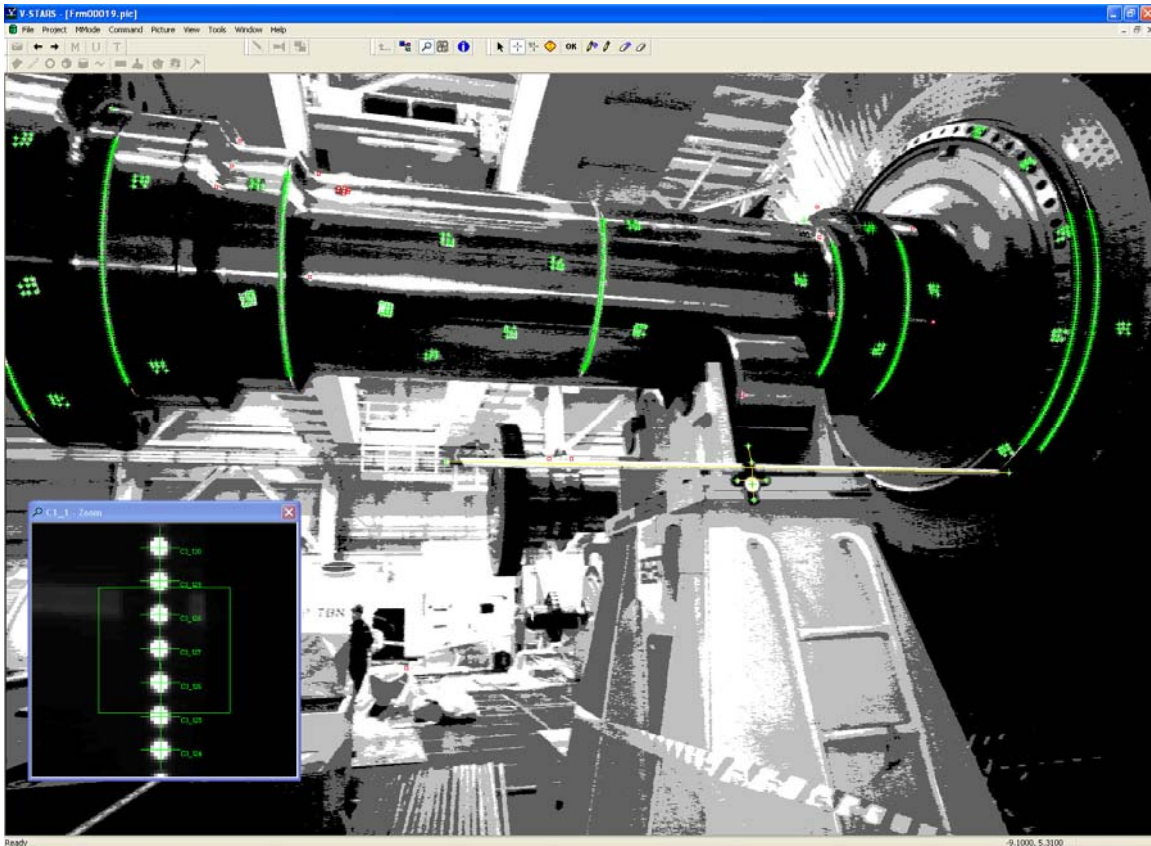
Photography

The diagram below illustrates the geometry used to create the point cloud for the measurement.



Network Geometry

Seen below is an image taken as part of the measurement.



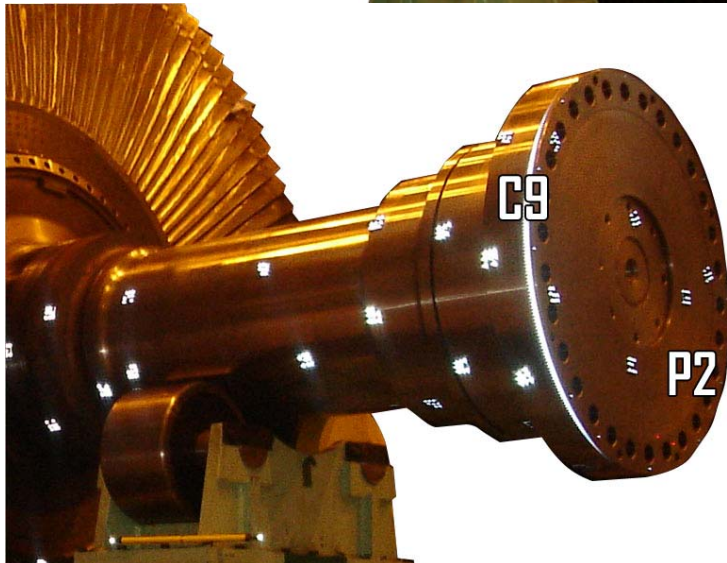
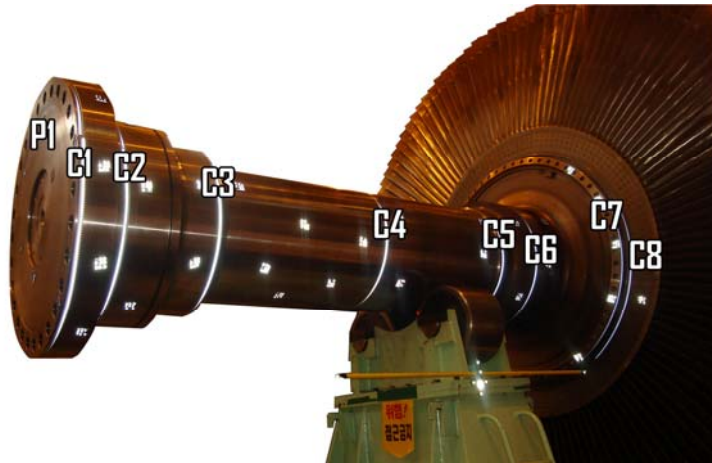
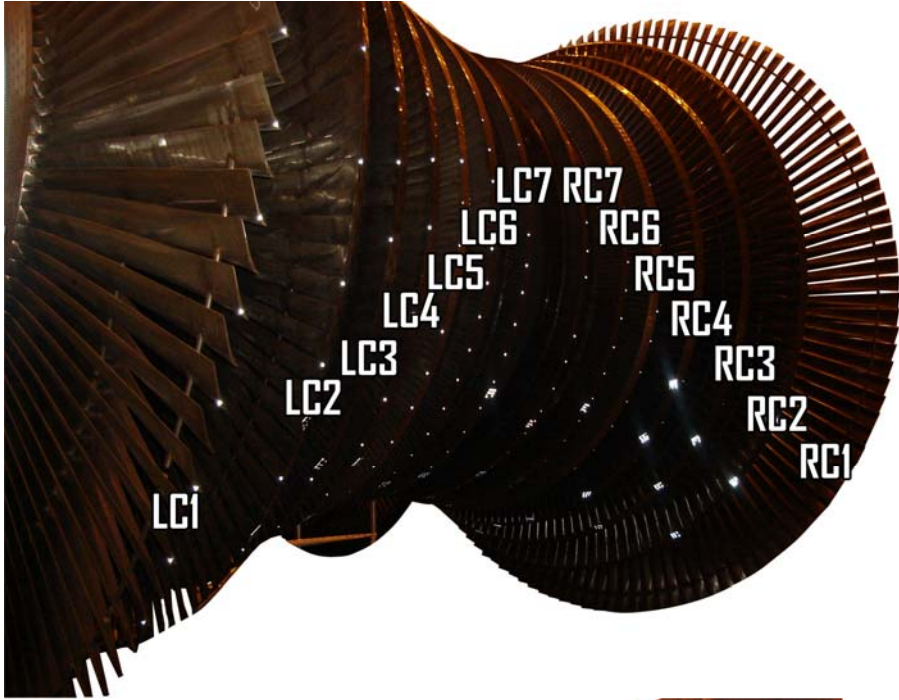
Measurement Statistics

	Measurement
No. of photos	233
No. of points	3822
Accuracy RMS X	0.0009"
Accuracy RMS Y	0.0008"
Accuracy RMS Z	0.0008"
Scale Agreement	0.0027"

Point Numbering

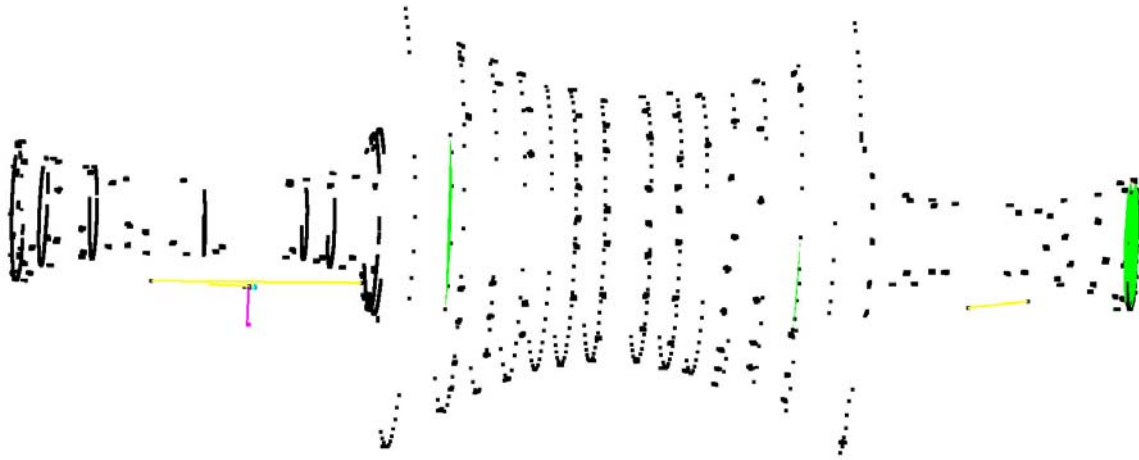
The points were renamed according to the following naming convention.

Points on End Plane	P1_* and P2_*
Points on turbine shaft	C1_* to C9_*
Points on turbine blades (left side)	LC1_* to LC7_*
Points on turbine blades (right side)	RC1_* to RC7_*
Points on planes between blades	P3_* to P6_*



Point Cloud

The point cloud produced is shown below:

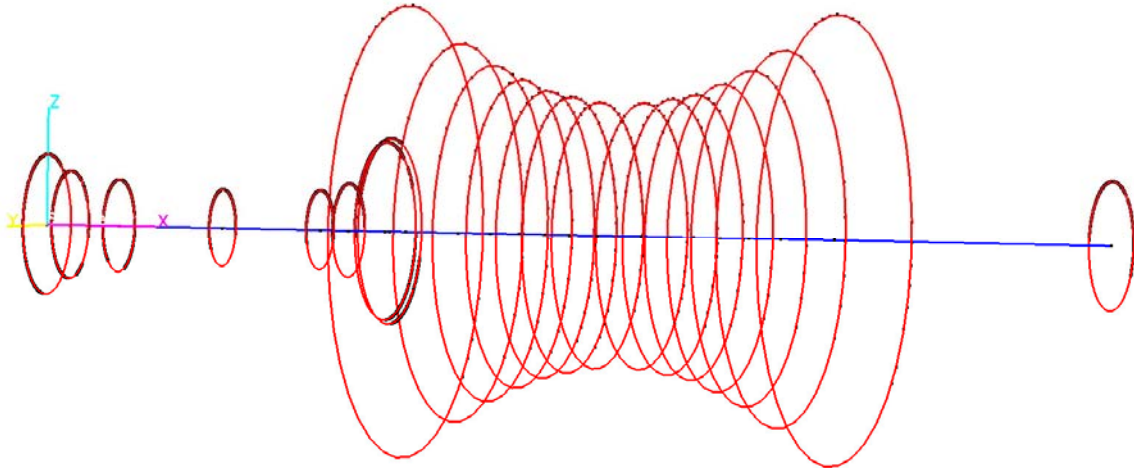


Alignment

An axis alignment carried out using the end point circles C1 and C9.

Analysis

The data collected in the measurement was used to compute the best fit planes, circle and distances. The circles produced are shown graphically below.



The plane results are tabulated below:

Dimension	U-STARS RMS
P1	0.0008"
P2	0.0007"
P3	0.0014"
P4	0.0014"
P5	0.0009"
P6	0.0038"

The distance results are tabulated below:

Dimension	U-STARs RMS
Length	439.0061"
P3 to P4	13.8975"
P5 to P6	13.9097"

The circle calculation results are shown below:

Circle	X	Y	Z	RMS	Radius	Diameter
C1	0.0000	0.0000	0.0000	0.0008	27.1546	54.3092
C2	9.5276	-0.0004	-0.0002	0.0011	20.9017	41.8034
C3	29.5276	0.0000	-0.0010	0.0012	17.9613	35.9226
C4	72.1260	0.0008	-0.0003	0.0008	14.9644	29.9288
C5	112.2047	0.0006	-0.0001	0.0008	15.4645	30.9290
C6	123.9764	0.0009	-0.0004	0.0007	18.2070	36.4140
C7	139.0551	-0.0007	-0.0019	0.0013	34.4665	68.9330
C8	140.8661	-0.0047	-0.0004	0.0027	36.0302	72.0604
C9	437.5152	0.0000	0.0000	0.0011	25.2207	50.4414
LC1	147.3622	0.0015	-0.0011	0.0012	87.6258	175.2516
LC2	168.9370	-0.0007	-0.0018	0.0009	73.3611	146.7222
LC3	182.1654	-0.0015	-0.0028	0.0012	65.1903	130.3806
LC4	193.9764	-0.0025	-0.0031	0.0018	59.8250	119.6500
LC5	204.7244	-0.0017	-0.0022	0.0012	55.7598	111.5196
LC6	214.6063	-0.0016	-0.0025	0.0014	53.6116	107.2232
LC7	226.2205	-0.0022	-0.0007	0.0010	51.7987	103.5974
RC1	323.5782	-0.0069	0.0009	0.0032	87.6214	175.2428
RC2	301.6490	0.0039	-0.0079	0.0029	73.3692	146.7384
RC3	288.4207	-0.0001	-0.0026	0.0005	65.1926	130.3852
RC4	276.6490	0.0018	-0.0042	0.0005	59.8288	119.6576
RC5	265.8223	-0.0044	0.0001	0.0017	55.4528	110.9056
RC6	256.0191	-0.0027	-0.0002	0.0005	53.6067	107.2134
RC7	244.4050	-0.0022	-0.0014	0.0010	51.7652	103.5304

The centerline was created based on the end points of the shaft between C1 and C9. The results are shown below:

Point	Delta Y	Delta Z	Total
C2	-0.0004	-0.0002	0.0004
C3	0.0000	-0.0010	0.0010
C4	0.0008	-0.0004	0.0009
C5	0.0006	-0.0001	0.0006
C6	0.0009	-0.0004	0.0010
C7	-0.0007	-0.0019	0.0020
C8	-0.0047	-0.0004	0.0047

Point	Delta Y	Delta Z	Total
LC1	0.0015	-0.0011	0.0018
LC2	-0.0007	-0.0018	0.0019
LC3	-0.0015	-0.0027	0.0031
LC4	-0.0025	-0.0031	0.0040
LC5	-0.0017	-0.0023	0.0028
LC6	-0.0016	-0.0025	0.0030
LC7	-0.0022	-0.0007	0.0023
RC1	-0.0069	0.0009	0.0070
RC2	0.0039	-0.0079	0.0088
RC3	-0.0001	-0.0026	0.0026
RC4	0.0018	-0.0042	0.0046
RC5	-0.0044	0.0001	0.0044
RC6	-0.0027	-0.0002	0.0028
RC7	-0.0022	-0.0014	0.0026

Measurement 2 - Cylindrical Mould

Objectives

1. Demonstrate PRO-SPOT use
2. Determine location of surface points
3. Determine cylindrical radius

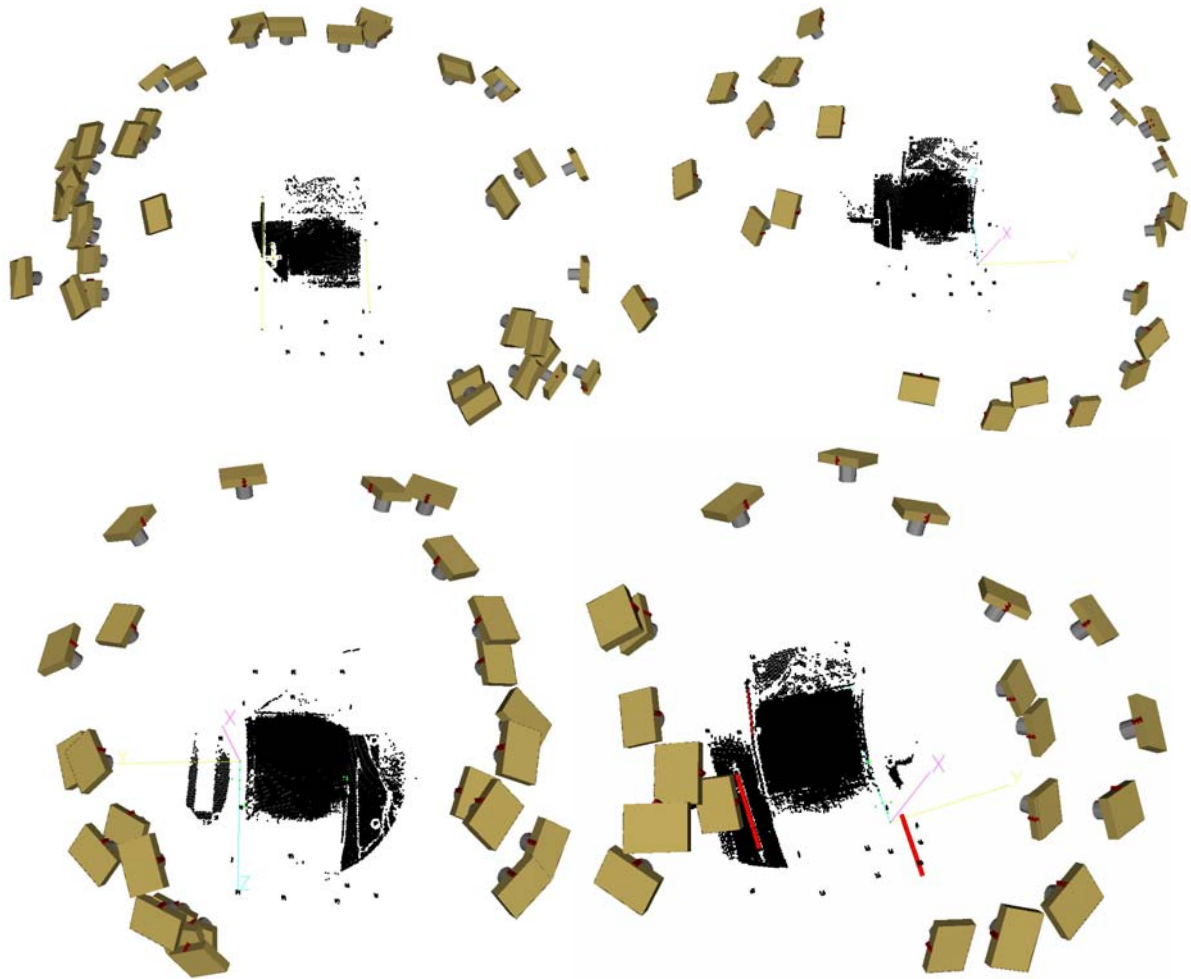
Targeting

1. AutoBar for initial coordinate system
2. Reference coded targets to tie photography together
3. PRO-SPOT Targets
4. Scale bar points to scale measurement.



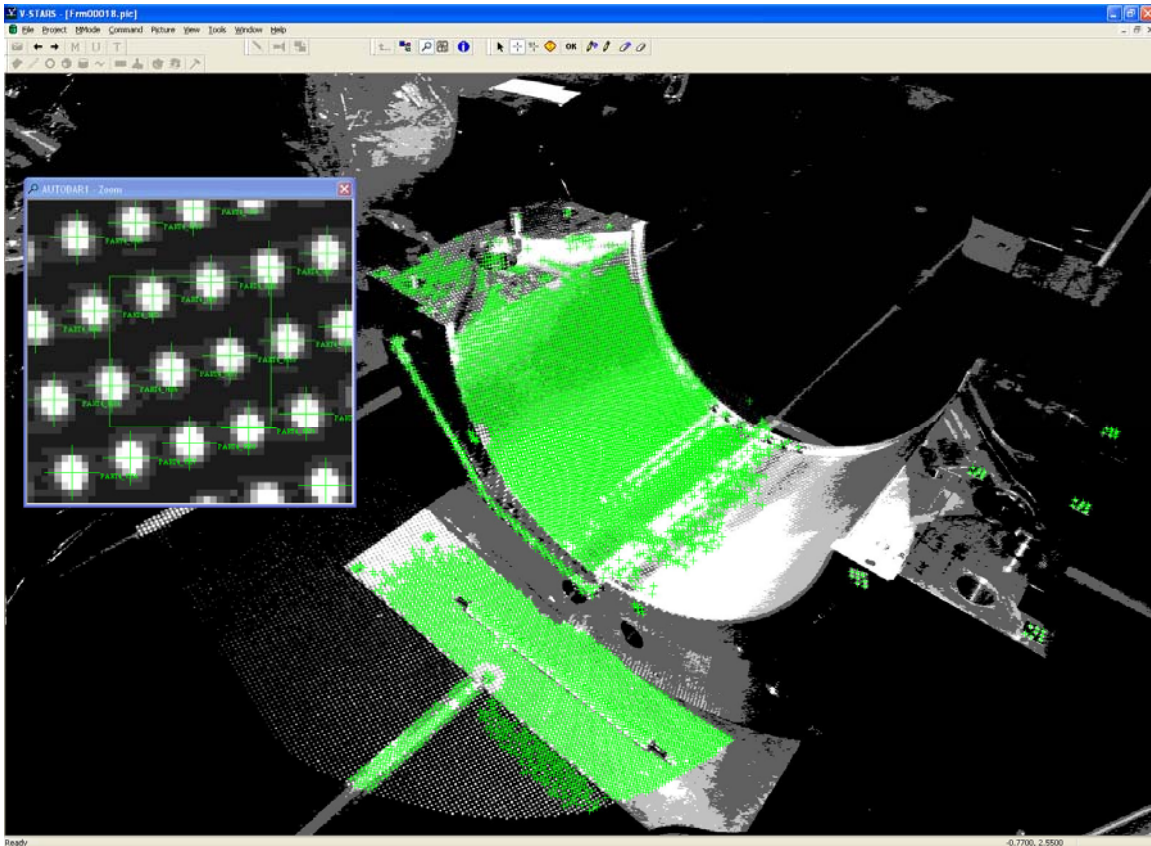
Photography

The object was measured in four setups. The diagrams below illustrate the geometry used to create the point cloud for the measurement.



Network Geometry

Seen below is an image taken as part of the measurement.



Measurement Statistics

	1	2	3	4
No. of photos	29	27	26	21
No. of points	5022	6706	10411	9467
Accuracy RMS X	0.0023"	0.0025"	0.0025"	0.0020"
Accuracy RMS Y	0.0010"	0.0012"	0.0011"	0.0010"
Accuracy RMS Z	0.0011"	0.0011"	0.0011"	0.0011"

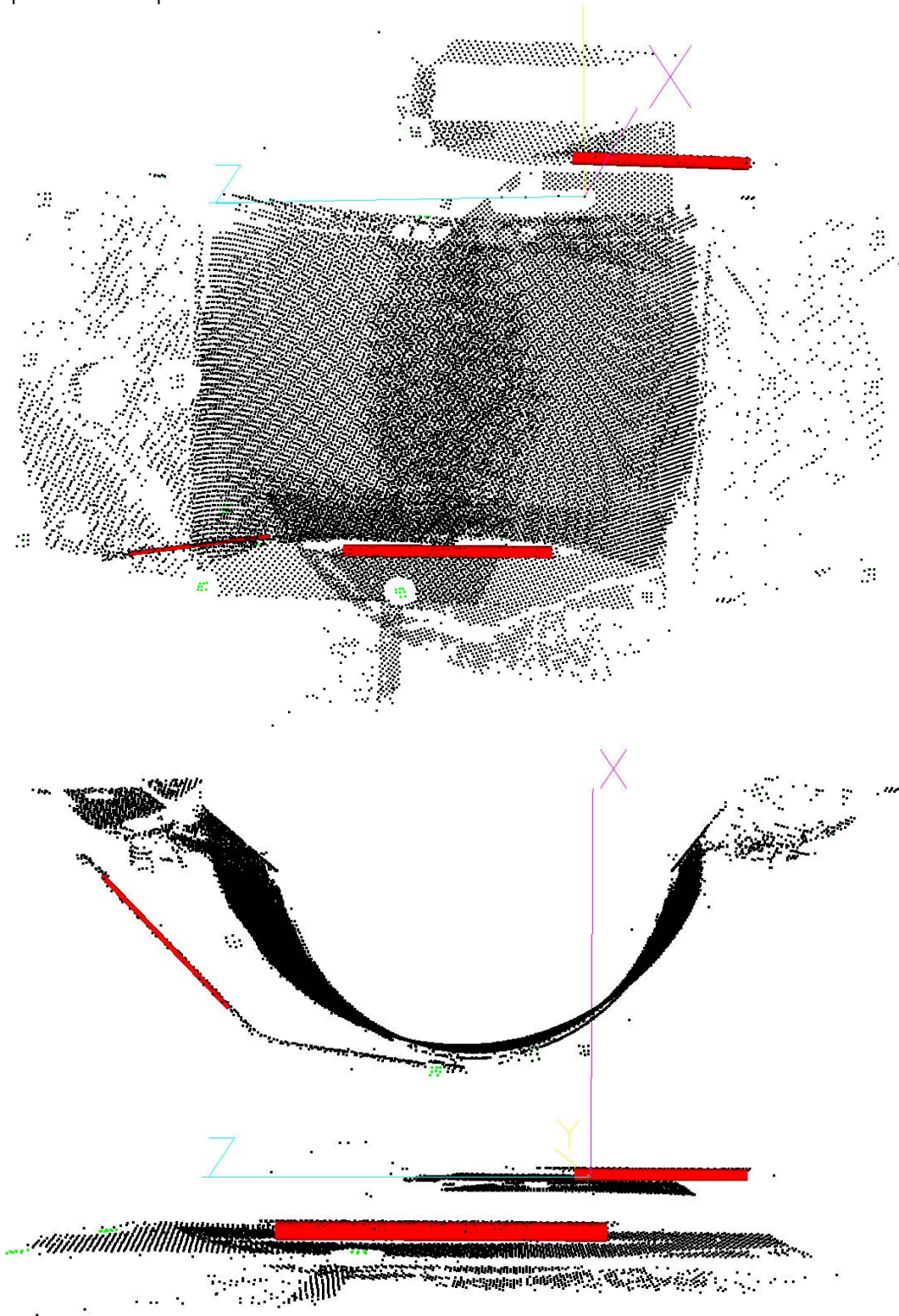
Point Numbering

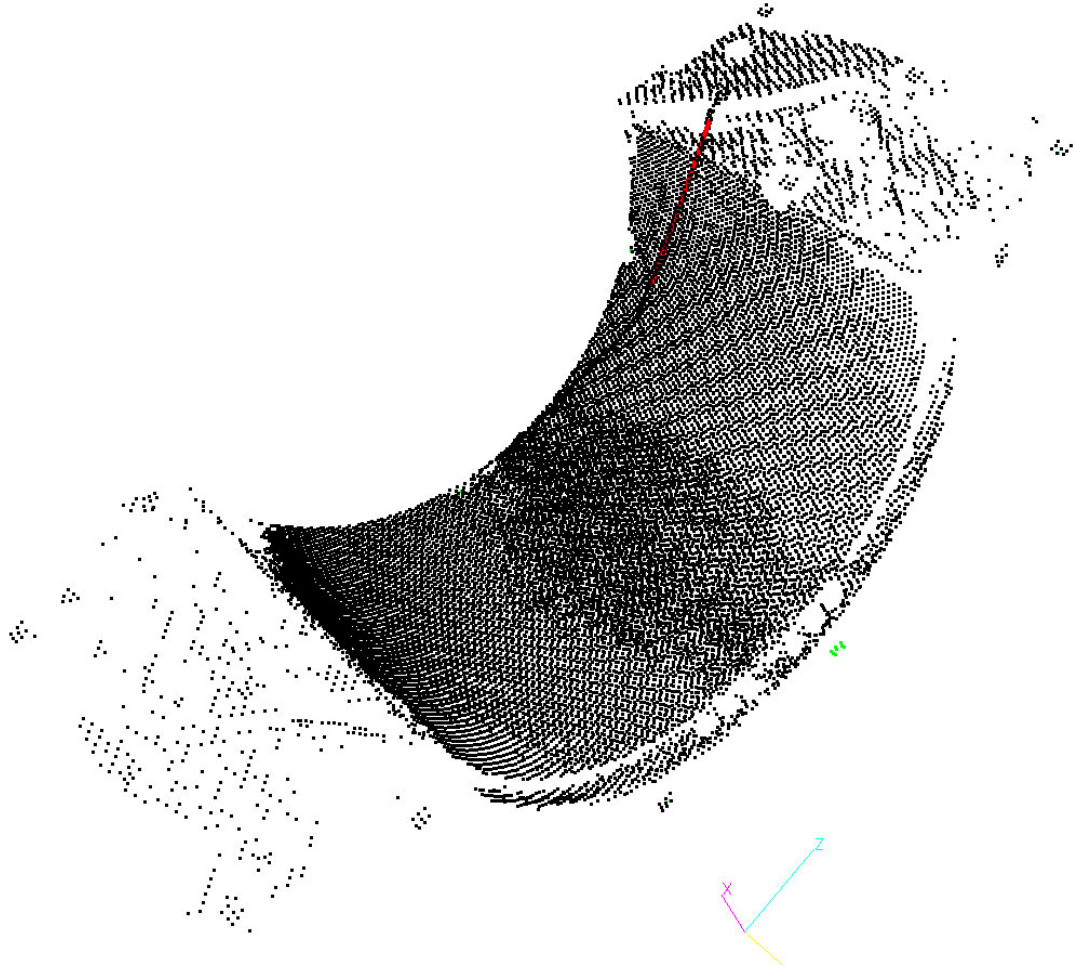
The points were renamed according to the following naming convention.

Points in first part	PART1_*
Points in second part	PART2_*
Points in third part	PART3_*
Points in fourth part	PART4_*

Point Cloud

The point cloud produced is shown below:



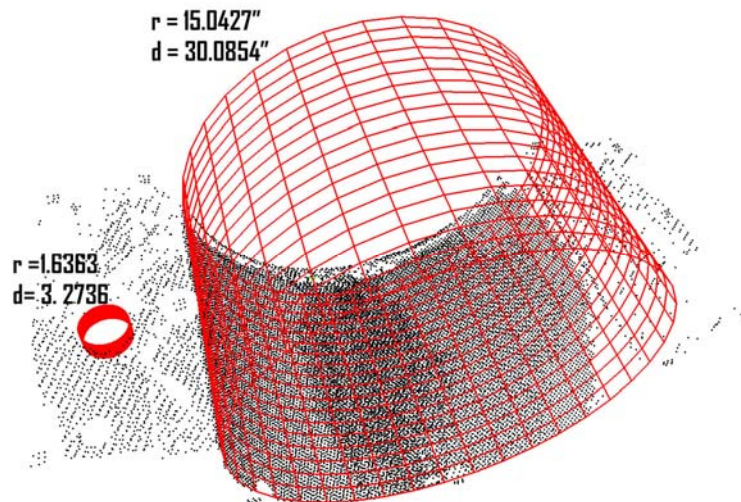


Alignment

No Alignment was needed for this measurement.

Analysis

The data collected in the measurement was used to compute the best fit cylinders.



Measurement 3 - Turbine Casing

Objectives

1. Determine location of center points on turbine casing
2. Determine points at key offsets

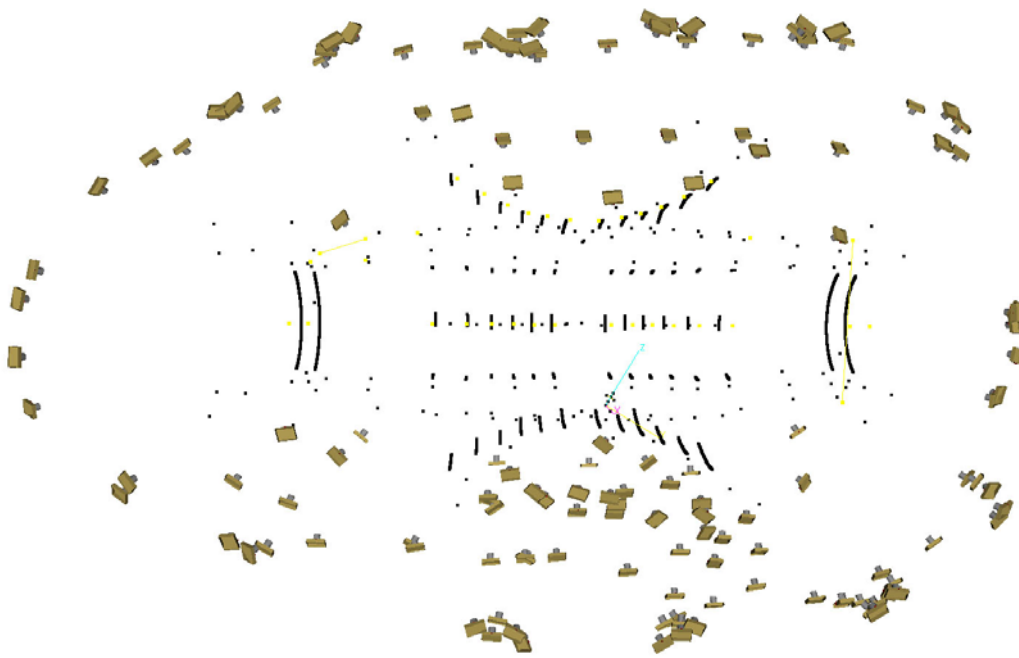
Targeting

1. AutoBar for initial coordinate system
2. Reference coded targets to tie photography together
3. Edge Targets to measure offset points
4. Strip tape to measure key circles
5. Scale bar points to scale measurement.



Photography

The diagram below illustrates the geometry used to create the point cloud for the measurement.



Network Geometry

Measurement Statistics

	1
No. of photos	140
No. of points	2327
Accuracy RMS X	0.0012"
Accuracy RMS Y	0.0011"
Accuracy RMS Z	0.0017"
Scale Agreement	0.0016"

Point Numbering

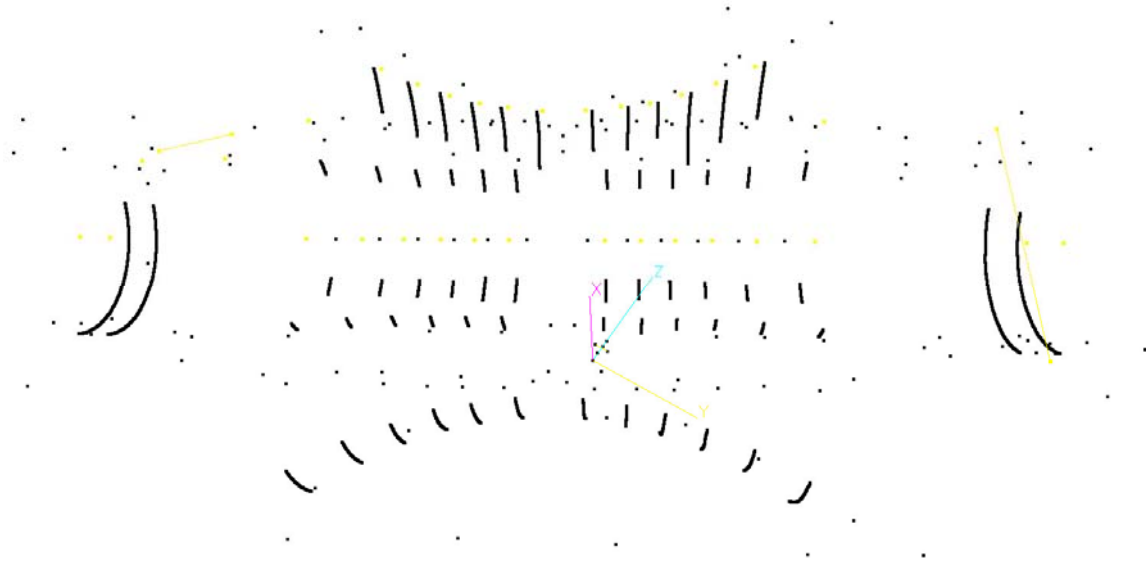
The points were renamed according to the following naming convention.

Points on top at set offsets	1 to 16
Points on turbine shaft	C1_* to C4_*
Points on turbine blades (left side)	LC2_* to LC7_*
Points on turbine blades (right side)	RC2_* to RC7_*
Points on turbine shaft (left side)	L1_* to L6_*
Points on turbine shaft (right side)	R1_* to R6_*
Points on planes between blades	P3_* to P6_*



Point Cloud

The point cloud produced is shown below:

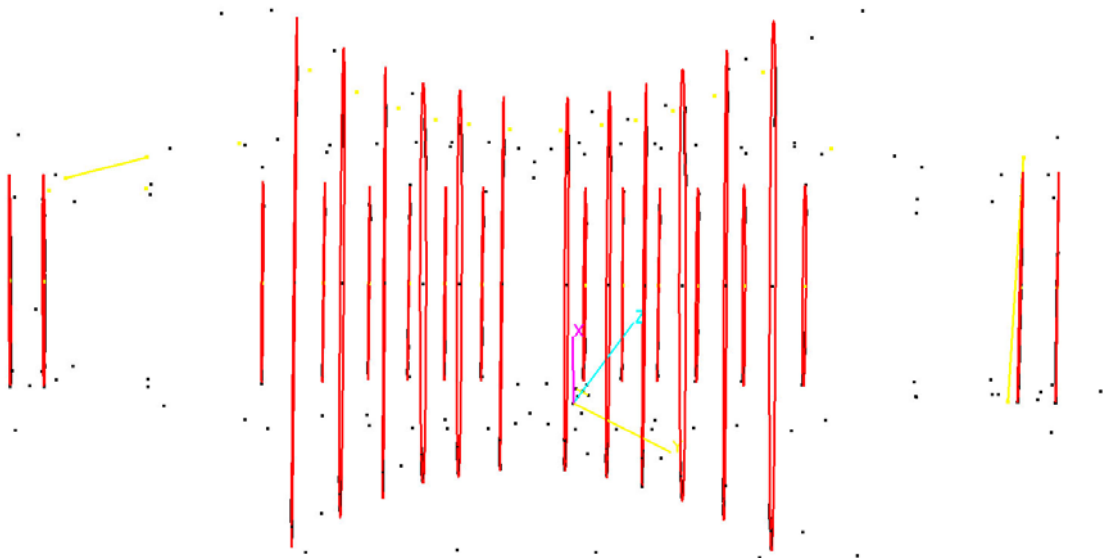


Alignment

An axis alignment carried out using the end point circles C1 and C4.

Analysis

The data collected in the measurement was used to compute the best fit circles. The circles produced are shown graphically below.



The circle calculation results are shown below:

Circle	X	Y	Z	RMS	Radius	Diameter
C1	0.0000	0.0000	0.0000	0.0146	29.5298	59.0596
C2	9.3904	0.0035	0.0000	0.0428	29.5297	59.0594
C3	280.3783	-0.0025	-0.0037	0.0287	32.0345	64.0690
C4	290.6238	0.0000	0.0000	0.0381	32.0273	64.0546
L1	220.4531	0.0510	0.0294	0.0315	28.0100	56.0200
L2	203.6603	0.0534	0.0180	0.0223	28.0109	56.0218
L3	190.7329	0.0403	0.0143	0.0075	27.0115	54.0230
L4	180.0315	0.0481	0.0178	0.0505	27.0108	54.0216
L5	170.0232	0.0452	0.0188	0.0306	27.0196	54.0392
L6	159.4939	0.0595	0.0207	0.0563	27.0112	54.0224
LC2	211.6358	-0.0035	-0.0072	0.0754	73.4467	146.8934
LC3	198.5290	-0.0077	-0.0065	0.0397	65.2689	130.5378
LC4	186.6575	-0.0204	-0.0164	0.0669	59.9002	119.8004
LC5	176.0448	0.0144	0.0039	0.0524	55.8298	111.6596
LC6	166.0517	-0.0109	-0.0086	0.0288	53.6779	107.3558
LC7	154.4353	0.0015	0.0035	0.0554	51.8702	103.7404
R1	70.0843	0.0258	0.0333	0.0214	28.0201	56.0402
R2	87.0794	0.0568	0.0394	0.0395	28.0099	56.0198
R3	99.6619	0.0353	0.0248	0.0592	27.0140	54.0280
R4	110.7163	0.0540	0.0290	0.0369	27.0112	54.0224
R5	120.7559	0.0434	0.0228	0.0302	27.0185	54.0370
R6	131.0550	0.0538	0.0220	0.0294	27.0168	54.0336
RC2	78.9258	-0.0152	0.0037	0.0665	73.4470	146.8940
RC3	92.1681	0.0026	0.0132	0.0248	65.2655	130.5310
RC4	103.8823	-0.0118	0.0053	0.0503	59.8944	119.7888
RC5	114.6772	0.0045	0.0089	0.0480	55.5218	111.0436
RC6	124.7157	-0.0124	-0.0022	0.0423	53.6798	107.3596
RC7	136.4915	0.0014	0.0038	0.0809	51.8482	103.6964

The centerline was created based on the end points of the shaft between C1 and C4. The results are shown below:

Point	Delta Y	Delta Z	Total
C2	0.0035	0.0000	0.0035
C3	-0.0024	-0.0037	0.0044
L1	0.0510	0.0294	0.0589
L2	0.0534	0.0181	0.0563
L3	0.0403	0.0143	0.0427
L4	0.0481	0.0178	0.0513
L5	0.0452	0.0188	0.0490

Point	Delta Y	Delta Z	Total
L6	0.0595	0.0208	0.0630
LC2	-0.0035	-0.0072	0.0080
LC3	-0.0077	-0.0065	0.0101
LC4	-0.0204	-0.0164	0.0262
LC5	0.0144	0.0039	0.0149
LC6	-0.0108	-0.0086	0.0138
LC7	0.0015	0.0035	0.0039
R1	0.0258	0.0333	0.0421
R2	0.0568	0.0394	0.0691
R3	0.0353	0.0248	0.0432
R4	0.0540	0.0290	0.0613
R5	0.0434	0.0228	0.0490
R6	0.0539	0.0220	0.0582
RC2	-0.0152	0.0037	0.0157
RC3	0.0026	0.0133	0.0135
RC4	-0.0119	0.0053	0.0130
RC5	0.0045	0.0089	0.0100
RC6	-0.0124	-0.0022	0.0126
RC7	0.0014	0.0038	0.0040

The circles computed for the turbine were compared to the circles computed for the casing. These are tabulated below:

	Turbine	Casing	Difference
LC1	175.2516	-	-
LC2	146.7222	146.8934	0.1713
LC3	130.3806	130.5378	0.1573
LC4	119.6500	119.8004	0.1505
LC5	111.5196	111.6596	0.1401
LC6	107.2232	107.3558	0.1327
LC7	103.5974	103.7404	0.1431
RC1	175.2428	-	-
RC2	146.7384	146.8940	0.1557
RC3	130.3852	130.5310	0.1459
RC4	119.6576	119.7888	0.1313
RC5	110.9056	111.0436	0.1381
RC6	107.2134	107.3596	0.1463
RC7	103.5304	103.6964	0.1661

Concluding Remarks

The measurement undertaken has shown that V-STARS can be a very powerful measurement tool. The results of the measurement undertaken were very accurate and produced quickly.

GSI would like to thank KHNP for welcoming us into their facility. We will be happy to discuss the results of this report or any other aspect of the technology presented.