ALSTOM	PROJECT : CLIENT :		ANGOSTURA Unit 3 COLBUN		ALSTOM Hydro France N° DOCUMENT : LTESS-14507	
Study N° :		Contract N°		N° O.E. :	Page :	1

Title :

ANGOSTURA

3 Vertical Francis Turbines
2 x 144.35 MW, Hn = 48.77 mWC, 107.14 rpm
1 x 47.15 MW, Hn = 48.65 mWC, 187.5 rpm

Hydro-mechanical Tests - Unit 3

To : Colbun
Alstom Hydro Power

* PREL : Preliminary
* BPE : Released for execution

A	18/09/2014	X.CORNUT	Y.LOWYS E.FLORES	J.SAVARIEAU	PREL	**Preliminary edition**
Index	Date	Prepared by (Name + sig.)	Checked by (Name + sig.)	Approved by (Name + sig.)	DOC STATUS	Observations

1332 E

CONTENT

1. Object

The purpose of these tests, is to study the hydro-mechanical behaviour along with the relative efficiency of the unit. It will also be the opportunity to compare the results with the guaranties.

2. Modification

Index A : Preliminary edition

3. General

3.1. Glossary

H_1, H_2	upstream and downstream geodesic water levels (m)
$H_b = H_1 - H_2$	gross head (m)
H_n	Net head (m)
FSNL	Full Speed No Load (rpm)
ρ	averaged specific mass of water (kg/m^3)
g	site gravity (m/s^2)
p_{atm}	Ambient pressure
T_{air}	Ambient temperature
pp	Raw Peak to Peak value
0-P	Raw Peak value
ppX	Peak to Peak value at X% threshold (X to be defined to 97%) along finite number of shaft revolution
RMS	Root Mean Squared value (global or at a constant frequency)
f_0	Rotational frequency (3.125 Hz at 187.5 rpm)
$2f_0$	2 times the rotational frequency (2 x 3.125 Hz at 187.5 rpm)
$0.3f_0$	0.3 time the rotational frequency (~0.3 x 3.125 Hz at 187.5 rpm)
Z_rf_0	Is the blabe number (Z_r =13)time the rotational frequency (13 * 3.125 Hz)
$2Z_rf_0$	2 times the blabe number (Z_r =13) time the rotational frequency(2*13*3.125 Hz)
NG	Global level (global level including the analysis range [0-800Hz])

NGA	Global acceleration level
NG Velocity	Global velocity level
1X, 1Y	refers respectively to an accelerometer on the upper generator guide bearing, on the X or Y direction, on same location as the monitoring system.
2X, 2Y, 2Z	refers respectively to an accelerometer on the lower generator combined thrust and guide bearing, on the X, Y or Z directions, on same location as the monitoring system.
3X, 3Y, 3Z	refers respectively to an accelerometer on the turbine guide bearing, on the X, Y or Z directions, on same location as the monitoring system.
Vib_ConeX, Vib_ConeY	refers to an accelerometer on the draft tube cone, on the X or Y directions, on same location as the monitoring system.
S1X, S1Y, S1Z	refers respectively to a shaft relative displacement on the upper generator guide bearing, on the X, Y or Z directions, on same location as the monitoring system.
S2X, S2Y	refers respectively to a shaft relative displacement on the lower generator combined thrust and guide bearing, on the X or Y directions, on same location as the monitoring system.
S3X, S3Y	refers respectively to a shaft relative displacement on the turbine guide bearing, on the X or Y directions, on same location as the monitoring system.
P_SC_Dyn	Dynamic pressure on spirale case man hole.
P_HC2, P_HC3	Dynamic pressure in between the runner and the guide vane.
P_HC1	Dynamic pressure in between the crown and the head cover.
P_Cone_Dyn	Dynamic pressure on the draft tube cone manhole.
P_membrane	Thrust bearing membrane pressure used to determine the turbine axial thrust.
P_Up_Before	Collected pressure in a single section before the convergent.

P_Up_After	Collected pressure in a single section after the convergent.
P_Down	Collected pressure in a single section of the draft tube outlet.
P_WK	Spirale case differential pressure used to estimate the flow.
P_WK_Client	Spirale case differential pressure used to estimate the flow (Customer sensor).
TP_Noise	refers to the noise in the turbine pit.
Axial_Valve_pos	refers to the axial valve opening.
Speed	refers to the speed measure with a key phasor.
SMS_GV	refers to the guide vane servomotor stroke.
Power	Generator output power of the unit gathered from the turbine governor.

3.2. General Characteristics of Turbine-Generator set

Nominal Generator Specifications:

Nominal shaft revolution : n_0 = 187.5 rpm
Combined thrust and guide bearing pad number : 12

Nominal Turbine Specifications:

Turbine type	Francis vertical
Rated output	47.15 MW
Rated Net Head :	Hn_0= 48.65 m
Rotation Speed :	n_0 = 187.5 rpm (f_0= 3.125Hz) clockwise
Number of Runner Blades :	Zr = 13
Number of Guide Vanes :	Zg = 24

3.3. Description of the Tests

List of Tests	***Appendix 1***
Description of Instrumentation :	***Appendix 3***
Calibration Sheets of Instruments :	***Appendix 4 & 5***

Tests have been performed on unit 3 on the 28/08/2014 under the responsibility of Alstom Hydro France, with assistance of Colbun.

4. Measurement process

4.1. Test

A procedure has been made by ALSTOM Hydro France and agreed by Colbun describing the mechanical behavioural tests that have been realised on Unit 3 of Angostura.

4.2. Analyser Records

Temporal signal have been recorded using portable OROS dynamic analysers (OR38). Sampling has been performed at 2.048 kS/s for all the inputs (which provides analysis range of 800 Hz), except for the microphone that has been set up at 51 kS/s (20 kHz analysis range, roughly the human hearing range).
Signal analysis is made using DYNAMX release 8, specific software which enables post processing of all the data recorded.
The 34 channels are recorded simultaneously on the analysers. The record duration has been set at 60 s (enabling maximum analysis observation of around 187.5 shaft revolutions) and each measurement point was recorded after stabilisation of the parameters, either thermal or hydraulic, for each steady state operation point.

We performed measurement as per Test list in ***Appendix 1***.

4.3. Tests conditions

Each parameter has been recorded under 12 steady state load points, from 4.7 to 47.2, with the gross head available at the time of the test Hg = 50.77 m. For each steady state point 3 air injection configuration have been tested:

1. Axial valve free, head cover and bottom ring air injection closed
2. Axial valve closed, head cover and bottom ring air injection closed
3. Axial valve free, head cover and bottom ring air injection opened (1 compressor running)

In addition transient operation have also been recorded like mechanical overspeed ,load rejection, normal start-up and shut-down.

The results are presented hereafter.

5. Hydraulic test results – Index tests

5.1. Principle

By measuring a differential pressure in a single section of the spiral case(ΔH_{WK}) we can build a relation between it and the turbine flow using the model test hill chart.

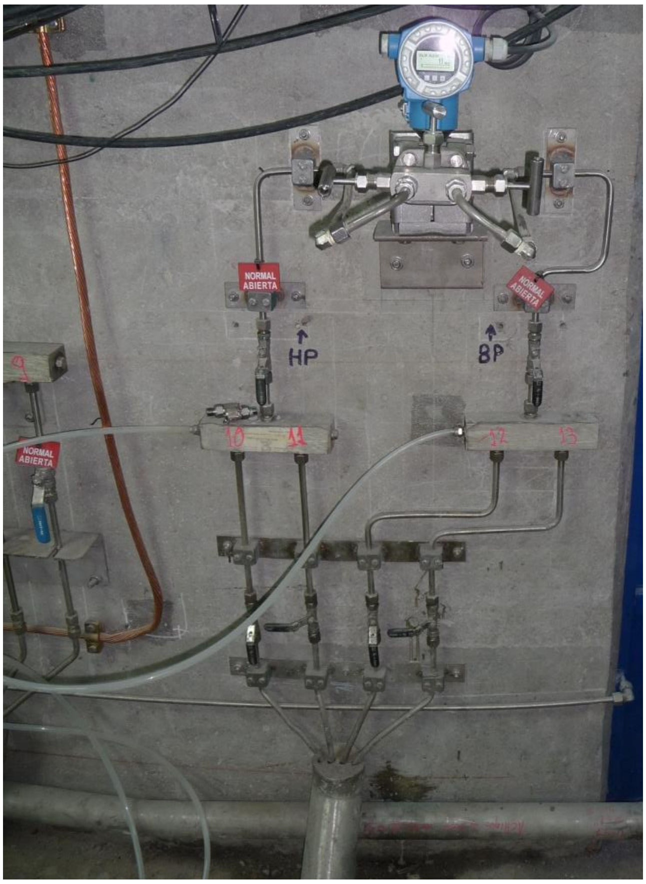
The ΔH_{WK} difference of pressure measured is related to the relative discharge by the following relation:

$$Q_{relat\_turb} = K(\Delta H_{WK})^n$$

Where:

Q_{relat_turb} : is the relative flow indexed on the hill chart.
K: is a coefficient that will be adjust to fit with the hill chart flow
n: is a number between 0.48 and 0.52 according to the hydraulic conditions

The differential pressure sensor is from ROSEMOUNT, DP5 E22 model; it is collected near the turbine pit, at the same location than customer one.It was calibrated on site, using a Druck DPI605 calibrator; the calibration sheet is provided in **Annex 4**:



5.2. Transposition rules

When grid frequency is stable and corresponds to nominal value (50 Hz in Chile) and if measured heads H_{nm} do not correspond exactly to the guaranteed net heads H_{ng}, within a range of $\pm$ 2% (considering a 50Hz frequency), IEC 41 code allows to transpose the results, by using following formulas :

$$Q(H_{ng}) = Q(H_{nm}) x \left(\frac{H_{ng}}{H_{nm}} \right)^{1/2}$$

$$P_m(H_{ng}) = P_m(H_{nm}) x \left(\frac{H_{ng}}{H_{nm}} \right)^{3/2}$$

$$\eta(H_{ng}) = \eta(H_{nm})$$

5.3. Index test results

The Winter Kennedy coefficients (K and n) were calibrated from the measured differential pressure and in comparison with the guaranteed efficiencies.

Below are presented the results at 50.77m for Alstom WK differential pressure device.

WK Coefficients for Alstom site test team sensor "P_WK":

P_WK (Pa)	
K (m3/s/Pa)	0.858
n (-)	0.48

WK customer sensor "P_WK_Client":

P_WK_Client (Pa)	
K (m3/s/Pa)	0.8315
n (-)	0.48

Main characteristics:

Designation	Value	Unit
Ambiente pressure	98171	Pa
Gravity	9.799	m/s2
Water average density	998.2	kg/m3

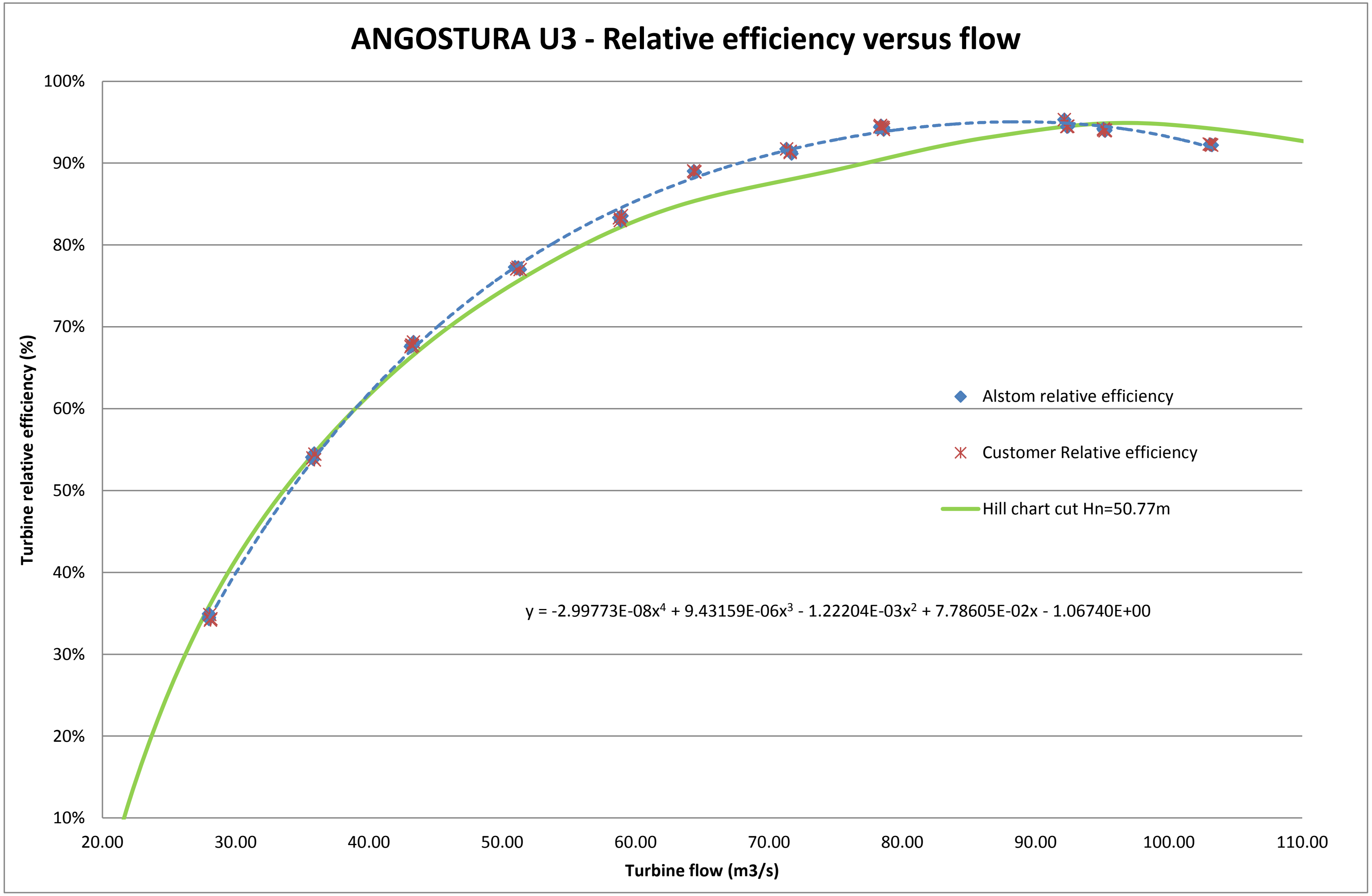
Pressure sensors elevations		
P_Up_Before elevation	266.06	m
P_Up_After elevation	266.06	m
P_Down elevation	265.045	m
P_SC_Dyn elevation	259.83	m
P_Cone_Dyn elevation	257.58	m
Upstream measuring section before convergent	26.421	m2
Upstream measuring section after convergent	13.527	m2
Downstream measuring section	31.658	m2

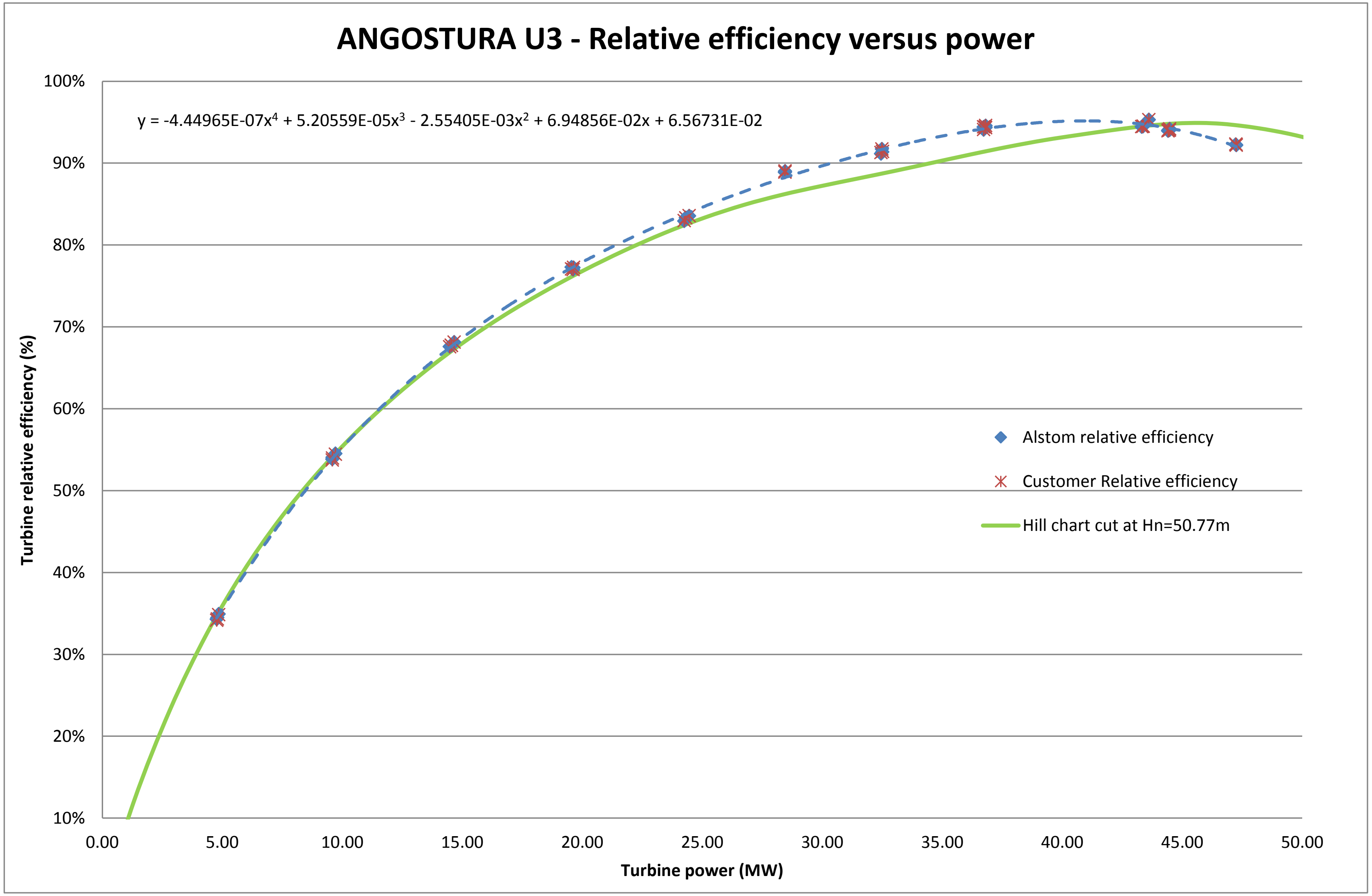
On the following graphs**, we notice a good correlation between WK sensors and guaranteed performances.**

ALSTOM	PROJECT : CLIENT :	ANGOSTURA Unit 3 COLBUN		ALSTOM Hydro France N° DOCUMENT : LTESS-14507	
Study N° :		Contract N°	N° O.E. :	Page :	13

													Results using Alstom WK sensor:					Results using Colbun WK sensor				
																Results transposed at Hn=					Results transposed at Hn=	
																50.77	m				50.77	m
Test point	SMS_GV	SMS_GV	Power TSLG	Turbine power	P_WK_Client	P_WK	P_Up_Before	P_Up_After	P_Down	P_Up_Before	P_Up_After	P_Down	WK Flow	Hn	Efficiency	WK Flow	Turbine power	WK Flow	Hn	Efficiency	WK Flow	Turbine power
(-)	(mm)	(°)	(MW)	(MW)	(Pa)	(Pa)	(Pa)	(Pa)	(Pa)	(m)	(m)	(m)	(m3/s)	(m)	%	(m3/s)	(MW)	(m3/s)	(m)	Client %	(m3/s)	(MW)
4.7MW1	83	10.4	4.804	4.757	1528	1417	595498	590316	113367	316.90	316.37	266.60	27.9	50.48	34.48%	28.0	4.797	28.1	50.49	34.31%	28.2	4.797
4.7MW2	83	10.4	4.774	4.726	1523	1415	595428	590289	113498	316.90	316.37	266.61	27.9	50.46	34.30%	28.0	4.769	28.0	50.46	34.16%	28.1	4.769
4.7MW3	83	10.4	4.865	4.816	1518	1416	595359	590268	113228	316.89	316.37	266.58	27.9	50.48	34.92%	28.0	4.857	28.0	50.48	34.85%	28.1	4.857
9.3MW1	106	13.4	9.416	9.498	2518	2352	594585	588380	114196	316.81	316.18	266.68	35.6	50.42	54.06%	35.7	9.598	35.7	50.42	53.98%	35.8	9.598
9.3MW2	106	13.4	9.388	9.486	2535	2364	594543	588307	114131	316.81	316.17	266.68	35.7	50.42	53.85%	35.8	9.584	35.8	50.42	53.73%	35.9	9.584
9.3MW3	106	13.4	9.507	9.597	2537	2370	594515	588292	114887	316.80	316.17	266.75	35.8	50.34	54.51%	35.9	9.720	35.8	50.34	54.43%	36.0	9.719
14.1MW1	125	15.9	14.136	14.335	3717	3481	593601	586018	115757	316.71	315.94	266.84	43.0	50.29	67.76%	43.2	14.541	43.0	50.29	67.76%	43.2	14.541
14.1MW2	125	15.9	14.109	14.279	3708	3471	593573	585961	115605	316.71	315.93	266.83	42.9	50.30	67.58%	43.1	14.480	43.0	50.30	67.56%	43.2	14.479
14.1MW3	125	15.9	14.187	14.349	3728	3494	593431	585770	115673	316.69	315.91	266.83	43.1	50.28	67.72%	43.3	14.558	43.1	50.28	67.73%	43.3	14.558
14.1MW4	125	15.9	14.294	14.465	3741	3505	593407	585729	115416	316.69	315.91	266.81	43.1	50.31	68.13%	43.3	14.665	43.1	50.31	68.14%	43.3	14.665
19MW1	148	18.7	19.061	19.263	5266	4906	592280	582807	116377	316.58	315.61	266.91	50.7	50.26	77.29%	51.0	19.560	50.8	50.26	77.08%	51.1	19.558
19MW2	148	18.7	19.158	19.361	5291	4959	592241	582748	116182	316.57	315.60	266.89	51.0	50.28	77.25%	51.2	19.646	51.0	50.28	77.27%	51.2	19.646
19MW3	148	18.7	19.161	19.338	5320	4982	592181	582701	116195	316.57	315.60	266.89	51.1	50.27	76.99%	51.3	19.626	51.1	50.27	76.98%	51.3	19.626
23MW1	169	21.4	23.608	23.862	7067	6629	590977	579516	117340	316.44	315.27	267.00	58.6	50.22	82.92%	58.9	24.255	58.5	50.22	82.98%	58.9	24.256
23MW2	169	21.4	23.657	23.923	7049	6598	590942	579463	117317	316.44	315.26	267.00	58.5	50.22	83.33%	58.8	24.321	58.5	50.22	83.30%	58.8	24.320
23MW3	169	21.4	23.913	24.174	7108	6664	590994	579469	115920	316.44	315.27	266.86	58.7	50.37	83.54%	59.0	24.462	58.7	50.37	83.58%	58.9	24.463
28MW1	183	23.2	28.643	28.929	8730	8183	590043	576514	107168	316.35	314.96	265.96	64.8	51.34	88.88%	64.5	28.449	64.8	51.34	88.91%	64.4	28.449
28MW2	183	23.2	28.669	28.963	8741	8185	590001	576445	106796	316.34	314.96	265.93	64.8	51.37	88.91%	64.4	28.454	64.8	51.37	88.90%	64.5	28.454
28MW3	183	23.2	28.715	29.010	8724	8176	590160	576551	106458	316.36	314.97	265.89	64.8	51.42	89.02%	64.4	28.459	64.8	51.42	89.04%	64.4	28.460
33MW1	205	25.9	33.321	33.661	11025	10359	588984	572740	101835	316.24	314.58	265.42	72.6	52.02	91.14%	71.7	32.455	72.5	52.02	91.28%	71.6	32.458
33MW2	205	25.9	33.456	33.801	11047	10360	589094	572798	101149	316.25	314.58	265.35	72.6	52.10	91.37%	71.7	32.514	72.5	52.10	91.43%	71.6	32.515
33MW3	205	25.9	33.471	33.817	10968	10269	589228	572924	100777	316.26	314.60	265.31	72.3	52.14	91.73%	71.3	32.491	72.3	52.14	91.71%	71.3	32.490
37MW1	229	28.8	37.745	38.115	13396	12552	588071	568986	103104	316.15	314.19	265.55	79.6	52.04	94.08%	78.6	36.728	79.6	52.04	94.09%	78.6	36.729
37MW12	229	28.8	37.740	38.128	13302	12466	588187	569090	103071	316.16	314.20	265.55	79.3	52.05	94.41%	78.4	36.734	79.3	52.04	94.43%	78.3	36.735
37MW2	229	28.8	37.742	38.164	13351	12509	588134	569047	103262	316.15	314.20	265.57	79.5	52.03	94.38%	78.5	36.791	79.5	52.03	94.39%	78.5	36.791
37MW22	229	28.8	37.777	38.207	13317	12484	588171	569048	103125	316.16	314.20	265.55	79.4	52.04	94.55%	78.4	36.816	79.4	52.04	94.59%	78.4	36.817
37MW3	229	28.8	37.865	38.249	13401	12551	588299	569135	102915	316.17	314.21	265.53	79.6	52.08	94.34%	78.6	36.813	79.6	52.08	94.33%	78.6	36.812
42MW1	281	34.8	42.490	43.098	18038	16901	588390	564409	124479	316.18	313.73	267.73	91.8	50.36	95.29%	92.2	43.620	91.8	50.36	95.30%	92.2	43.620
42MW2	281	34.8	42.472	42.792	18114	16972	588383	564413	124633	316.18	313.73	267.75	92.0	50.36	94.44%	92.4	43.320	92.0	50.36	94.45%	92.4	43.321
42MW31	281	34.8	42.472	42.808	18132	16986	588249	564280	124756	316.16	313.71	267.76	92.0	50.33	94.48%	92.4	43.370	92.0	50.33	94.49%	92.4	43.370
42MW32	281	34.8	42.489	42.823	18132	16997	588177	564201	124653	316.16	313.70	267.75	92.1	50.34	94.48%	92.5	43.379	92.0	50.33	94.51%	92.4	43.380
43MW1	294	36.2	43.429	43.786	19229	18024	587396	562194	125512	316.08	313.50	267.84	94.7	50.28	94.03%	95.1	44.428	94.7	50.28	94.06%	95.1	44.430
43MW2	294	36.2	43.419	43.782	19272	18053	587327	562135	125454	316.07	313.49	267.83	94.8	50.28	93.94%	95.2	44.422	94.8	50.28	93.94%	95.2	44.422
43MW31	294	36.2	43.472	43.827	19220	18005	587331	562118	125530	316.07	313.49	267.84	94.6	50.27	94.18%	95.1	44.483	94.6	50.27	94.18%	95.1	44.483
43MW32	294	36.2	43.481	43.832	19286	18066	587293	562063	125479	316.07	313.49	267.84	94.8	50.28	94.02%	95.3	44.478	94.8	50.28	94.02%	95.3	44.478
46MW1	342	41.4	46.130	46.544	22790	21352	585319	556238	127178	315.86	312.89	268.01	102.7	50.26	92.18%	103.2	47.257	102.7	50.26	92.19%	103.2	47.257
46MW21	342	41.4	46.171	46.520	22705	21289	585267	556174	127074	315.86	312.88	268.00	102.6	50.26	92.27%	103.1	47.235	102.5	50.25	92.31%	103.0	47.238
46MW22	342	41.4	46.191	46.567	22760	21326	585184	556077	126807	315.85	312.87	267.97	102.7	50.28	92.24%	103.2	47.250	102.6	50.28	92.25%	103.1	47.251

ALSTOM	PROJECT : CLIENT :	**ANGOSTURA** **Unit 3** **COLBUN**			ALSTOM Hydro France N° DOCUMENT : LTESS-14507	
Study N° :		Contract N°		N° O.E. :	Page :	14





ANGOSTURA U3 - Relative efficiency versus power
y = -4.44965E-07x⁴ + 5.20559E-05x³ - 2.55405E-03x² + 6.94856E-02x + 6.56731E-02
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
Turbine relative efficiency (%)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
Turbine power (MW)
Alstom relative efficiency
Customer Relative efficiency
Hill chart cut at Hn=50.77m

6. Turbine power guaranties

6.1. Maximum power of the unit

Contract reminder " FCG 6701 Turbinas Francis_RevF":

1. POTENCIA MAXIMA DE LAS TURBINAS

ALTURA NETA H(m)	POTENCIA MAXIMA (kW)	APERTURA DEL DISTRIBUIDOR EN % DE LA APERTURA NOMINAL (1)
H0=55,00	51170	92.5 (2)
H1=51,78	47997	96.3
H2=48,65	45006	100.0
H3=48,04	44402	100.7
H4=46,54	42899	102.7

NOTA: (1) = Apertura Nominal = Apertura con Q =100 m^3/s y H2 = 48,65 m.
(2): Esta altura neta no está disponible con Q>40 m^3/s y nivel de embalse 317 m.

(*) Potencias máximas para un caudal nominal de 100 m^3/s.

If we transpose the winter Kennedy results at Hn=51.78m we obtain:

	Results using Alstom WK sensor:					Results using Colbun WK sensor				
				Results transposed at Hn=					Results transposed at Hn=	
				51.78	m				51.78	m
Test point	WK Flow	Hn	Efficiency	WK Flow	Turbine power	WK Flow	Hn	Efficiency	WK Flow	Turbine power
(-)	(m3/s)	(m)	%	(m3/s)	(MW)	(m3/s)	(m)	Client %	(m3/s)	(MW)
46MW1	102.7	50.26	92.18%	104.3	48.674	102.7	50.26	92.19%	104.2	48.674
46MW21	102.6	50.26	92.27%	104.1	48.651	102.5	50.25	92.31%	104.1	48.655
46MW22	102.7	50.28	92.24%	104.2	48.667	102.6	50.28	92.25%	104.2	48.668

During the tests we reached 48.6MW to be compared to the 47.997MW guaranteed, the guaranty is fulfilled.

6.2. Power plant

		Medidciones de Nivel											
Unidad	N° de medición	1	Nivel Embalse	QU1	QU2	QU3	Qtotal	Potencia Unidad en Prueba[MW]	Potencia al eje turbina [MW]	% de Carga	Fecha	Hora	Estimacion del Altura neta
U1	1	267.32	316.97	319	321	109	749	141.9	149.33	109%	05/09/2014	08:05	52.44
U2	1	267.15	316.97	322	324	109	755	142.1	149.54		05/09/2014	08:06	52.61
U3	1	267.63	316.97	316	322	109	747	45.9	47.25		05/09/2014	08:07	49.65
									346.12				
U1	2	267.31	316.96	319	322	109	750	142.0	149.43	109%	05/09/2014	08:17	52.44
U2	2	267.27	316.96	319	320	109	748	141.7	149.12		05/09/2014	08:18	52.48
U3	2	267.66	316.96	319	320	109	748	45.9	47.25		05/09/2014	08:19	49.61
									345.80				
U1	1	267.33	316.95	321	320	109	750	142.6	150.06	109%	05/09/2014	08:30	52.41
U2	2	267.24	316.95	319	320	109	748	142.5	149.96		05/09/2014	08:31	52.50
U3	3	267.66	316.94	319	320	109	748	45.9	47.25		05/09/2014	08:32	49.59
									347.27				

During the tests we reached 47.25MW at approximatively Hn=49.6m, if we transpose the power at the guaranteed head H2, we obtain:

$$P_m(H_{ng}) = P_m(H_{nm}) x \left(\frac{H_{ng}}{H_{nm}}\right)^{3/2}$$

With: $P_m(H_{nm})$=47.25MW

H_{ng} =48.65 m

And H_{nm} =49.59 m

Therefore $\mathbf{P_{m(Hn=48.65m)} = 45.92MW}$

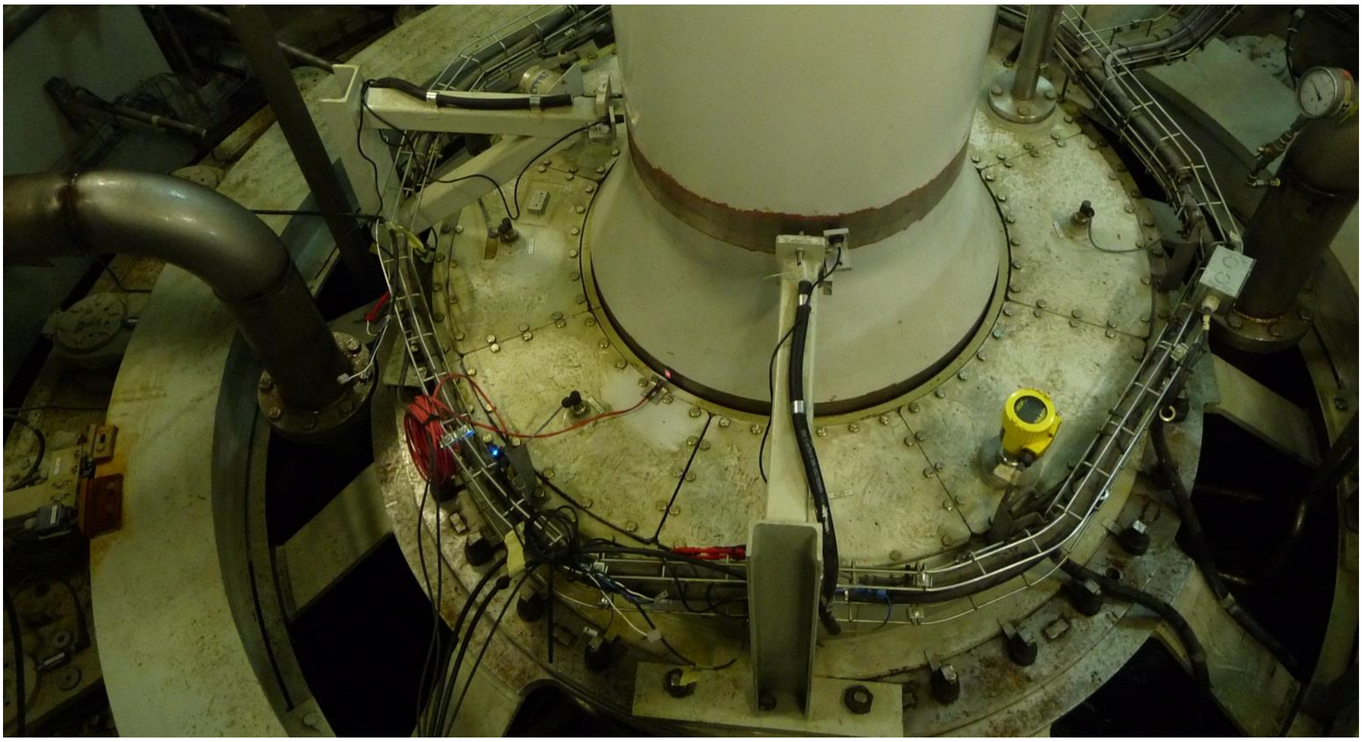
To be compared to 45.009MW guaranteed, the guaranty is fulfilled.

7. Mechanical test results

7.1. Key remarks on test results

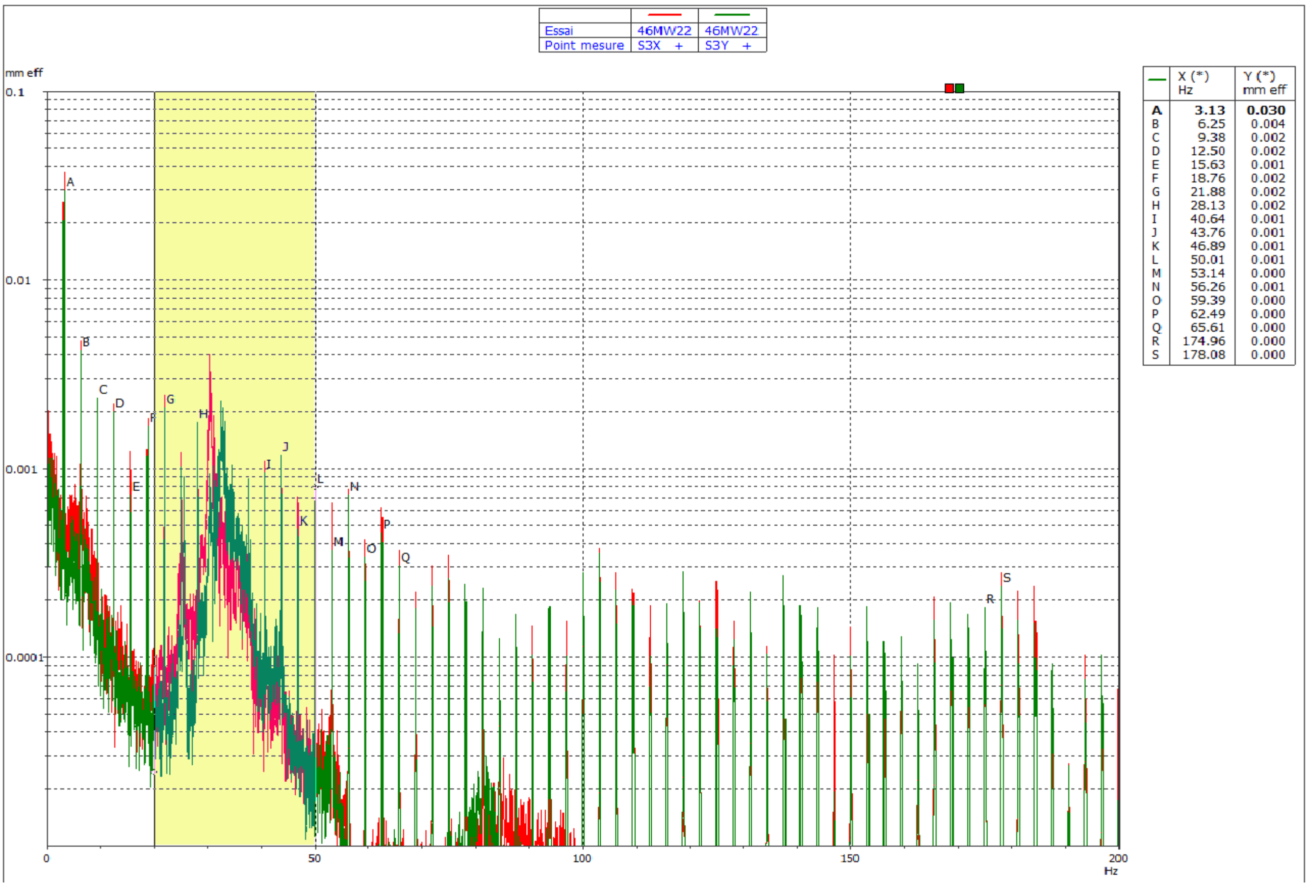
7.1.1. Remarks on turbine shaft displacement

As we can see on the following picture the displacement sensors in the turbine pit (S3X and S3Y) are installed on supports.

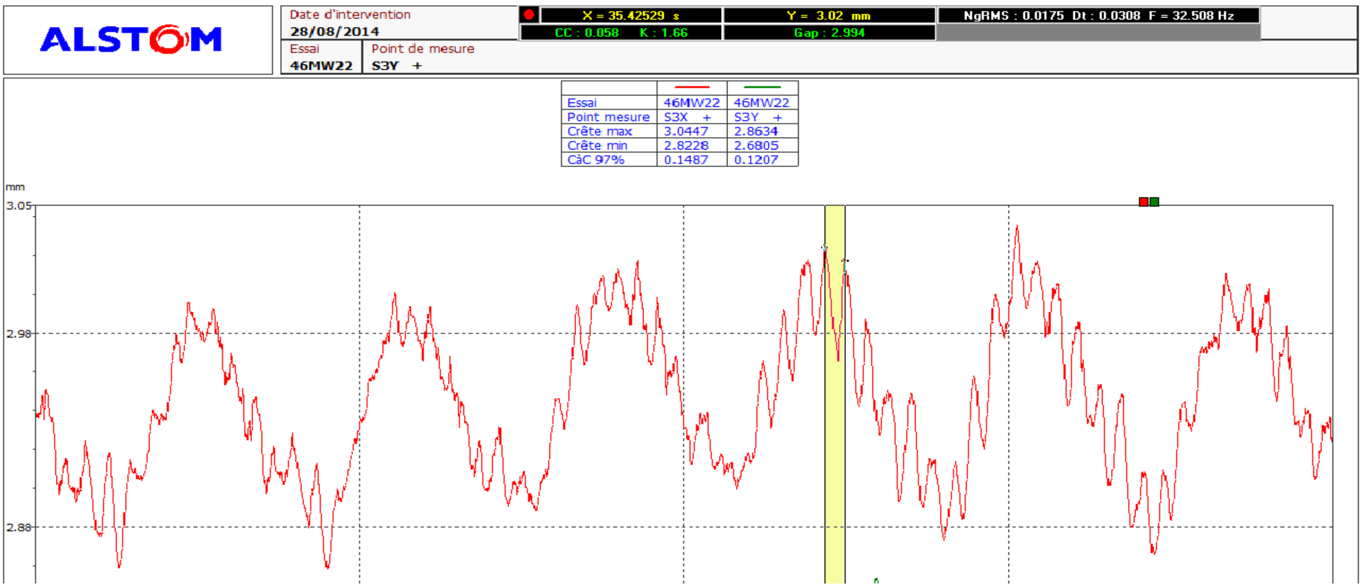


ALSTOM	PROJECT : CLIENT :	ANGOSTURA Unit 3 COLBUN		ALSTOM Hydro France N° DOCUMENT : LTESS-14507	
Study N° :		Contract N°		N° O.E. :		Page :	19

Those supports have a natural frequency between 20-50Hz as shown on the following spectrums.



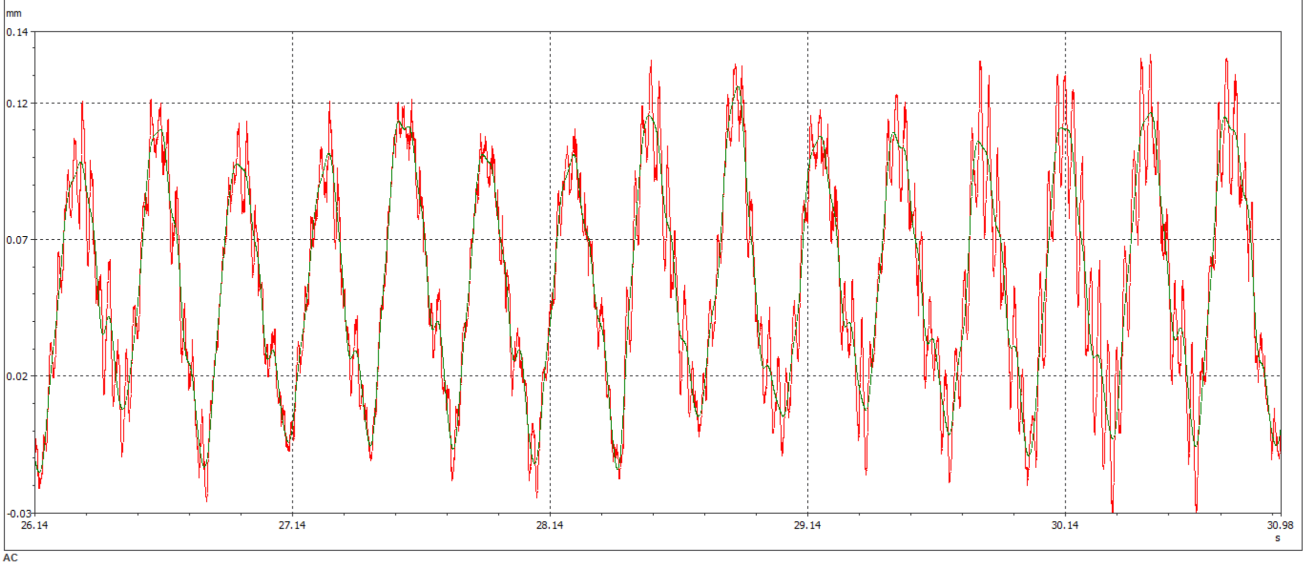
This excitation could also be seen on temporal records:



In this report, so as to get rid of the displacement of the support, all results of turbine shaft displacement will be post process with a low pass filter of 20 Hz, given that most of the level is below 20Hz the signal won't be too affected.

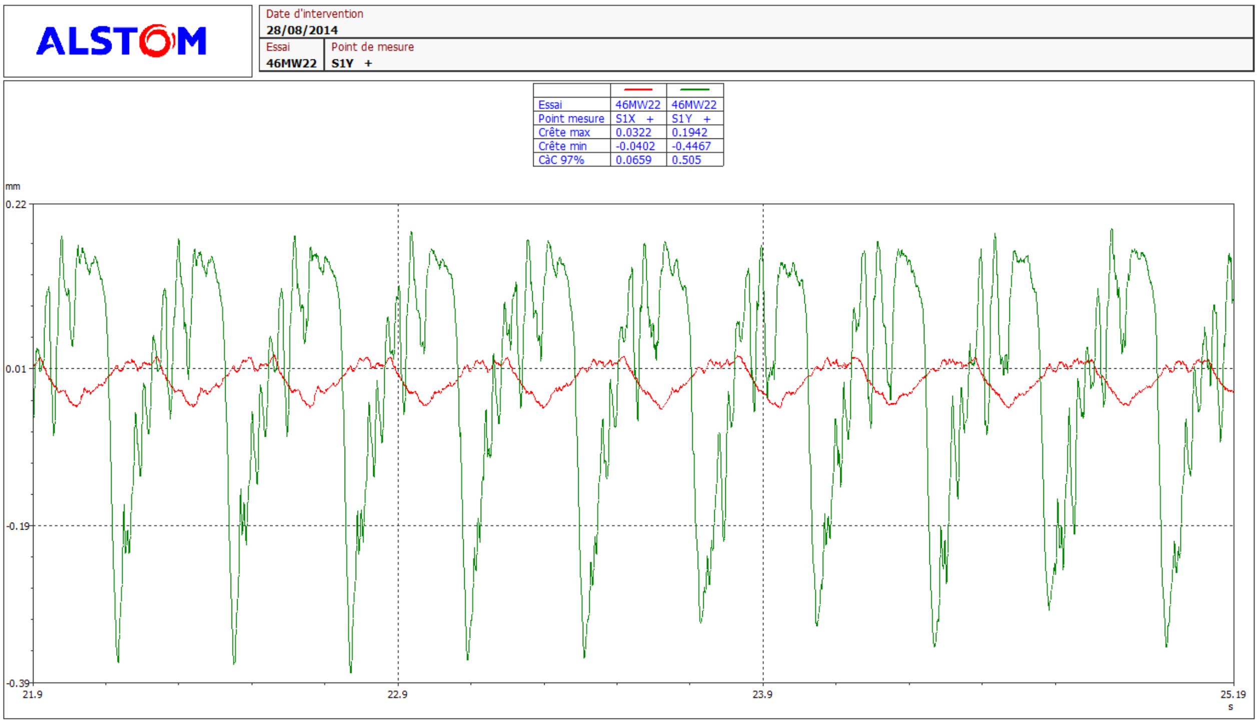
ALSTOM	Date d'intervention 28/08/2014	
	Essai LR_47.2MW	Point de mesure S3X +

Essai	LR_47.2MW	LR_47.2MW
Point mesure	S3X +	S3X +
Crête max	3.8215	3.2705
Crête min	2.1922	2.7103
CàC 97%	0.3291	0.2218



7.1.2. Remarks on "S1Y" generator upper bearing shaft displacement

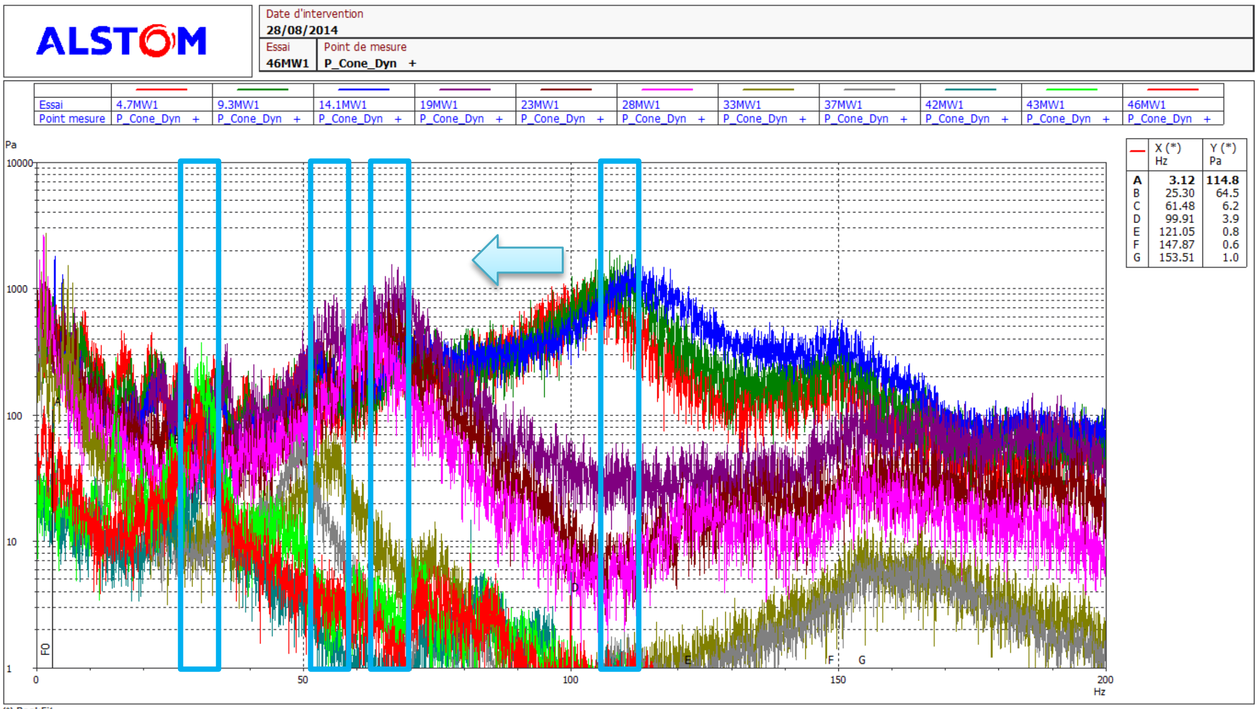
Compared to S1X , S1Y shows displacements 10 times higher. The peak to peak 97% on S1Y is even higher than the shaft running clearance on this bearing(diametral 0.440mm). For this kind of measurement, we use lazer technology, this technology target a precise spot on the shaft and if the two sensors aren't perfectly aligned, we can see significant divergence betyween the sensors, especially in our case, when one of the sensor is facing a track default.



In this report we will only give S1Y results for indication, given that the signal is corrupted we won't be able to draw orbite, or compare to the ISO7919-5 on the generator upper bearing.

7.1.3. Remarks on draft tube cone pressure pulsation

As we can see on the draft tube cone pressure pulsation spectrums, we have an amplification probably due to a air buble .This amplification slide with the counter pressure increase from 150 to 20Hz, a typical behaviourwhen there is air bubble in the measuring pipe.

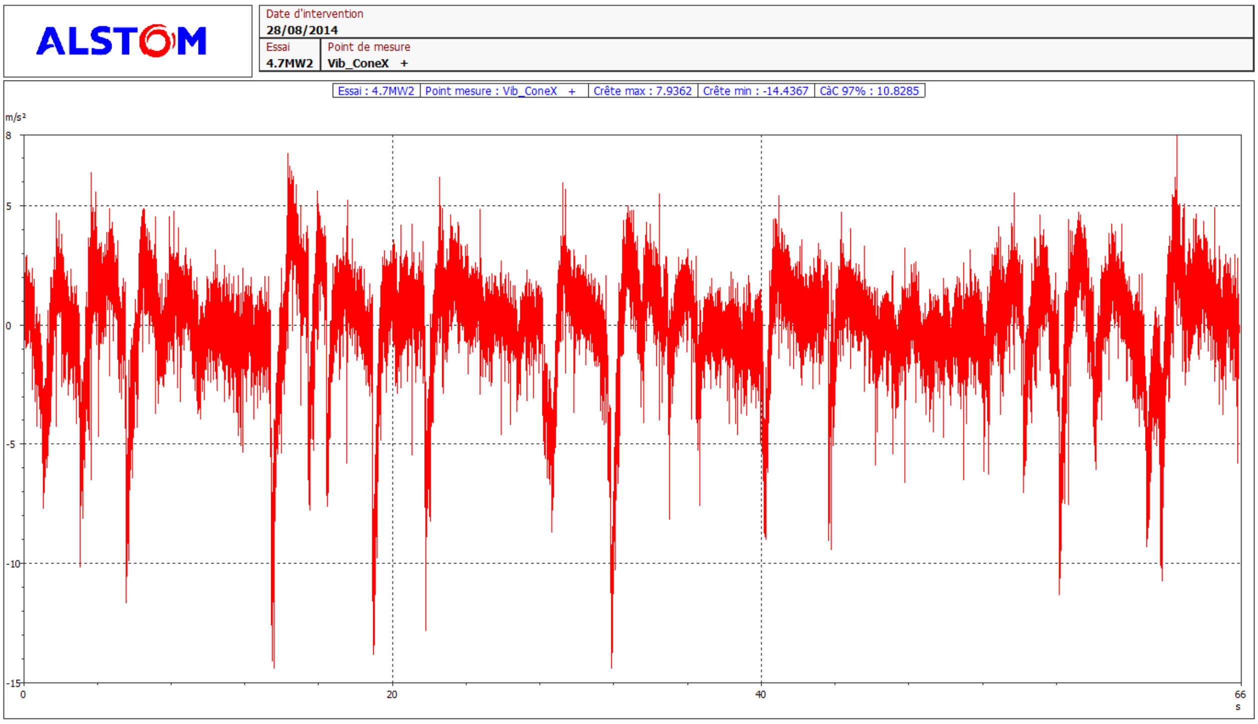


(*) PeakFit

In this report, so as to get rid of this amplification, all results of the pressure fluctuation will be post process with a low pass filter of 20 Hz.

7.1.4. Remarks on draft tube cone vibration

In the next section you will see that "ConeX" value out stand the others due to this signal saturation. Therefore "ConeX" results cannot be used. We can see on the temporal records that draft tube cone radial vibration "ConeX" saturate:



7.2. Results for Steady State Operation

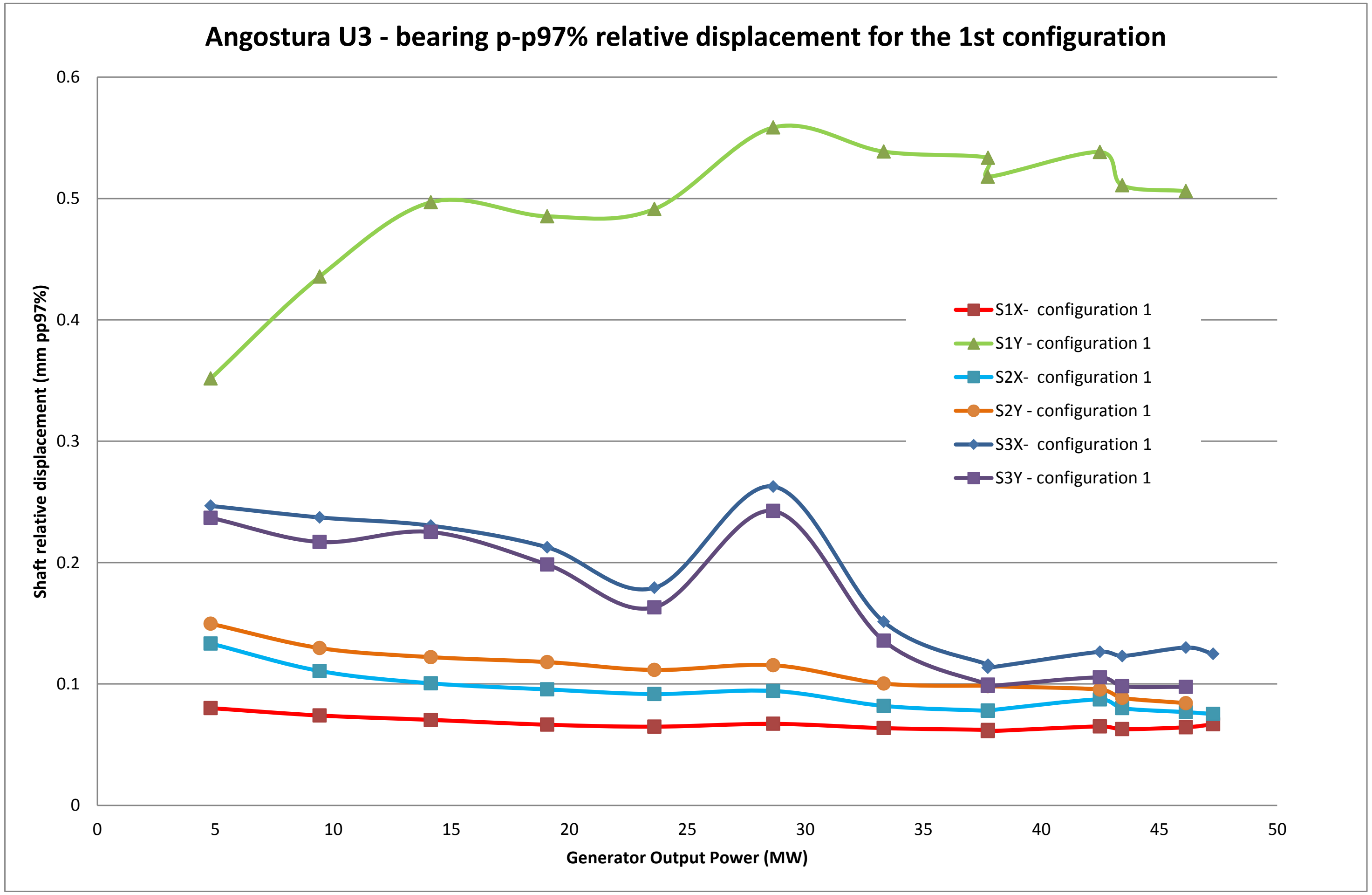
Hereafter are presented tables issued from either time or frequency domain analysis.

7.2.1. Time Domain shaft relative displacement signals

Following results are given in PP97 values. PP97 values have been calculated along 10 shaft revolutions (approximately 3.2 s of temporal record). Average along entire temporal record is calculated and presented in the table. Orbit statistic as S_{max} and Spp_{max} are also presented.

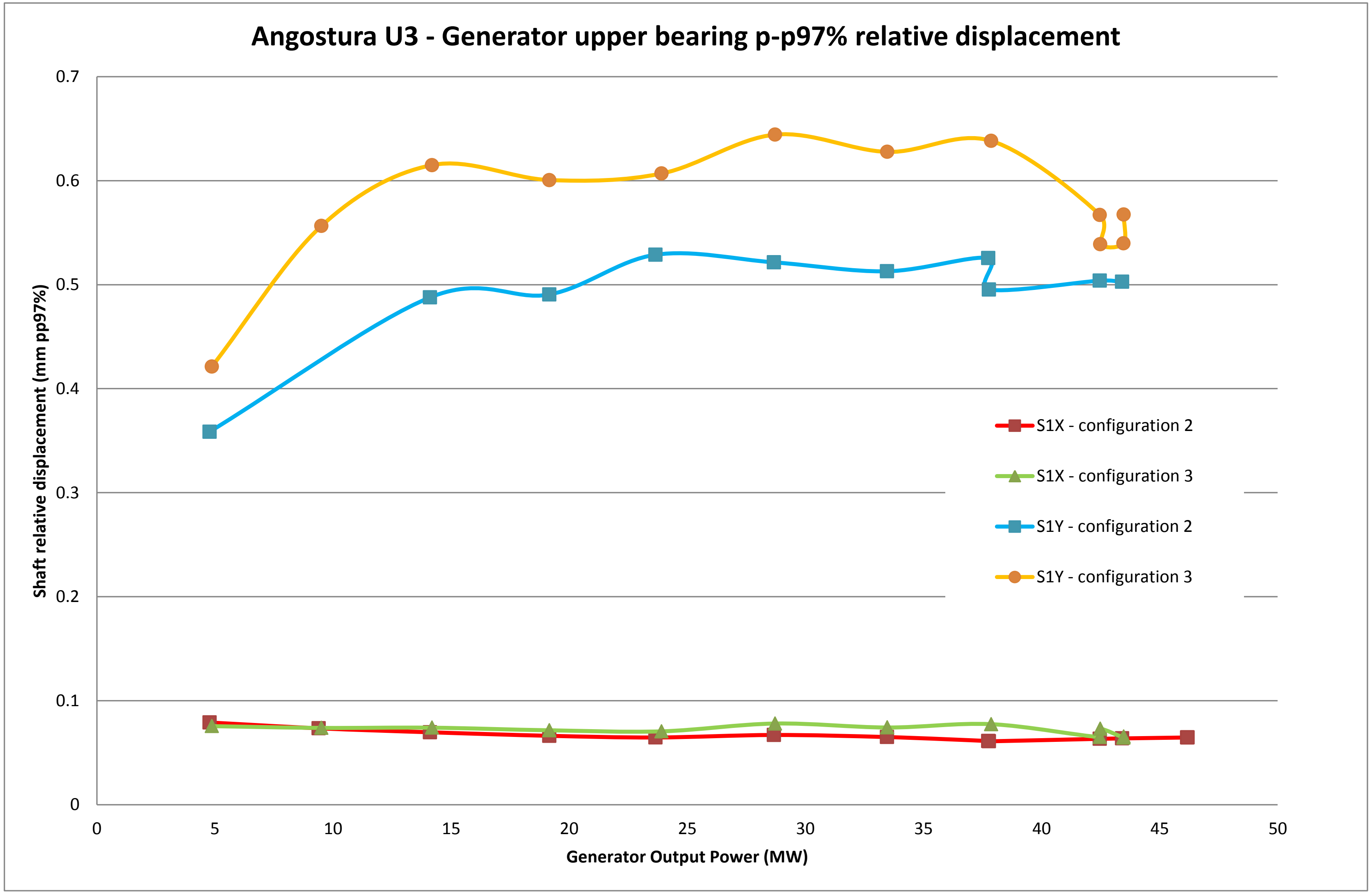
Test point (-)	Generator output power (MW)	S1X pp97% (mm)	S1Y pp97% (mm)	S2X pp97% (mm)	S2Y pp97% (mm)	S3X pp97% LPF20Hz (mm)	S3Y pp97% LPF20Hz (mm)
4.7MW1	4.804	0.0801	0.3517	0.1333	0.1496	0.2467	0.2369
4.7MW2	4.774	0.079	0.3586	0.1279	0.146	0.2512	0.2275
4.7MW3	4.865	0.0755	0.4212	0.1194	0.1304	0.2358	0.2268
9.3MW1	9.416	0.074	0.4356	0.1107	0.1296	0.2372	0.217
9.3MW2	9.388	0.0734	0.4314	0.1104	0.1293	0.233	0.2191
9.3MW3	9.507	0.0738	0.5565	0.106	0.1226	0.2208	0.2204
14.1MW1	14.136	0.0704	0.4969	0.1005	0.1221	0.2304	0.2252
14.1MW2	14.109	0.0696	0.4878	0.0993	0.1191	0.2155	0.2079
14.1MW3	14.187	0.074	0.615	0.0937	0.1067	0.2196	0.2167
14.1MW4	14.294	0.0762	0.6231	0.0974	0.1127	0.1891	0.1926
19MW1	19.061	0.0664	0.4853	0.0955	0.118	0.2126	0.1984
19MW2	19.158	0.0662	0.4834	0.0944	0.1191	0.2218	0.2056
19MW3	19.161	0.0715	0.6006	0.0938	0.1103	0.2109	0.2051
23MW1	23.608	0.0648	0.4913	0.0917	0.1115	0.1792	0.1631
23MW2	23.657	0.0646	0.4906	0.0925	0.114	0.1823	0.1626
23MW3	23.913	0.0705	0.6069	0.0915	0.1096	0.1695	0.1628
28MW1	28.643	0.0671	0.5585	0.0942	0.1154	0.2627	0.2425
28MW2	28.669	0.067	0.5566	0.0938	0.1126	0.2725	0.2519
28MW3	28.715	0.078	0.6443	0.0915	0.1069	0.2569	0.2407
33MW1	33.321	0.0636	0.5386	0.0819	0.1003	0.1512	0.1356
33MW2	33.456	0.065	0.5288	0.0818	0.1028	0.1584	0.1345
33MW3	33.471	0.0742	0.6277	0.0804	0.099	0.1226	0.1064
37MW1	37.745	0.0621	0.5335	0.0779	0.0985	0.1158	0.0994
37MW12	37.740	0.0611	0.5179	0.0781	0.0981	0.1134	0.0982
37MW2	37.742	0.0612	0.5215	0.0781	0.0998	0.1152	0.0975
37MW22	37.777	0.0609	0.5129	0.078	0.0986	0.1141	0.0985
37MW3	37.865	0.0774	0.6383	0.0758	0.0904	0.1001	0.0903
42MW1	42.490	0.065	0.5383	0.0873	0.0954	0.1265	0.1054
42MW2	42.472	0.0633	0.5256	0.0863	0.0129	0.1284	0.1066
42MW31	42.472	0.065	0.5671	0.0825	0.0924	0.1163	0.0984
42MW32	42.489	0.073	0	0.0804	0.086	0.1155	0.0972
43MW1	43.429	0.0627	0.5108	0.08	0.0885	0.123	0.0981
43MW2	43.419	0.0637	0.4954	0.0787	0.0889	0.1224	0.0976
43MW31	43.472	0.0645	0.5398	0.0794	0.0884	0.1171	0.097
43MW32	43.481	0.0655	0.5675	0.0779	0.085	0.1181	0.0963
46MW1	46.130	0.0643	0.5061	0.0768	0.0842	0.13	0.0976
46MW21	46.171	0.0646	0.5039	0.0762	0.0837	0.1299	0.1013
46MW22	46.191	0.0647	0.5029	0.0765	0.0838	0.1291	0.0995
Before LR 47.2MW	47.285	0.0668	0.5322	0.0752	0.0736	0.1248	0.1023

Statistic values have been calculated during 10 shaft revolutions. We plot the trend of PP97 parameter hereafter:

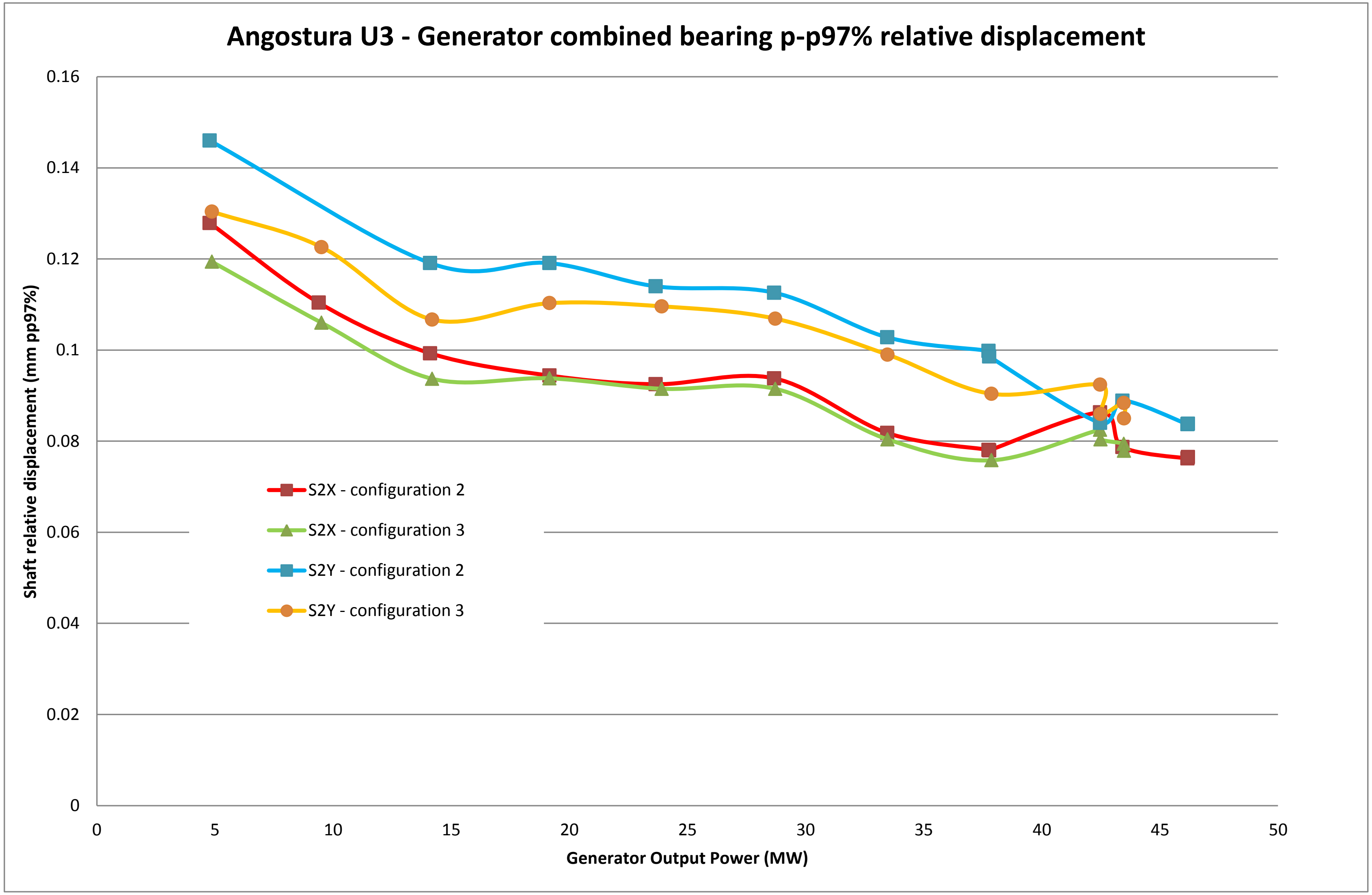


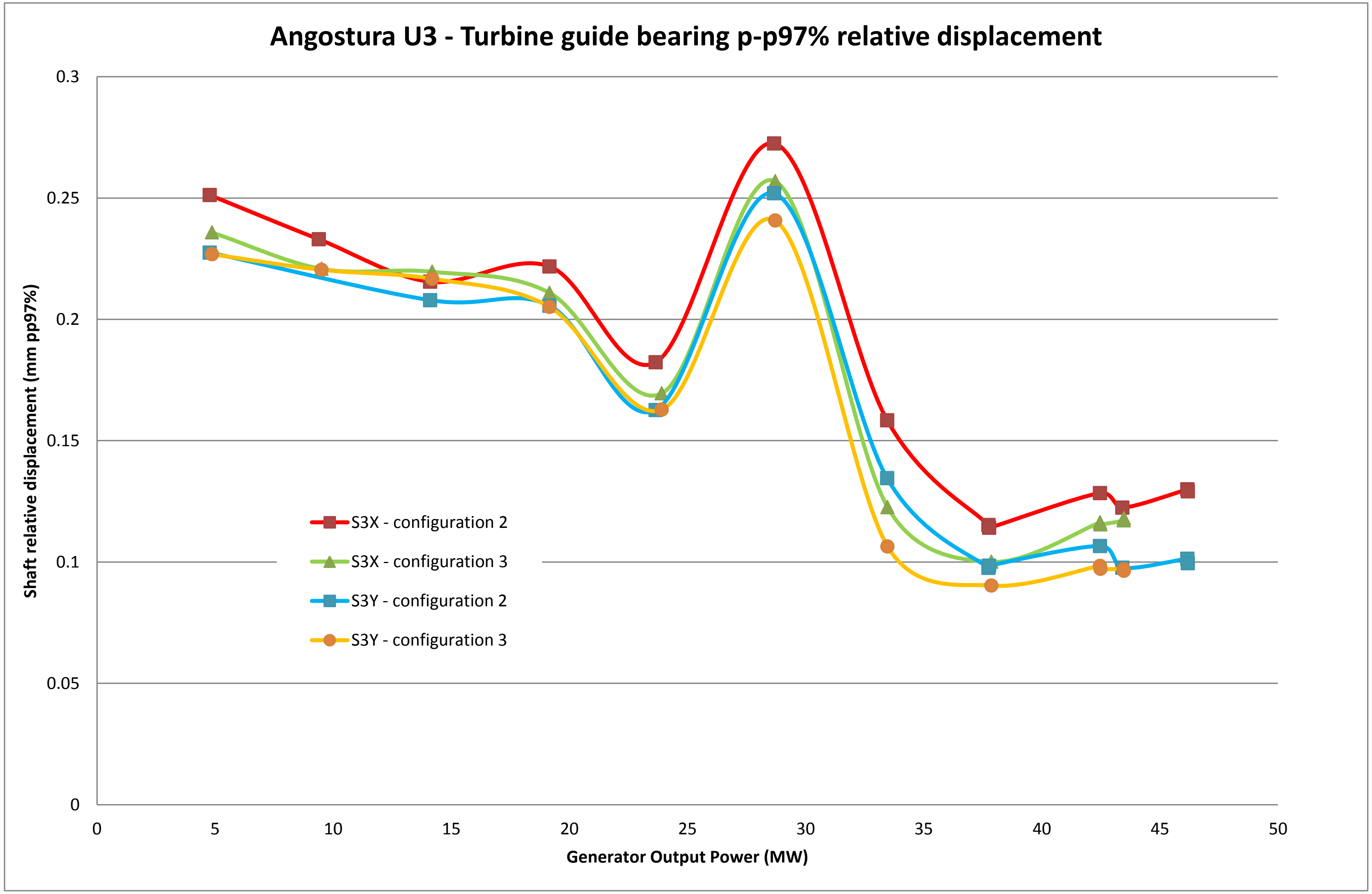
S1Y peak to peak 97% is more than 6 time higher than S1X wich would suggest a track default on the shaft, this may append when the two displacement sensors are not exactly aligned on the same track. S1Z return dubious value, the sensor targeting surface being not flat, it isn't display on this graph.

ALSTOM		PROJECT : CLIENT :	**ANGOSTURA** **Unit 3** **COLBUN**			ALSTOM Hydro France N° DOCUMENT : LTESS-14507	
Study N° :		Contract N°		N° O.E. :		Page :	26



ALSTOM	PROJECT : CLIENT :		**ANGOSTURA** **Unit 3** **COLBUN**		ALSTOM Hydro France N° DOCUMENT : LTESS-14507	
Study N° :		Contract N°		N° O.E. :	Page :	27





Angostura U3 - Turbine guide bearing p-p97% relative displacement
Shaft relative displacement (mm pp97%)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
5
10
15
20
25
30
35
40
45
50
Generator Output Power (MW)
S3X - configuration 2
S3X - configuration 3
S3Y - configuration 2
S3Y - configuration 3

Comparison with ISO 7919-5 (2005) standard:

ISO 7919-5:2005 standard define vibration limitation versus shaft rotation. Two main zones have been defined according to Smax or PP values:

A-B: Machines magnitudes within this major range are considered acceptable for unrestricted long-term operation.

C-D: For machines in this major range, we will have to check if the measured values are permissible for long-term continuous operation considering the specific design and operating conditions. In this aim, in the following part, we will compare the shaft relative displacement to the bearing running diametrical clearance.

The boundarie between A-B and C-D zones given by the ISO 7919-5:2005 standard for machines running under 187.5 rpm nominal speed are **0.136 mm** for the **Smax** and **0.251 mm pp** for the **Spp.**

Once again, we can suspect a track default on S1Y , this will lead to a corrupted generator upper bearing orbit, so that in this section the generator upper guide bearing orbit won't be presented.

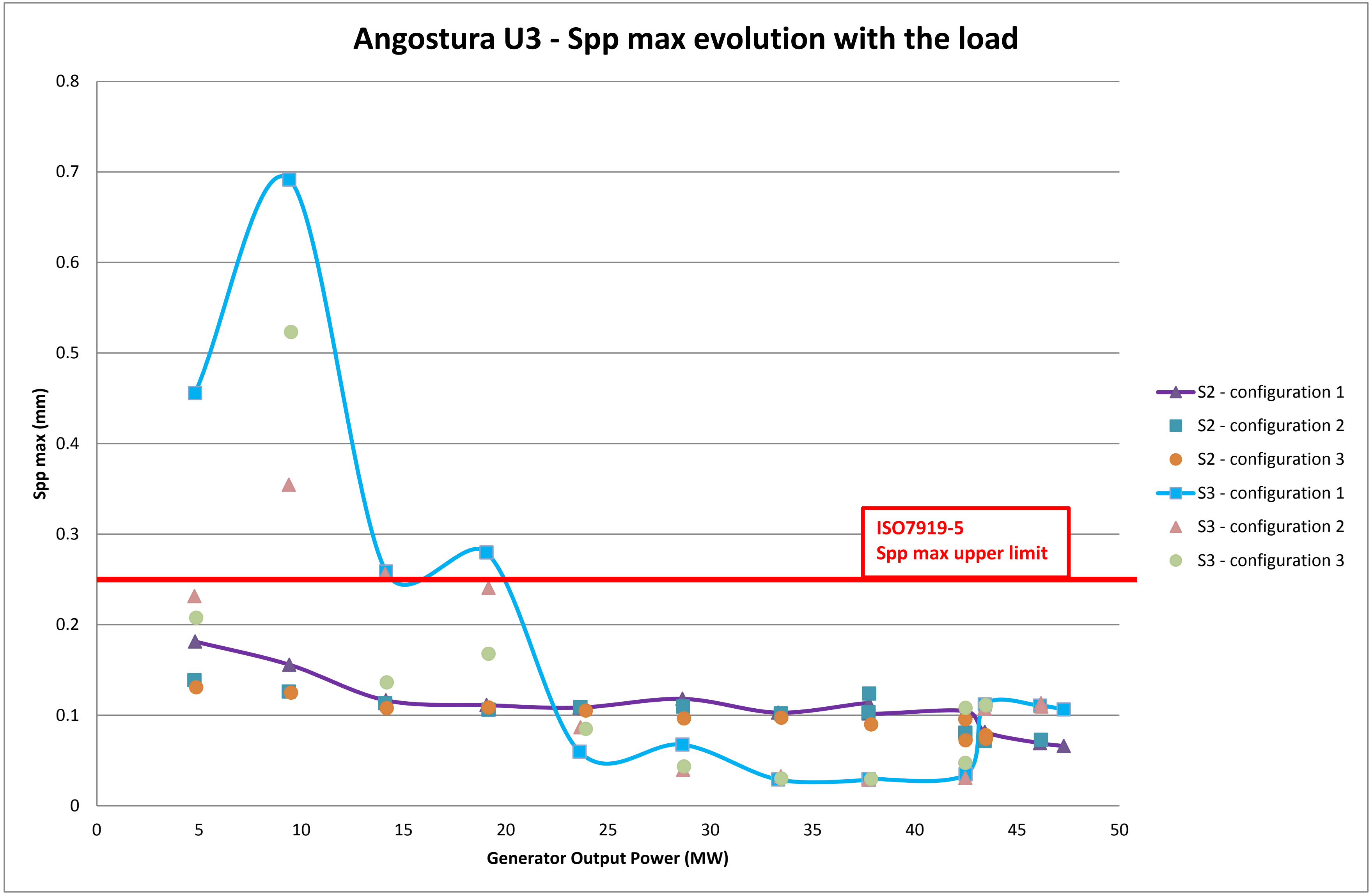
Hereafter are presented the orbit results of the shaft relative displacements:

Test point (-)	Generator output power (MW)	S1 Spp max (mm)	ISO7919-5 standard zone	S2 Spp max (mm)	ISO7919-5 standard zone	S3 Spp max LPF 20Hz (mm)	ISO7919-5 standard zone
4.7MW1	4.804	0.4046	C-D	0.1813	A-B	0.4556	C-D
4.7MW2	4.774	0.4008	C-D	0.1385	A-B	0.2315	A-B
4.7MW3	4.865	0.4828	C-D	0.1306	A-B	0.2076	A-B
9.3MW1	9.416	0.4931	C-D	0.1557	A-B	0.6914	C-D
9.3MW2	9.388	0.48	C-D	0.1259	A-B	0.3544	C-D
9.3MW3	9.507	0.5864	C-D	0.1248	A-B	0.5231	C-D
14.1MW1	14.136	0.5564	C-D	0.1164	A-B	0.2587	C-D
14.1MW2	14.109	0.54	C-D	0.1133	A-B	0.2561	C-D
14.1MW3	14.187	0.6436	C-D	0.1077	A-B	0.1362	A-B
14.1MW4	14.294	0.6546	C-D	0.1246	A-B	0.2015	A-B
19MW1	19.061	0.5261	C-D	0.1111	A-B	0.2796	C-D
19MW2	19.158	0.5257	C-D	0.1061	A-B	0.2406	A-B
19MW3	19.161	0.6322	C-D	0.1086	A-B	0.1678	A-B
23MW1	23.608	0.5231	C-D	0.1084	A-B	0.0595	A-B
23MW2	23.657	0.5639	C-D	0.1119	A-B	0.0864	A-B
23MW3	23.913	0.6391	C-D	0.1051	A-B	0.0849	A-B
28MW1	28.643	0.5885	C-D	0.118	A-B	0.0675	A-B
28MW2	28.669	0.5967	C-D	0.1091	A-B	0.0395	A-B
28MW3	28.715	0.6447	C-D	0.0965	A-B	0.0434	A-B
33MW1	33.321	0.568	C-D	0.1028	A-B	0.0289	A-B
33MW2	33.456	0.5925	C-D	0.1094	A-B	0.0325	A-B
33MW3	33.471	0.635	C-D	0.0971	A-B	0.0299	A-B
37MW1	37.745	0.5923	C-D	0.1133	A-B	0.0284	A-B
37MW12	37.740	0.5686	C-D	0.1018	A-B	0.0296	A-B
37MW2	37.742	0.5521	C-D	0.1019	A-B	0.0295	A-B
37MW22	37.777	0.5388	C-D	0.1032	A-B	0.0289	A-B
37MW3	37.865	0.6449	C-D	0.0897	A-B	0.0294	A-B
42MW1	42.490	0.5893	C-D	0.1045	A-B	0.0347	A-B
42MW2	42.472	0.558	C-D	0.1239	A-B	0.0308	A-B
42MW31	42.472	0.623	C-D	0.0955	A-B	0.0472	A-B
42MW32	42.489	0.0598	A-B	0.0722	A-B	0.108	A-B
43MW1	43.429	0.4543	C-D	0.0816	A-B	0.1118	A-B
43MW2	43.419	0.4367	C-D	0.0807	A-B	0.1073	A-B
43MW31	43.472	0.4694	C-D	0.0778	A-B	0.1113	A-B
43MW32	43.481	0.515	C-D	0.0739	A-B	0.1108	A-B
46MW1	46.130	0.356	C-D	0.0691	A-B	0.1105	A-B
46MW21	46.171	0.3779	C-D	0.0715	A-B	0.1131	A-B
46MW22	46.191	0.4364	C-D	0.0728	A-B	0.1095	A-B
fore LR 47.2M	47.285	0.4381	C-D	0.0659	A-B	0.1062	A-B

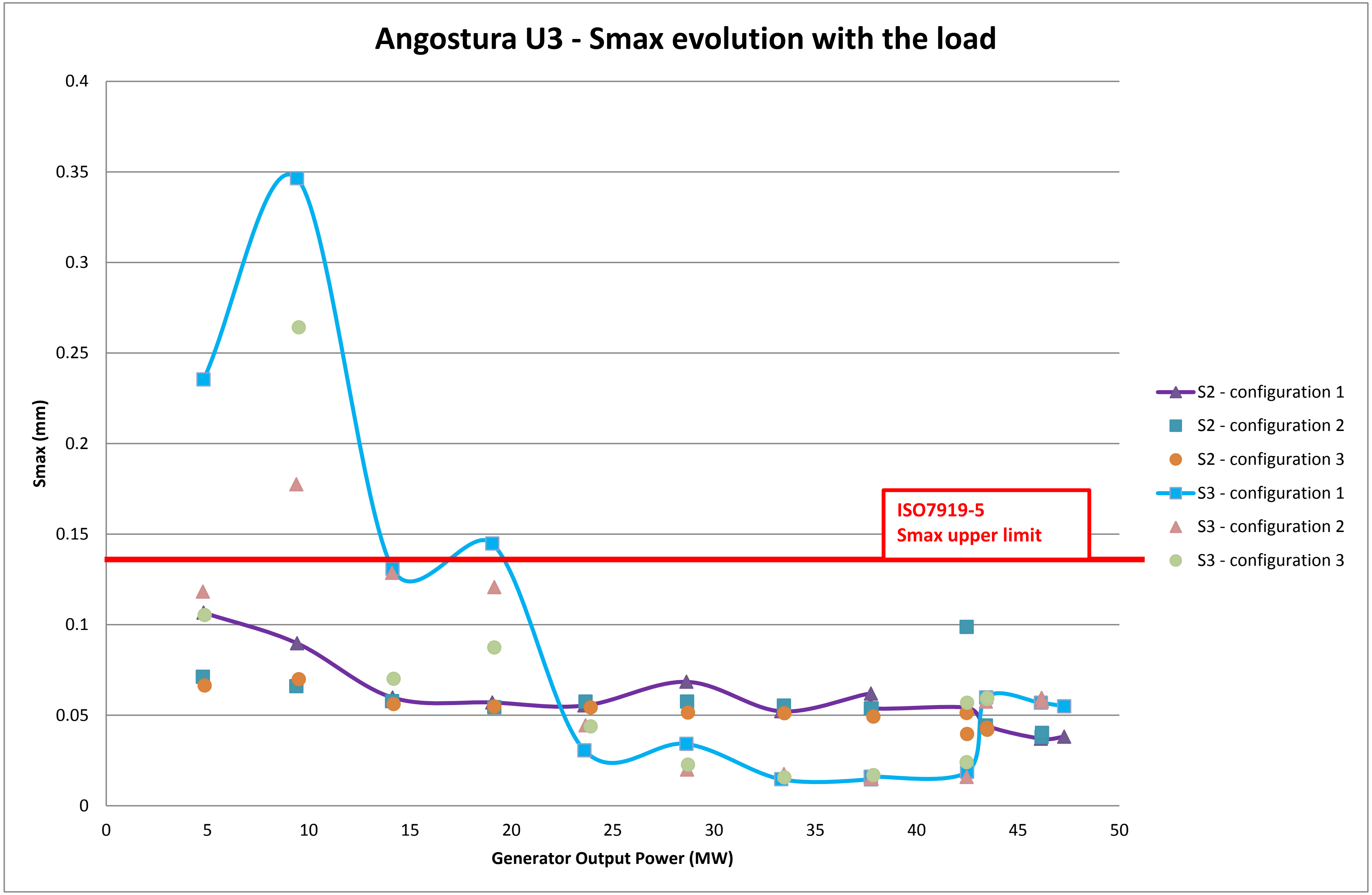
Test point (-)	Generator output power (MW)	S1 Smax (mm)	ISO7919-5 standard zone	S2 Smax (mm)	ISO7919-5 standard zone	S3 Smax LPF 20Hz (mm)	ISO7919-5 standard zone
4.7MW1	4.804	0.2504	C-D	0.1066	A-B	0.2353	C-D
4.7MW2	4.774	0.2439	C-D	0.0711	A-B	0.1182	A-B
4.7MW3	4.865	0.3098	C-D	0.0663	A-B	0.1052	A-B
9.3MW1	9.416	0.3262	C-D	0.0897	A-B	0.3464	C-D
9.3MW2	9.388	0.3088	C-D	0.066	A-B	0.1775	C-D
9.3MW3	9.507	0.4015	C-D	0.0698	A-B	0.2641	C-D
14.1MW1	14.136	0.3719	C-D	0.0597	A-B	0.1308	A-B
14.1MW2	14.109	0.3573	C-D	0.0577	A-B	0.1286	A-B
14.1MW3	14.187	0.4537	C-D	0.0561	A-B	0.07	A-B
14.1MW4	14.294	0.4592	C-D	0.0738	A-B	0.109	A-B
19MW1	19.061	0.3471	C-D	0.057	A-B	0.1447	C-D
19MW2	19.158	0.352	C-D	0.0544	A-B	0.1206	A-B
19MW3	19.161	0.4433	C-D	0.0547	A-B	0.0873	A-B
23MW1	23.608	0.3489	C-D	0.0553	A-B	0.0305	A-B
23MW2	23.657	0.3772	C-D	0.0575	A-B	0.0444	A-B
23MW3	23.913	0.4514	C-D	0.0542	A-B	0.0438	A-B
28MW1	28.643	0.4097	C-D	0.0684	A-B	0.0341	A-B
28MW2	28.669	0.417	C-D	0.0575	A-B	0.0199	A-B
28MW3	28.715	0.455	C-D	0.0514	A-B	0.0227	A-B
33MW1	33.321	0.3909	C-D	0.0521	A-B	0.0146	A-B
33MW2	33.456	0.4112	C-D	0.0552	A-B	0.0174	A-B
33MW3	33.471	0.4508	C-D	0.051	A-B	0.0156	A-B
37MW1	37.745	0.4094	C-D	0.0619	A-B	0.0145	A-B
37MW12	37.740	0.3885	C-D	0.0539	A-B	0.016	A-B
37MW2	37.742	0.3762	C-D	0.0536	A-B	0.0155	A-B
37MW22	37.777	0.3643	C-D	0.0538	A-B	0.0149	A-B
37MW3	37.865	0.4491	C-D	0.0492	A-B	0.0168	A-B
42MW1	42.490	0.3985	C-D	0.0541	A-B	0.0187	A-B
42MW2	42.472	0.3809	C-D	0.0987	A-B	0.0159	A-B
42MW31	42.472	0.4391	C-D	0.0511	A-B	0.024	A-B
42MW32	42.489	0.0301	A-B	0.0395	A-B	0.0568	A-B
43MW1	43.429	0.299	C-D	0.0443	A-B	0.0598	A-B
43MW2	43.419	0.2825	C-D	0.0442	A-B	0.0574	A-B
43MW31	43.472	0.3123	C-D	0.043	A-B	0.0589	A-B
43MW32	43.481	0.354	C-D	0.0419	A-B	0.0595	A-B
46MW1	46.130	0.215	C-D	0.037	A-B	0.0568	A-B
46MW21	46.171	0.2281	C-D	0.038	A-B	0.0596	A-B
46MW22	46.191	0.2826	C-D	0.0402	A-B	0.0576	A-B
fore LR 47.2M	47.285	0.2826	C-D	0.0381	A-B	0.0549	A-B

Test point (-)	Generator output power (MW)	S1 Spp max (mm)	Comparison with running clearance (%)	S2 Spp max (mm)	Comparison with running clearance (%)	S3 Spp max LPF 20Hz (mm)	Comparison with running clearance (%)
4.7MW1	4.804	0.4046	91.95%	0.1813	22.66%	0.4556	75.93%
4.7MW2	4.774	0.4008	91.09%	0.1385	17.31%	0.2315	38.58%
4.7MW3	4.865	0.4828	109.73%	0.1306	16.33%	0.2076	34.60%
9.3MW1	9.416	0.4931	112.07%	0.1557	19.46%	0.6914	115.23%
9.3MW2	9.388	0.48	109.09%	0.1259	15.74%	0.3544	59.07%
9.3MW3	9.507	0.5864	133.27%	0.1248	15.60%	0.5231	87.18%
14.1MW1	14.136	0.5564	126.45%	0.1164	14.55%	0.2587	43.12%
14.1MW2	14.109	0.54	122.73%	0.1133	14.16%	0.2561	42.68%
14.1MW3	14.187	0.6436	146.27%	0.1077	13.46%	0.1362	22.70%
14.1MW4	14.294	0.6546	148.77%	0.1246	15.58%	0.2015	33.58%
19MW1	19.061	0.5261	119.57%	0.1111	13.89%	0.2796	46.60%
19MW2	19.158	0.5257	119.48%	0.1061	13.26%	0.2406	40.10%
19MW3	19.161	0.6322	143.68%	0.1086	13.58%	0.1678	27.97%
23MW1	23.608	0.5231	118.89%	0.1084	13.55%	0.0595	9.92%
23MW2	23.657	0.5639	128.16%	0.1119	13.99%	0.0864	14.40%
23MW3	23.913	0.6391	145.25%	0.1051	13.14%	0.0849	14.15%
28MW1	28.643	0.5885	133.75%	0.118	14.75%	0.0675	11.25%
28MW2	28.669	0.5967	135.61%	0.1091	13.64%	0.0395	6.58%
28MW3	28.715	0.6447	146.52%	0.0965	12.06%	0.0434	7.23%
33MW1	33.321	0.568	129.09%	0.1028	12.85%	0.0289	4.82%
33MW2	33.456	0.5925	134.66%	0.1094	13.68%	0.0325	5.42%
33MW3	33.471	0.635	144.32%	0.0971	12.14%	0.0299	4.98%
37MW1	37.745	0.5923	134.61%	0.1133	14.16%	0.0284	4.73%
37MW12	37.740	0.5686	129.23%	0.1018	12.73%	0.0296	4.93%
37MW2	37.742	0.5521	125.48%	0.1019	12.74%	0.0295	4.92%
37MW22	37.777	0.5388	122.45%	0.1032	12.90%	0.0289	4.82%
37MW3	37.865	0.6449	146.57%	0.0897	11.21%	0.0294	4.90%
42MW1	42.490	0.5893	133.93%	0.1045	13.06%	0.0347	5.78%
42MW2	42.472	0.558	126.82%	0.1239	15.49%	0.0308	5.13%
42MW31	42.472	0.623	141.59%	0.0955	11.94%	0.0472	7.87%
42MW32	42.489	0.0725	16.48%	0.0845	10.56%	0.0311	5.18%
43MW1	43.429	0.5587	126.98%	0.0947	11.84%	0.0360	6.00%
43MW2	43.419	0.5276	119.91%	0.0919	11.49%	0.0463	7.72%
43MW31	43.472	0.6013	136.66%	0.0937	11.71%	0.0468	7.80%
43MW32	43.481	0.5936	134.91%	0.082	10.25%	0.0367	6.12%
46MW1	46.130	0.5269	119.75%	0.0871	10.89%	0.0343	5.72%
46MW21	46.171	0.531	120.68%	0.0873	10.91%	0.0445	7.42%
46MW22	46.191	0.5307	120.61%	0.0841	10.51%	0.0348	5.80%
Before LR 47.2MW	47.285	0.5822	132.32%	0.076	9.50%	0.0338	5.63%

Except for the track default on S1Y, the two other bearings, show acceptable results, according to the shaft running clearances (please refer to Appendix 2 for running clearance values), following graphs show results of Spp and Smax.



Angostura U3 - Spp max evolution with the load
Spp max (mm)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
35
40
45
50
Generator Output Power (MW)
ISO7919-5
Spp max upper limit
S2 - configuration 1
S2 - configuration 2
S2 - configuration 3
S3 - configuration 1
S3 - configuration 2
S3 - configuration 3



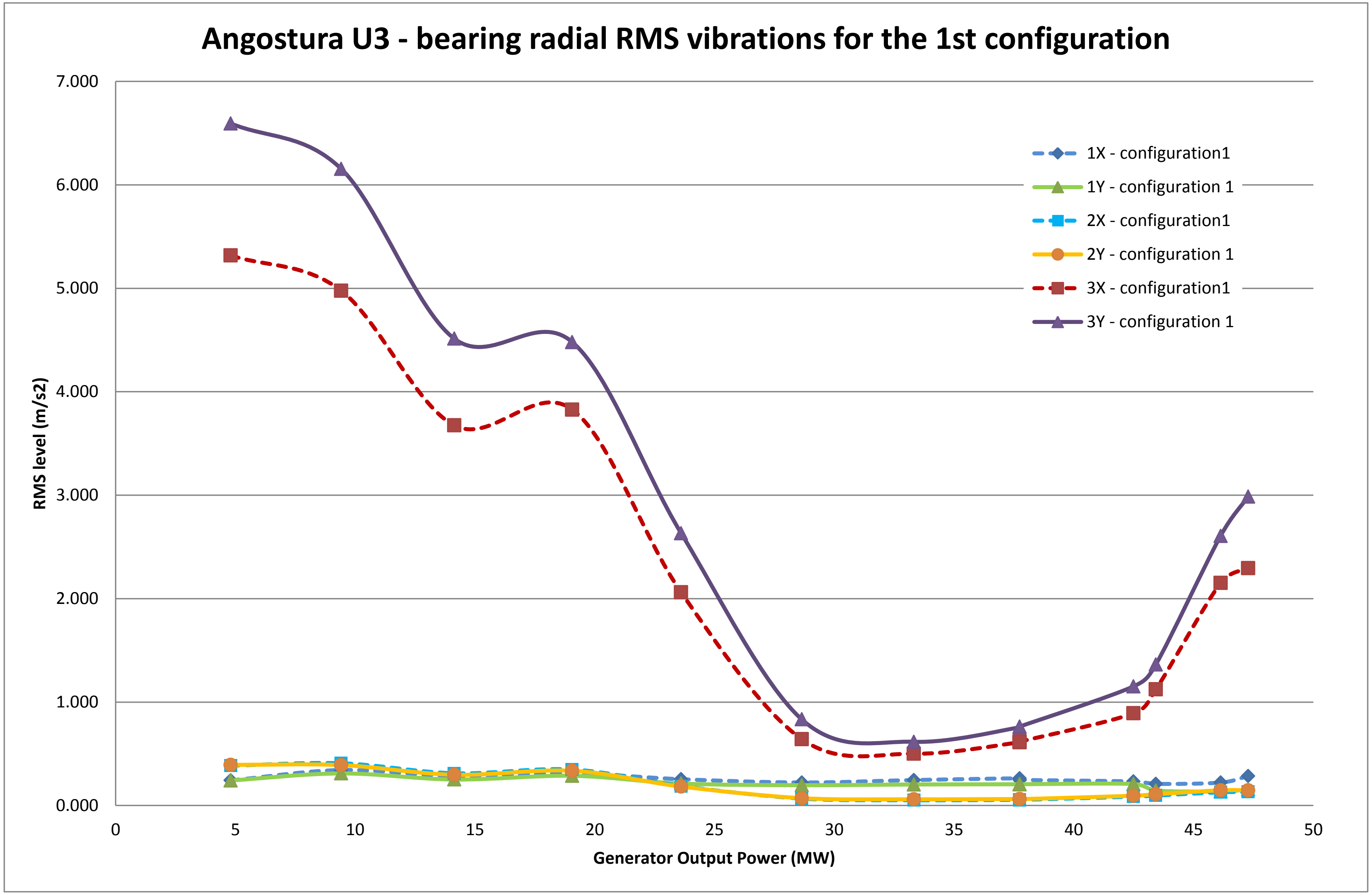
Angostura U3 - Smax evolution with the load
Smax (mm)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
5
10
15
20
25
30
35
40
45
50
Generator Output Power (MW)
ISO7919-5
Smax upper limit
S2 - configuration 1
S2 - configuration 2
S2 - configuration 3
S3 - configuration 1
S3 - configuration 2
S3 - configuration 3

7.2.2. Time Domain acceleration signals

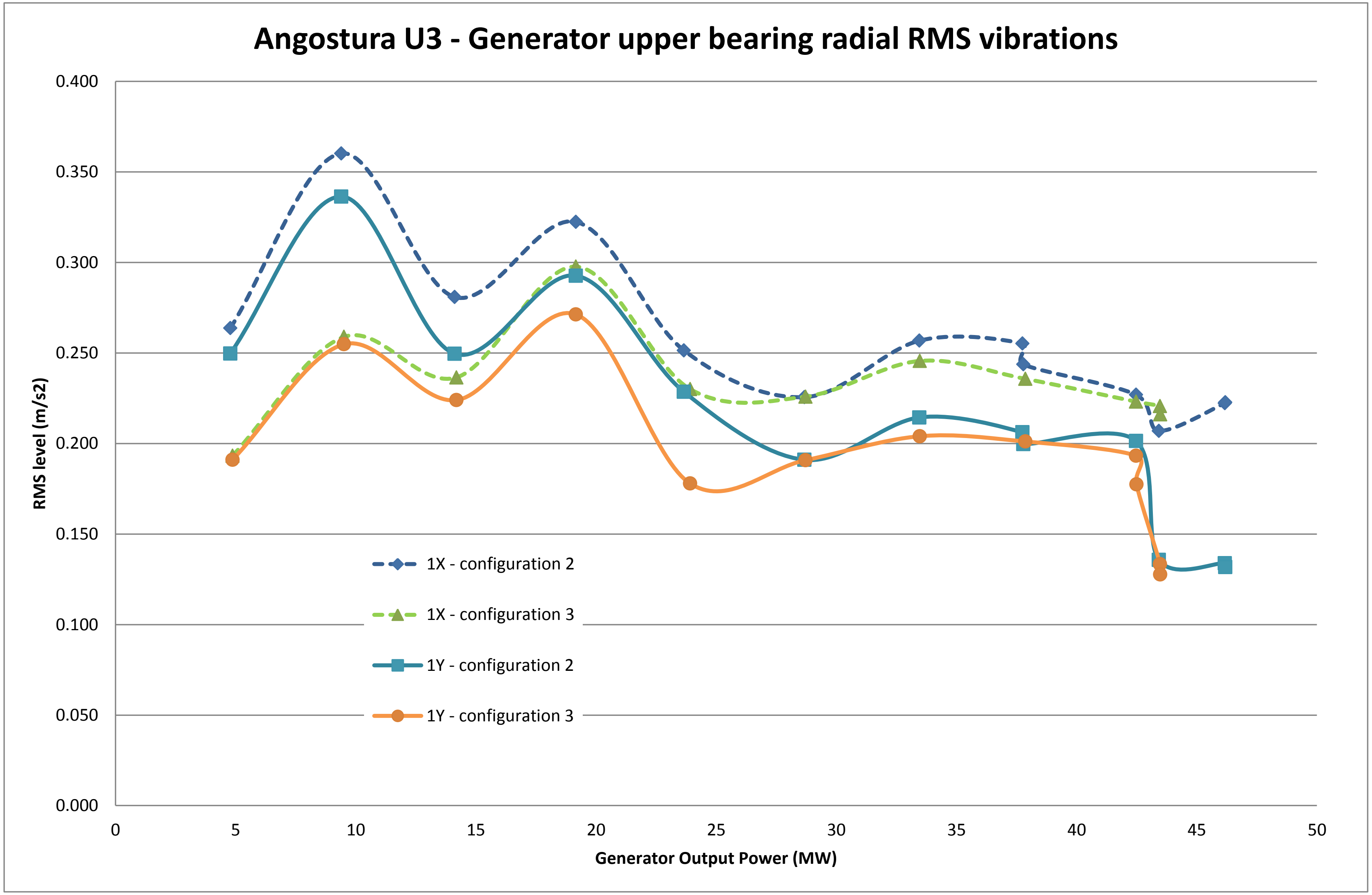
Global RMS values are calculated on the time domain signal and presented in m/s².Integrated values of acceleration are part of Spectrum analysis paragraph.

Test point (-)	1X RMS level m/s^2	1Y RMS level m/s^2	2X RMS level m/s^2	2Y RMS level m/s^2	2Z RMS level m/s^2	3X RMS level m/s^2	3Y RMS level m/s^2	3Z RMS level m/s^2	Vib_ConeX RMS level m/s^2	Vib_ConeY RMS level m/s^2
4.7MW1	0.244	0.243	0.386	0.393	0.658	5.317	6.593	1.788	1.958	10.164
4.7MW2	0.264	0.250	0.382	0.391	0.657	5.363	6.710	1.816	2.118	10.176
4.7MW3	0.193	0.191	0.223	0.213	0.370	1.307	1.615	0.684	4.977	4.498
9.3MW1	0.344	0.311	0.409	0.391	0.655	4.977	6.154	1.578	6.726	10.561
9.3MW2	0.360	0.336	0.414	0.401	0.664	5.091	6.278	1.590	6.312	10.527
9.3MW3	0.259	0.255	0.227	0.214	0.373	1.421	1.739	0.708	6.778	5.057
14.1MW1	0.286	0.252	0.312	0.298	0.481	3.675	4.513	1.262	1.544	10.554
14.1MW2	0.281	0.250	0.306	0.292	0.476	3.591	4.373	1.245	1.344	10.536
14.1MW3	0.237	0.224	0.173	0.169	0.301	1.313	1.657	0.599	1.161	5.381
14.1MW4	0.214	0.188	0.138	0.135	0.231	0.802	0.929	0.479	1.057	3.545
19MW1	0.311	0.288	0.349	0.336	0.604	3.828	4.480	1.260	0.987	7.978
19MW2	0.322	0.293	0.352	0.338	0.602	3.882	4.528	1.278	1.164	7.894
19MW3	0.298	0.271	0.202	0.198	0.339	1.537	2.117	0.687	0.965	4.970
23MW1	0.255	0.213	0.189	0.184	0.270	2.061	2.632	0.568	0.434	2.576
23MW2	0.251	0.229	0.188	0.183	0.269	2.065	2.639	0.576	0.314	2.558
23MW3	0.230	0.178	0.098	0.102	0.155	1.316	1.471	0.304	1.468	1.122
28MW1	0.223	0.197	0.067	0.072	0.132	0.643	0.833	0.208	2.279	0.908
28MW2	0.226	0.191	0.072	0.076	0.154	0.714	0.955	0.242	0.447	1.184
28MW3	0.226	0.191	0.062	0.070	0.101	0.808	1.345	0.196	0.874	0.475
33MW1	0.247	0.204	0.051	0.061	0.078	0.501	0.617	0.150	1.128	0.300
33MW2	0.257	0.214	0.062	0.072	0.123	0.639	0.832	0.199	0.951	0.760
33MW3	0.246	0.204	0.069	0.080	0.097	1.126	1.900	0.216	0.741	0.464
37MW1	0.263	0.206	0.055	0.063	0.074	0.612	0.756	0.187	0.291	0.342
37MW12	0.249	0.206	0.055	0.062	0.074	0.617	0.763	0.197	0.353	0.322
37MW2	0.255	0.206	0.055	0.062	0.073	0.615	0.761	0.198	0.550	0.322
37MW22	0.244	0.200	0.055	0.062	0.076	0.622	0.769	0.201	0.251	0.323
37MW3	0.236	0.201	0.075	0.085	0.103	1.075	2.304	0.265	0.316	0.569
42MW1	0.233	0.209	0.086	0.095	0.098	0.892	1.152	0.195	0.259	0.638
42MW2	0.227	0.201	0.088	0.097	0.099	0.903	1.176	0.208	0.290	0.612
42MW31	0.223	0.193	0.102	0.111	0.125	1.083	1.858	0.317	0.325	0.756
42MW32	0.221	0.177	0.104	0.115	0.125	1.072	1.440	0.300	0.271	0.671
43MW1	0.210	0.145	0.096	0.110	0.111	1.123	1.364	0.206	0.301	0.767
43MW2	0.207	0.136	0.094	0.107	0.112	1.072	1.269	0.207	0.258	0.778
43MW31	0.216	0.133	0.106	0.119	0.135	1.031	1.640	0.327	0.141	0.822
43MW32	0.210	0.128	0.106	0.121	0.131	1.079	1.501	0.319	0.271	0.727
46MW1	0.222	0.137	0.129	0.148	0.141	2.151	2.607	0.330	0.496	1.484
46MW21	0.222	0.134	0.128	0.146	0.145	2.160	2.578	0.334	0.442	1.487
46MW22	0.223	0.132	0.127	0.145	0.152	2.150	2.517	0.333	0.341	1.472
fore LR 47.2M	0.286	0.155	0.131	0.148	0.185	2.295	2.987	0.447	0.248	1.866

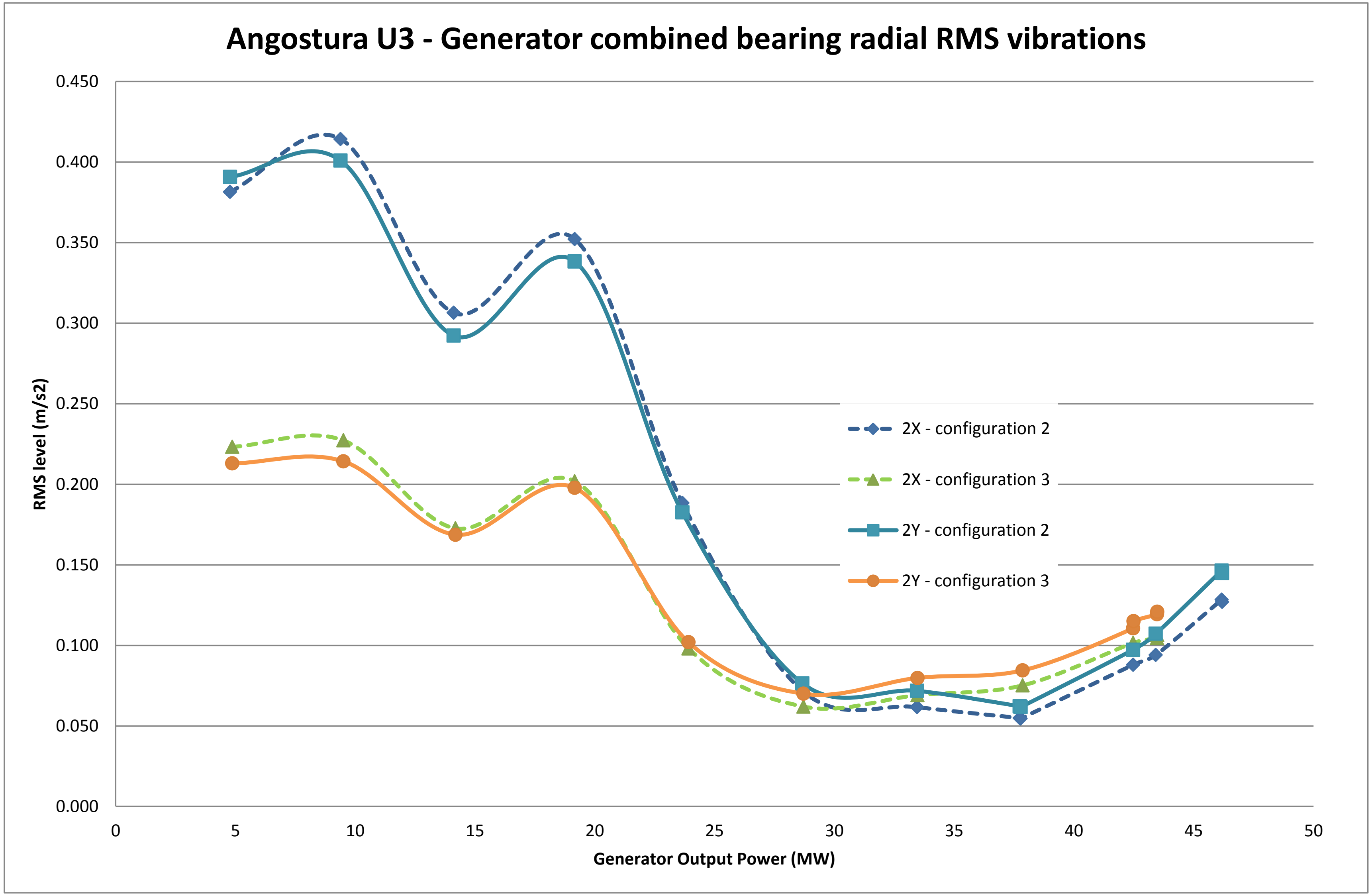
As we can see in graphs hereunder, the head cover and bottom ring air injection reduce drastically the vibration levels.



Angostura U3 - bearing radial RMS vibrations for the 1st configuration
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
RMS level (m/s2)
0
5
10
15
20
25
30
35
40
45
50
Generator Output Power (MW)
1X - configuration1
1Y - configuration 1
2X - configuration1
2Y - configuration 1
3X - configuration1
3Y - configuration 1

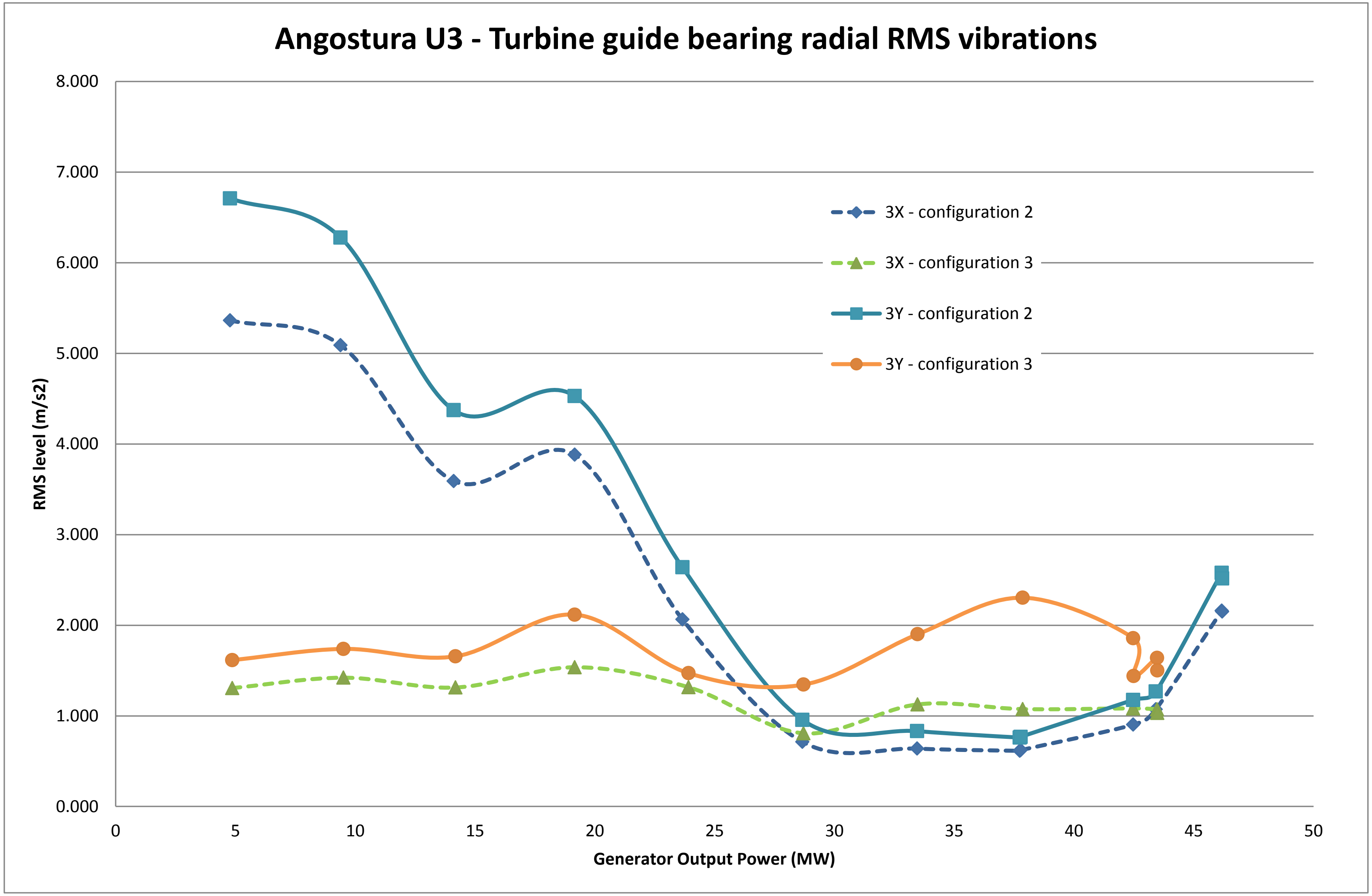


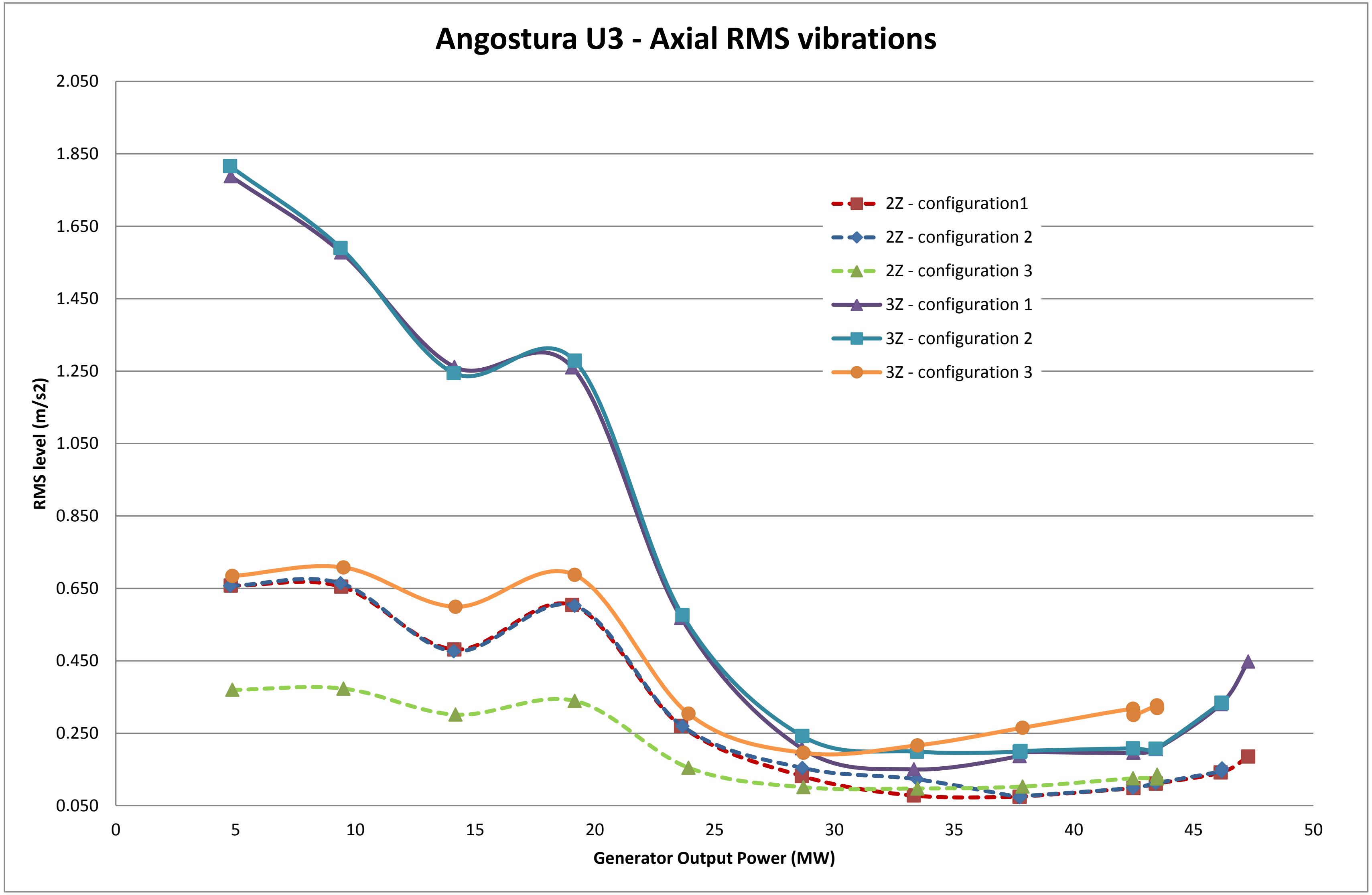
Angostura U3 - Generator upper bearing radial RMS vibrations
RMS level (m/s2)
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0
5
10
15
20
25
30
35
40
45
50
Generator Output Power (MW)
1X - configuration 2
1X - configuration 3
1Y - configuration 2
1Y - configuration 3



Angostura U3 - Generator combined bearing radial RMS vibrations
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
RMS level (m/s2)
0
5
10
15
20
25
30
35
40
45
50
Generator Output Power (MW)
2X - configuration 2
2X - configuration 3
2Y - configuration 2
2Y - configuration 3

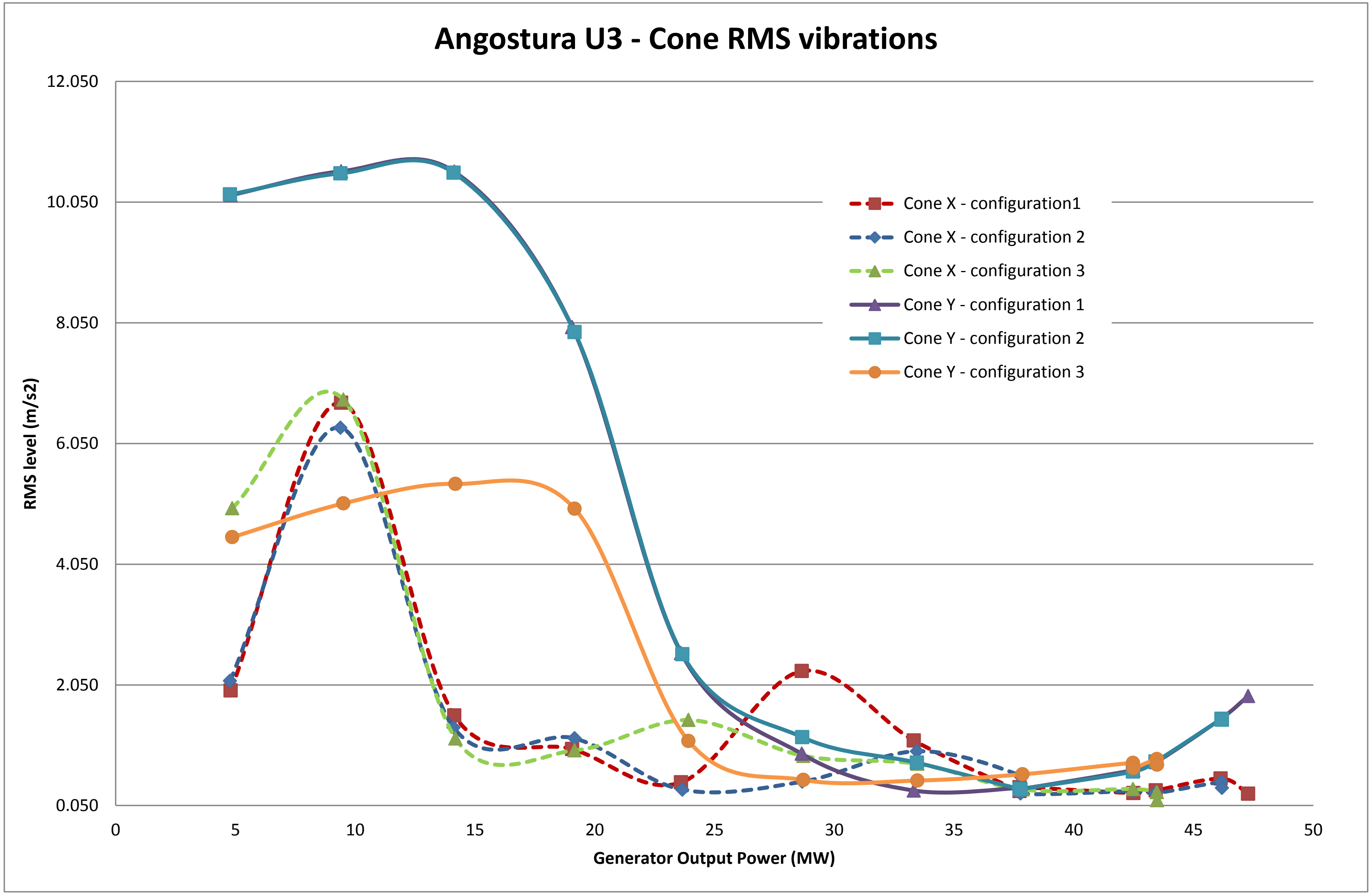
ALSTOM	PROJECT : CLIENT :	ANGOSTURA Unit 3 COLBUN		ALSTOM Hydro France N° DOCUMENT : LTESS-14507	
Study N° :		Contract N°	N° O.E. :	Page :	39





Angostura U3 - Axial RMS vibrations
RMS level (m/s2)
2.050
1.850
1.650
1.450
1.250
1.050
0.850
0.650
0.450
0.250
0.050
0
5
10
15
20
25
30
35
40
45
50
Generator Output Power (MW)
2Z - configuration1
2Z - configuration 2
2Z - configuration 3
3Z - configuration 1
3Z - configuration 2
3Z - configuration 3

ALSTOM	PROJECT : CLIENT :	ANGOSTURA Unit 3 COLBUN		ALSTOM Hydro France N° DOCUMENT : LTESS-14507	
Study N° :		Contract N°		N° O.E. :		Page :	41



7.2.3. Time Domain pressures

Hereafter are presented peak to peak 97% results on 10 shaft revolutions.

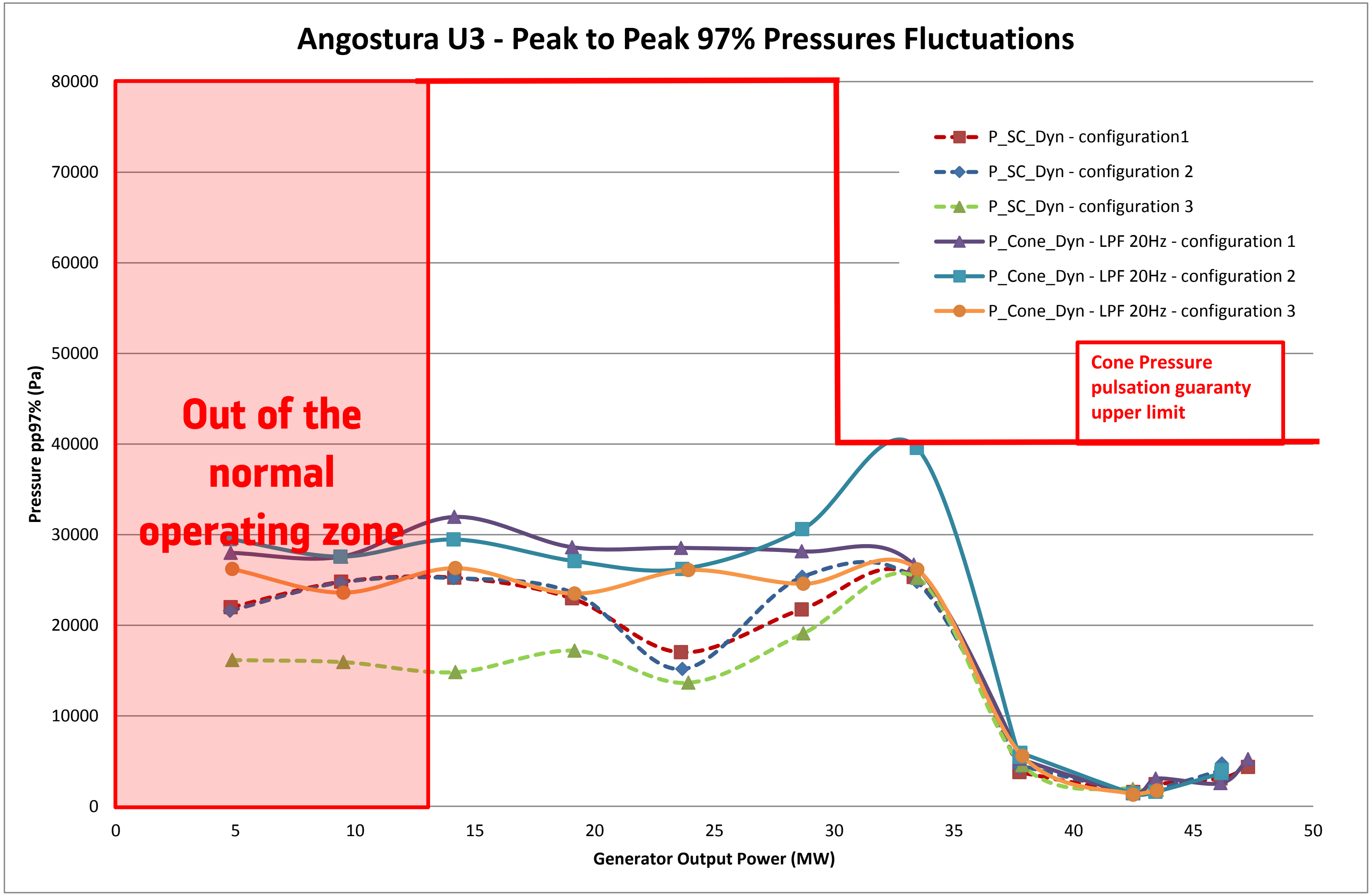
Test point (-)	Net Head from WK (m)	P_SC_Dyn pp97% (Pa)	P_SC_Dyn /Net Head (%)	P_Cone_Dyn pp97% LPF 20Hz (Pa)	P_Cone_Dyn /Net Head (%)
4.7MW1	50.38	21969	4.46%	27990	5.68%
4.7MW2	50.36	21586	4.38%	29497	5.99%
4.7MW3	50.38	16150	3.28%	26198	5.32%
9.3MW1	50.25	24786	5.04%	27567	5.61%
9.3MW2	50.25	24718	5.03%	27572	5.61%
9.3MW3	50.17	15919	3.24%	23592	4.81%
14.1MW1	50.04	25246	5.16%	31950	6.53%
14.1MW2	50.06	25198	5.15%	29460	6.02%
14.1MW3	50.04	14812	3.03%	26299	5.37%
14.1MW4	50.06	13329	2.72%	25143	5.13%
19MW1	49.92	22954	4.70%	28608	5.86%
19MW2	49.94	23514	4.81%	27070	5.54%
19MW3	49.93	17191	3.52%	23489	4.81%
23MW1	49.77	17003	3.49%	28534	5.86%
23MW2	49.77	15152	3.11%	26213	5.38%
23MW3	49.92	13647	2.79%	26081	5.34%
28MW1	50.80	21742	4.38%	28156	5.67%
28MW2	50.83	25331	5.10%	30592	6.15%
28MW3	50.88	19101	3.84%	24566	4.94%
33MW1	51.34	25319	5.04%	26676	5.31%
33MW2	51.42	24781	4.93%	39557	7.86%
33MW3	51.47	25220	5.01%	26151	5.19%
37MW1	51.23	4143	0.83%	5678	1.13%
37MW12	51.24	3787	0.76%	5257	1.05%
37MW2	51.22	4304	0.86%	5454	1.09%
37MW22	51.23	4480	0.89%	5894	1.18%
37MW3	51.27	4540	0.91%	5544	1.11%
42MW1	49.30	1574	0.33%	1442	0.30%
42MW2	49.28	1590	0.33%	1426	0.30%
42MW31	49.26	1898	0.39%	1318	0.27%
42MW32	49.26	1835	0.38%	1291	0.27%
43MW1	49.15	2435	0.51%	3067	0.64%
43MW2	49.15	1874	0.39%	1610	0.33%
43MW31	49.14	2707	0.56%	1704	0.35%
43MW32	49.14	2394	0.50%	1756	0.37%
46MW1	48.93	3096	0.65%	2560	0.53%
46MW21	48.93	4051	0.85%	3687	0.77%
46MW22	48.95	4722	0.99%	4013	0.84%
fore LR 47.2M	52.24	4344	0.85%	5200	1.02%

According to the contract, the peak to peak shall not exceed the following values:

From el “ACTA de Acuerdos N°1 Rev1”:

2.2 Fluctuaciones de presión en el difusor. ALSTOM confirma las garantías de fluctuaciones de presión dentro de la zona de funcionamiento continuo, contempladas en su propuesta:

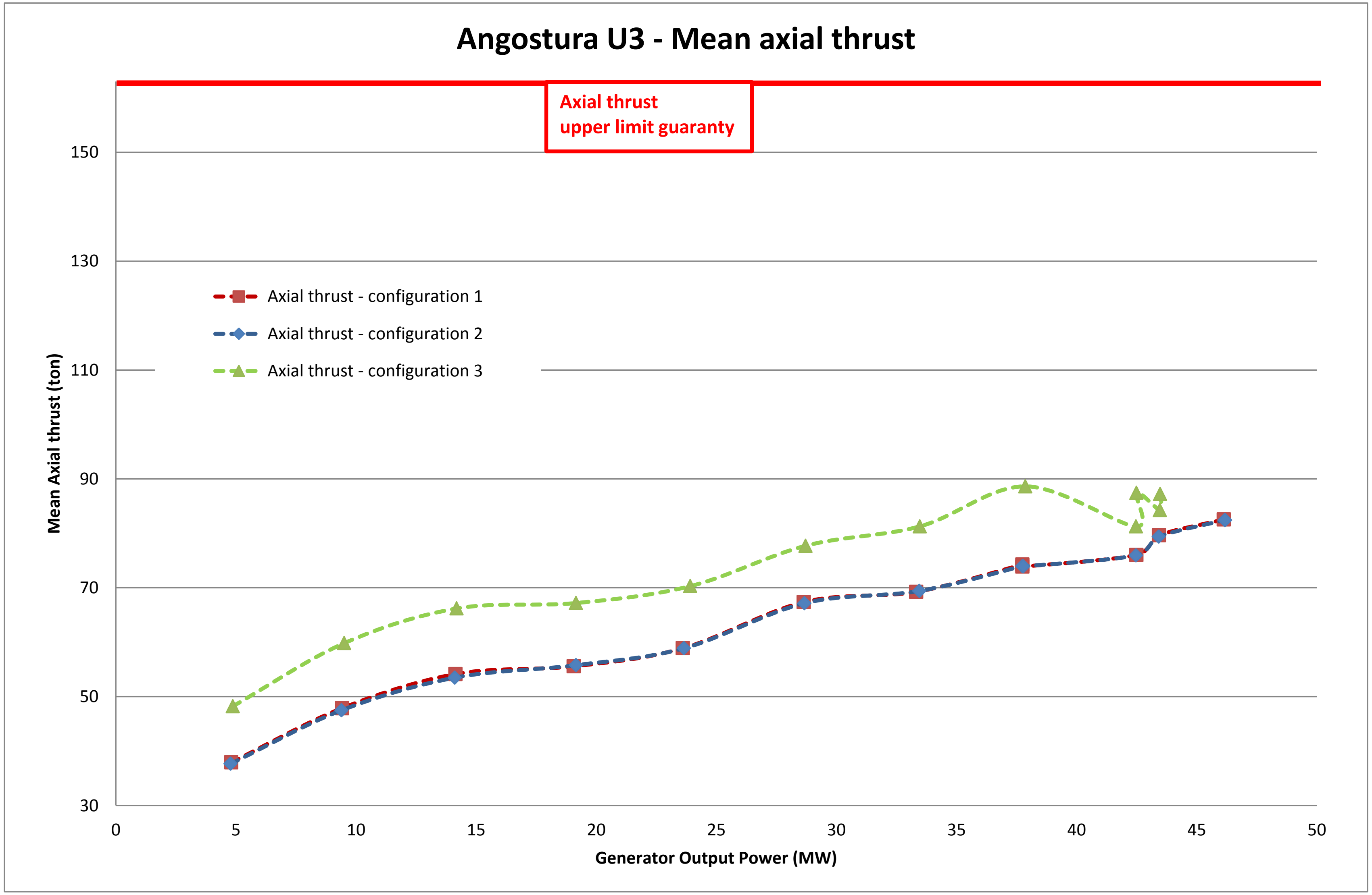
- U1/U2 : [210 m^3/s – 330 m^3/s] 4 mca peak-to-peak.
  [120 m^3/s – 210 m^3/s] 8 mca peak-to-peak.
- U3 : [70 m^3/s – 110 m^3/s] 4 mca peak-to-peak.
  [40 m^3/s – 70 m^3/s] 8 mca peak-to-peak.



As we can see on the previous graphs, the guaranty is fulfill.

7.2.4. Time Domain axial thrust

Test name (-)	Generator output power (MW)	P_membrane mean (N)	Axial thrust mean (ton)	P_membrane pp97% 10rev (N)	Axial thrust pp97% 10rev (ton)
4.7MW1	4.804	1943754	37.919	197479	20.153
4.7MW2	4.774	1941250	37.664	198340	20.241
4.7MW3	4.865	2044808	48.232	153207	15.635
9.3MW1	9.416	2041329	47.877	184304	18.808
9.3MW2	9.388	2037546	47.491	176057	17.967
9.3MW3	9.507	2158434	59.828	136664	13.947
14.1MW1	14.136	2102760	54.146	167741	17.118
14.1MW2	14.109	2096373	53.494	162596	16.593
14.1MW3	14.187	2220845	66.197	107721	10.993
14.1MW4	14.294	2242556	68.412	105645	10.781
19MW1	19.061	2116795	55.578	140701	14.359
19MW2	19.158	2118793	55.782	148729	15.178
19MW3	19.161	2230667	67.199	110295	11.256
23MW1	23.608	2149221	58.887	144140	14.710
23MW2	23.657	2149305	58.896	136283	13.908
23MW3	23.913	2261019	70.296	105576	10.774
28MW1	28.643	2232355	67.371	146673	14.968
28MW2	28.669	2230324	67.164	180402	18.410
28MW3	28.715	2333702	77.714	128847	13.149
33MW1	33.321	2250830	69.257	121469	12.396
33MW2	33.456	2252404	69.417	214425	21.882
33MW3	33.471	2368549	81.270	121774	12.427
37MW1	37.745	2299733	74.247	41793	4.265
37MW12	37.740	2296357	73.903	40258	4.108
37MW2	37.742	2297102	73.979	42693	4.357
37MW22	37.777	2296616	73.929	43497	4.439
37MW3	37.865	2440710	88.634	41952	4.281
42MW1	42.490	2317176	76.027	31613	3.226
42MW2	42.472	2316492	75.958	31580	3.223
42MW31	42.472	2368518	81.267	30959	3.159
42MW32	42.489	2429002	87.439	30587	3.121
43MW1	43.429	2352363	79.618	54582	5.570
43MW2	43.419	2350297	79.407	32589	3.326
43MW31	43.472	2398041	84.280	39029	3.983
43MW32	43.481	2427087	87.244	39343	4.015
46MW1	46.130	2381127	82.554	33291	3.397
46MW21	46.171	2379813	82.420	41369	4.222
46MW22	46.191	2379857	82.424	76537	7.811
Before LR 47.2MW	47.285	939358	-64.581	31891	3.255



Angostura U3 - Mean axial thrust
Axial thrust
upper limit guaranty
Axial thrust - configuration 1
Axial thrust - configuration 2
Axial thrust - configuration 3
Mean Axial thrust (ton)
150
130
110
90
70
50
30
0
5
10
15
20
25
30
35
40
45
50
Generator Output Power (MW)

7.2.5. Accelerometers spectrum analysis

Comparison with ISO 10816-5 standard:

ISO 10816-5 standard defines radial vibration limitation for bearing housing under normal operating conditions. Four zones have been defined according to RMS velocity levels and Peak to Peak relative displacement.

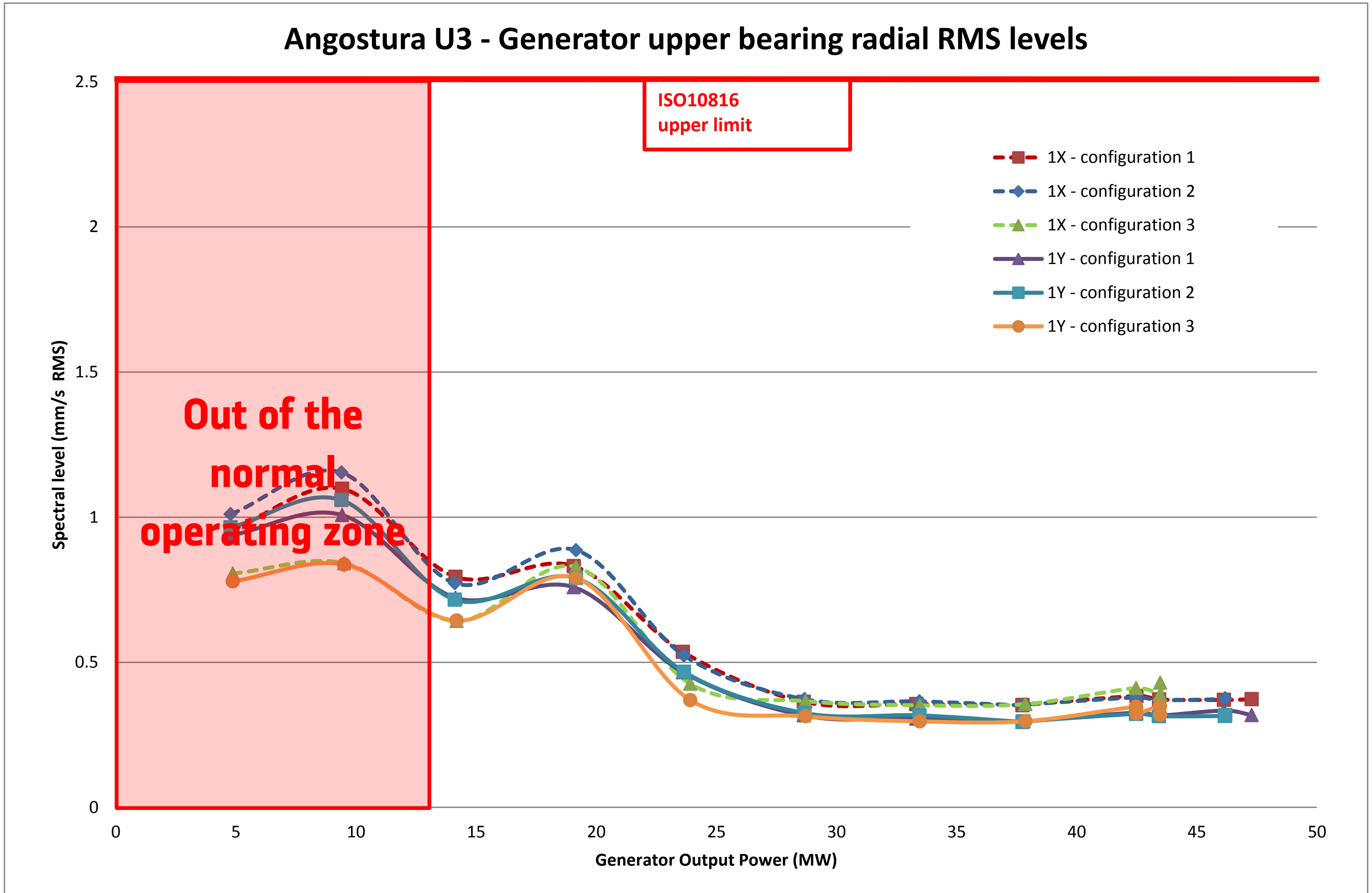
A: New machines
B: acceptable without restriction
C: Bearable for limited time operation
D: abnormal

Hereafter, the A,B,C and D zone boundaries given by the ISO 10816-5 standard :

Zone	RMS Velocity (mm/s)
A-B	1.6
B-C	2.5
C-D	4

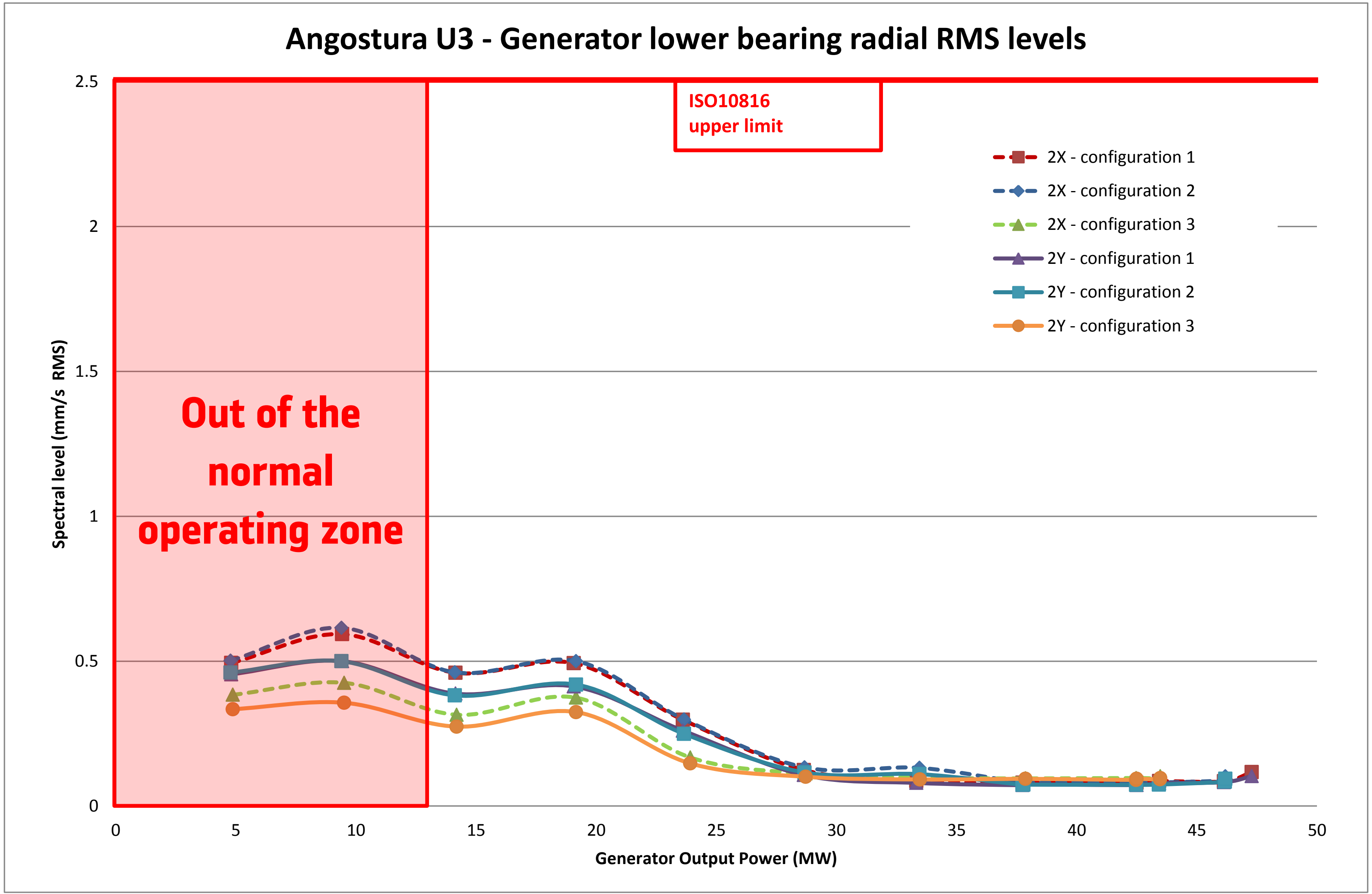
Test name (-)	1X 1 - 800 Hz (mm pp)	1Y 1 - 800 Hz (mm pp)	2X 1 - 800 Hz (mm pp)	2Y 1 - 800 Hz (mm pp)	3X 1 - 800 Hz (mm pp)	3Y 1 - 800 Hz (mm pp)
4.7MW1	0.0694	0.0668	0.0291	0.0274	0.0358	0.0365
4.7MW2	0.0691	0.0656	0.0298	0.0301	0.0386	0.0392
4.7MW3	0.0618	0.0564	0.0146	0.0155	0.028	0.0247
9.3MW1	0.0621	0.0583	0.0284	0.0281	0.0359	0.0358
9.3MW2	0.0628	0.0594	0.0285	0.0261	0.0362	0.0362
9.3MW3	0.0566	0.0514	0.0191	0.02	0.026	0.0237
14.1MW1	0.0565	0.0504	0.0252	0.0259	0.027	0.0404
14.1MW2	0.056	0.05	0.0237	0.0258	0.0271	0.0274
14.1MW3	0.0511	0.0448	0.014	0.0167	0.0149	0.0148
14.1MW4	0.0501	0.0435	0.0116	0.0155	0.0131	0.0117
19MW1	0.0568	0.0505	0.0259	0.0251	0.0292	0.0284
19MW2	0.0565	0.0509	0.0254	0.0237	0.0291	0.0292
19MW3	0.0511	0.0444	0.012	0.0135	0.0153	0.0129
23MW1	0.0553	0.049	0.0261	0.0283	0.0234	0.025
23MW2	0.0539	0.0473	0.0219	0.0222	0.0196	0.0211
23MW3	0.0497	0.0424	0.0112	0.0136	0.009	0.0084
28MW1	0.0498	0.0428	0.012	0.0142	0.0106	0.0099
28MW2	0.0506	0.043	0.0127	0.0149	0.0105	0.0096
28MW3	0.0487	0.041	0.0115	0.0144	0.0103	0.0099
33MW1	0.0493	0.0417	0.0113	0.0159	0.0084	0.0086
33MW2	0.0506	0.0428	0.0164	0.0166	0.0134	0.0144
33MW3	0.0481	0.0405	0.0109	0.0147	0.0078	0.0078
37MW1	0.0487	0.0409	0.0114	0.014	0.0075	0.0078
37MW12	0.0489	0.0409	0.0111	0.0146	0.0073	0.0083
37MW2	0.0487	0.041	0.0105	0.0155	0.0075	0.0082
37MW22	0.049	0.0413	0.011	0.0142	0.0071	0.0078
37MW3	0.0481	0.0398	0.0114	0.0145	0.0066	0.007
42MW1	0.0536	0.0459	0.0109	0.0137	0.0082	0.0089
42MW2	0.053	0.0452	0.0111	0.0141	0.0081	0.0085
42MW31	0.053	0.0452	0.0107	0.0148	0.0079	0.0078
42MW32	0.0517	0.044	0.0107	0.0157	0.0084	0.0076
43MW1	0.0518	0.0444	0.0107	0.0143	0.0079	0.0086
43MW2	0.0516	0.0443	0.0107	0.0123	0.0075	0.0085
43MW31	0.051	0.0437	0.0106	0.0137	0.0074	0.0086
43MW32	0.0503	0.0435	0.0107	0.0136	0.0078	0.0084
46MW1	0.0513	0.0584	0.0106	0.0142	0.0078	0.0095
46MW21	0.0516	0.0439	0.0116	0.0149	0.0085	0.0095
46MW22	0.0514	0.0437	0.0104	0.0142	0.0082	0.0096
Before LR 47.2MW	0.0527	0.0457	0.0185	0.0188	0.0161	0.0191

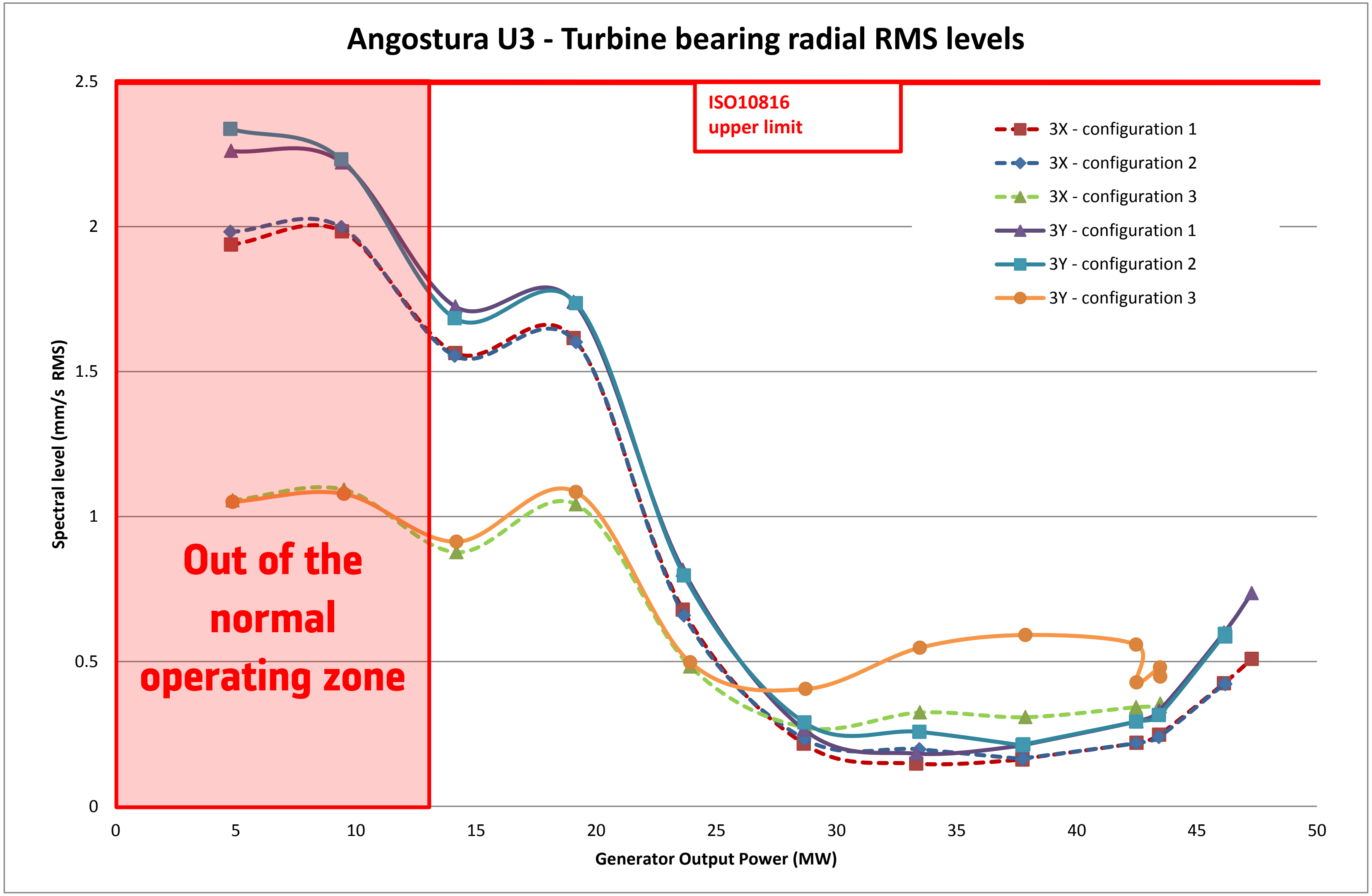
Test name (-)	1X 1 - 800 Hz (mm pp)	1Y 1 - 800 Hz (mm pp)	2X 1 - 800 Hz (mm pp)	2Y 1 - 800 Hz (mm pp)	3X 1 - 800 Hz (mm pp)	3Y 1 - 800 Hz (mm pp)
4.7MW1	0.0694	0.0668	0.0291	0.0274	0.0358	0.0365
4.7MW2	0.0691	0.0656	0.0298	0.0301	0.0386	0.0392
4.7MW3	0.0618	0.0564	0.0146	0.0155	0.028	0.0247
9.3MW1	0.0621	0.0583	0.0284	0.0281	0.0359	0.0358
9.3MW2	0.0628	0.0594	0.0285	0.0261	0.0362	0.0362
9.3MW3	0.0566	0.0514	0.0191	0.02	0.026	0.0237
14.1MW1	0.0565	0.0504	0.0252	0.0259	0.027	0.0404
14.1MW2	0.056	0.05	0.0237	0.0258	0.0271	0.0274
14.1MW3	0.0511	0.0448	0.014	0.0167	0.0149	0.0148
14.1MW4	0.0501	0.0435	0.0116	0.0155	0.0131	0.0117
19MW1	0.0568	0.0505	0.0259	0.0251	0.0292	0.0284
19MW2	0.0565	0.0509	0.0254	0.0237	0.0291	0.0292
19MW3	0.0511	0.0444	0.012	0.0135	0.0153	0.0129
23MW1	0.0553	0.049	0.0261	0.0283	0.0234	0.025
23MW2	0.0539	0.0473	0.0219	0.0222	0.0196	0.0211
23MW3	0.0497	0.0424	0.0112	0.0136	0.009	0.0084
28MW1	0.0498	0.0428	0.012	0.0142	0.0106	0.0099
28MW2	0.0506	0.043	0.0127	0.0149	0.0105	0.0096
28MW3	0.0487	0.041	0.0115	0.0144	0.0103	0.0099
33MW1	0.0493	0.0417	0.0113	0.0159	0.0084	0.0086
33MW2	0.0506	0.0428	0.0164	0.0166	0.0134	0.0144
33MW3	0.0481	0.0405	0.0109	0.0147	0.0078	0.0078
37MW1	0.0487	0.0409	0.0114	0.014	0.0075	0.0078
37MW12	0.0489	0.0409	0.0111	0.0146	0.0073	0.0083
37MW2	0.0487	0.041	0.0105	0.0155	0.0075	0.0082
37MW22	0.049	0.0413	0.011	0.0142	0.0071	0.0078
37MW3	0.0481	0.0398	0.0114	0.0145	0.0066	0.007
42MW1	0.0536	0.0459	0.0109	0.0137	0.0082	0.0089
42MW2	0.053	0.0452	0.0111	0.0141	0.0081	0.0085
42MW31	0.053	0.0452	0.0107	0.0148	0.0079	0.0078
42MW32	0.0517	0.044	0.0107	0.0157	0.0084	0.0076
43MW1	0.0518	0.0444	0.0107	0.0143	0.0079	0.0086
43MW2	0.0516	0.0443	0.0107	0.0123	0.0075	0.0085
43MW31	0.051	0.0437	0.0106	0.0137	0.0074	0.0086
43MW32	0.0503	0.0435	0.0107	0.0136	0.0078	0.0084
46MW1	0.0513	0.0584	0.0106	0.0142	0.0078	0.0095
46MW21	0.0516	0.0439	0.0116	0.0149	0.0085	0.0095
46MW22	0.0514	0.0437	0.0104	0.0142	0.0082	0.0096
fore LR 47.2M	0.0527	0.0457	0.0185	0.0188	0.0161	0.0191



Angostura U3 - Generator upper bearing radial RMS levels
ISO10816
upper limit
1X - configuration 1
1X - configuration 2
1X - configuration 3
1Y - configuration 1
1Y - configuration 2
1Y - configuration 3
Out of the
normal
operating zone
Spectral level (mm/s RMS)
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
45
50
Generator Output Power (MW)

ALSTOM	PROJECT : CLIENT :	ANGOSTURA Unit 3 COLBUN			ALSTOM Hydro France N° DOCUMENT : LTESS-14507	
Study N° :		Contract N°		N° O.E. :		Page : 50





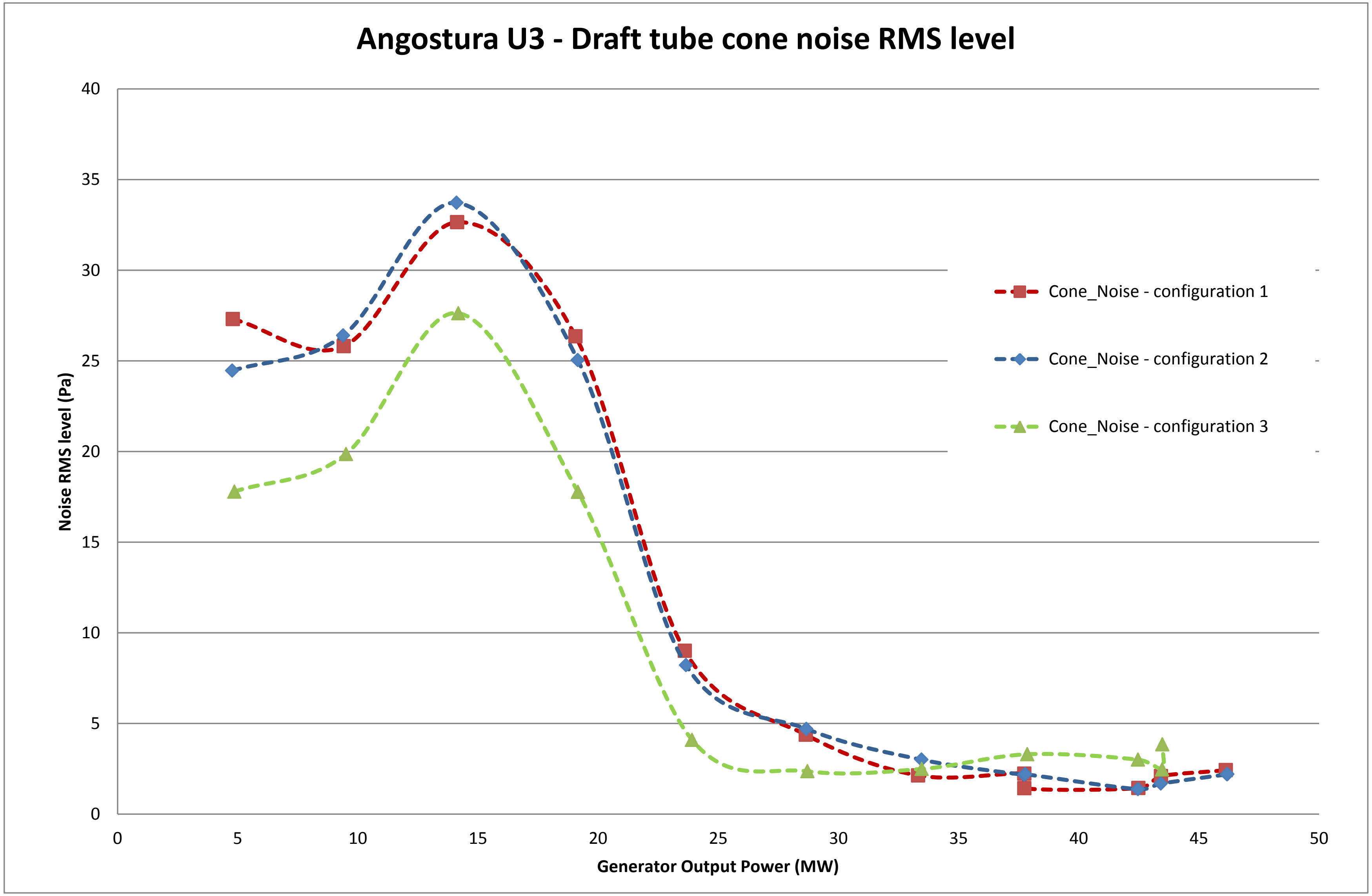
Angostura U3 - Turbine bearing radial RMS levels
ISO10816 upper limit
Out of the normal operating zone
3X - configuration 1
3X - configuration 2
3X - configuration 3
3Y - configuration 1
3Y - configuration 2
3Y - configuration 3
Spectral level (mm/s RMS)
Generator Output Power (MW)
0
0.5
1
1.5
2
2.5
0
5
10
15
20
25
30
35
40
45
50

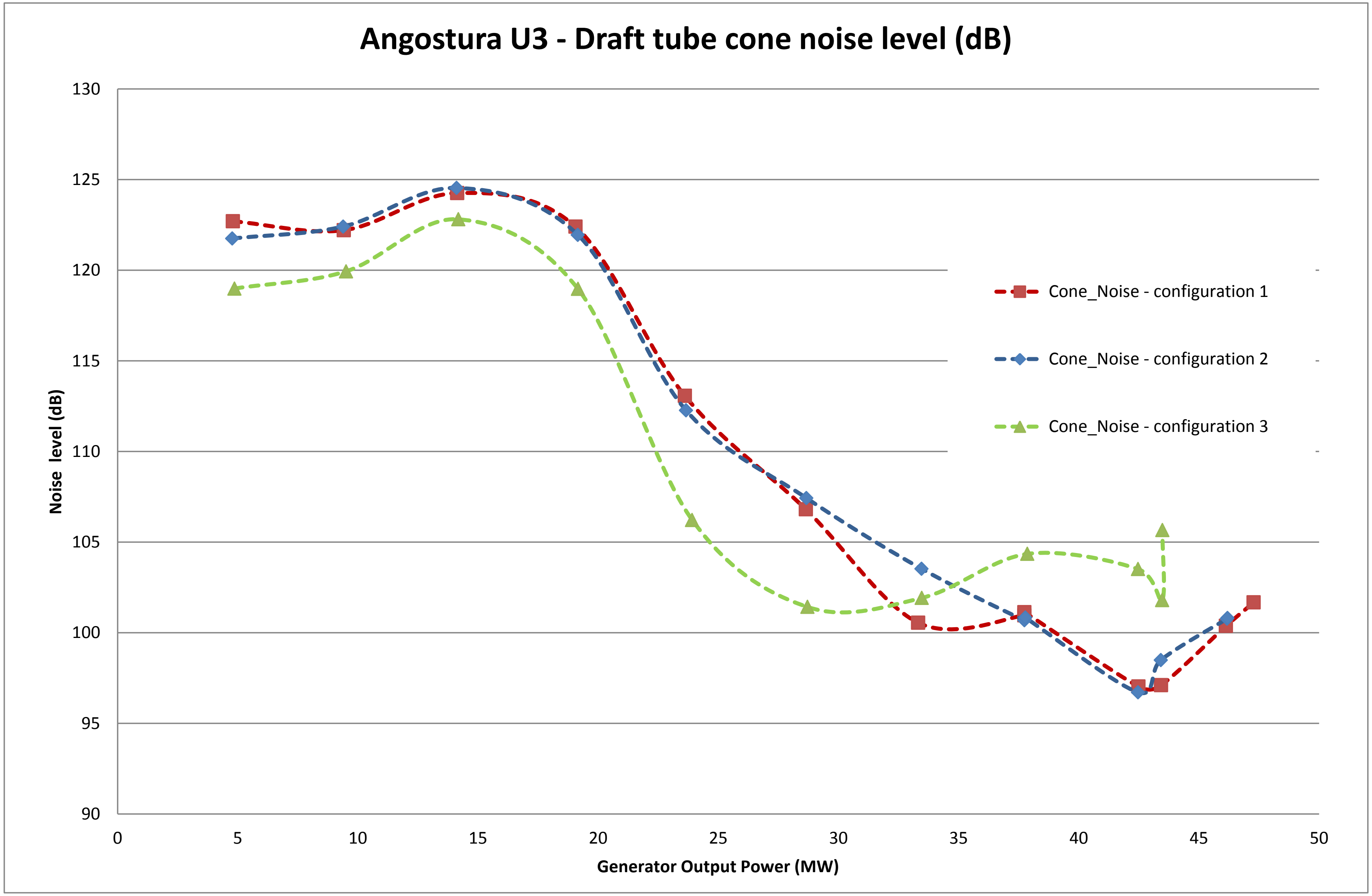
7.2.6. Noise

The noise has been measured at the draft tube cone entrance. We used a microphone B&K 4189 type. Temporal domain signals and associated spectrum analysis are performed using DynamX software, the results are presented hereafter.

Essai	Generator output power (MW)	Cone_Noise RMS (Pa)	Cone_Noise (dB)	Cone_Noise (dBA)
4.7MW1	4.804	27.300	122.700	107.780
4.7MW2	4.774	24.460	121.750	107.580
4.7MW3	4.865	17.790	118.990	101.000
9.3MW1	9.416	25.810	122.210	107.860
9.3MW2	9.388	26.400	122.410	107.810
9.3MW3	9.507	19.860	119.940	101.820
14.1MW1	14.136	32.650	124.260	107.760
14.1MW2	14.109	33.720	124.540	107.710
14.1MW3	14.187	27.630	122.810	103.290
14.1MW4	14.294	17.580	118.880	98.920
19MW1	19.061	26.360	122.400	105.690
19MW2	19.158	25.040	121.950	105.550
19MW3	19.161	17.770	118.970	101.650
23MW1	23.608	9.010	113.070	97.020
23MW2	23.657	8.220	112.270	96.290
23MW3	23.913	4.090	106.220	89.620
28MW1	28.643	4.380	106.810	88.860
28MW2	28.669	4.700	107.430	89.650
28MW3	28.715	2.360	101.420	84.410
33MW1	33.321	2.130	100.550	82.030
33MW2	33.456	3.000	103.530	87.110
33MW3	33.471	2.490	101.920	85.600
37MW1	37.745	2.230	100.960	82.290
37MW2	37.740	2.160	100.680	82.040
37MW12	37.742	2.280	101.130	82.120
37MW22	37.777	2.200	100.830	82.040
37MW3	37.865	3.300	104.350	86.500
42MW1	42.490	1.420	97.030	85.900
42MW2	42.472	1.370	96.710	85.640
42MW31	42.472	3.000	103.510	88.390
42MW32	42.489	2.460	101.790	87.730
43MW1	43.429	1.433	97.106	87.360
43MW2	43.419	1.680	98.490	87.280
43MW31	43.472	3.840	105.660	89.100
43MW32	43.481	3.080	103.750	88.270
46MW1	46.130	2.090	100.370	92.540
46MW21	46.171	2.190	100.770	92.500
46MW22	46.191	2.200	100.810	92.350
fore LR 47.2M	47.285	2.420	101.670	93.980

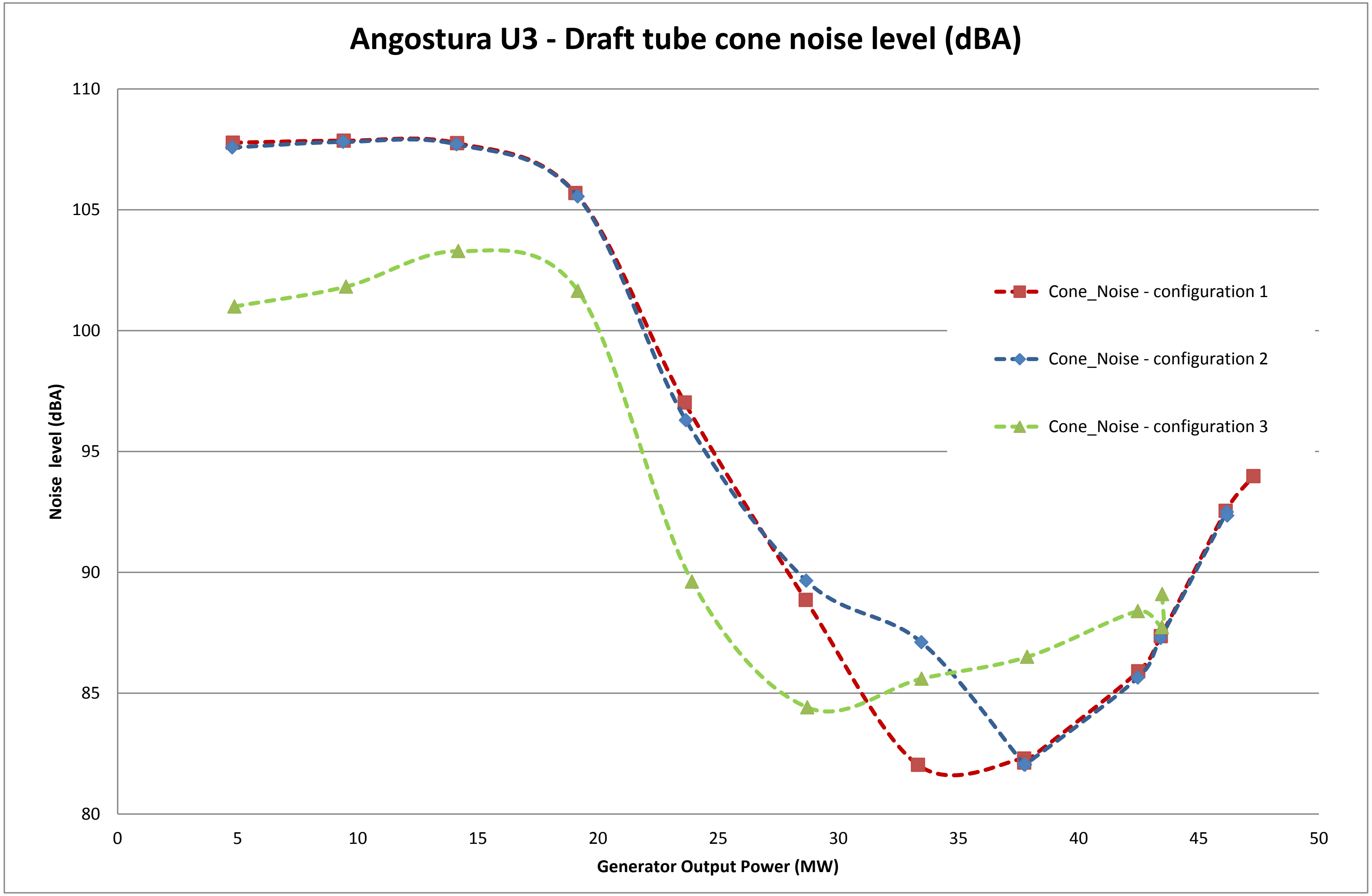
ALSTOM	PROJECT : CLIENT :		**ANGOSTURA** **Unit 3** **COLBUN**		ALSTOM Hydro France N° DOCUMENT : LTESS-14507	
Study N° :		Contract N°		N° O.E. :	Page :	54





Angostura U3 - Draft tube cone noise level (dB)
Noise level (dB)
130
125
120
115
110
105
100
95
90
0
5
10
15
20
25
30
35
40
45
50
Generator Output Power (MW)
Cone_Noise - configuration 1
Cone_Noise - configuration 2
Cone_Noise - configuration 3

ALSTOM	PROJECT : CLIENT :		ANGOSTURA Unit 3 COLBUN		ALSTOM Hydro France N° DOCUMENT : LTESS-14507	
Study N° :		Contract N°		N° O.E. :	Page :	56



7.3. Results for Transient Operation

7.3.1. Unit load rejection from 47.2MW

Guaranteed maximum pressure at the spiral case entrance during a load rejection:

1.2 **COMPORTAMIENTO EN CASO DE RECHAZOS DE CARGA**

1.2.1 Sobrepresión máxima debida al golpe de ariete medido a la entrada del caracol : 0.84 MPa

1.2.2 Maniobra que produce el golpe de ariete máximo : Cierre de emergencia

1.2.3 Sobrevelocidad máxima del grupo : **314.1 rpm** < 67.5% de la velocidad nominal

1.2.5 Sobrevelocidad y sobrepresiones en los siguientes casos:

RECHAZO DE CARGA CON	Altura Neta H0 = 55,00 m		Altura Neta H1 = 51,78 m		Altura Neta H2 = 48,65 m	
	Velocidad (rpm)	Presión en la Entrada del Caracol (mca)	Velocidad (rpm)	Presión en la Entrada del Caracol (mca)	Velocidad (rpm)	Presión en la Entrada del Caracol (mca)
25% DE LA CARGA NOMINAL	< 314	< 84	< 314	< 84	< 314	< 84
50% DE LA CARGA NOMINAL	na	na	< 314	< 84	< 314	< 84
75% DE LA CARGA NOMINAL	na	na	< 314	< 84	< 314	< 84
100% DE LA CARGA NOMINAL	na	na	< 314	< 84	< 314	< 84
POTENCIA MAXIMA PERMANENTE	na	na	na	na		

Nota: Completar según corresponda

k) Golpe de ariete en el difusor

Con la disposición propuesta para la turbina, el golpe de ariete negativo en el difusor (zona bajo rodete) en régimen transitorio no debe ser inferior a –6 m.c.a.

4. **EMPUJE HIDRAULICO**

4.1 Peso de las partes rotatorias de la turbina : 42.5 t

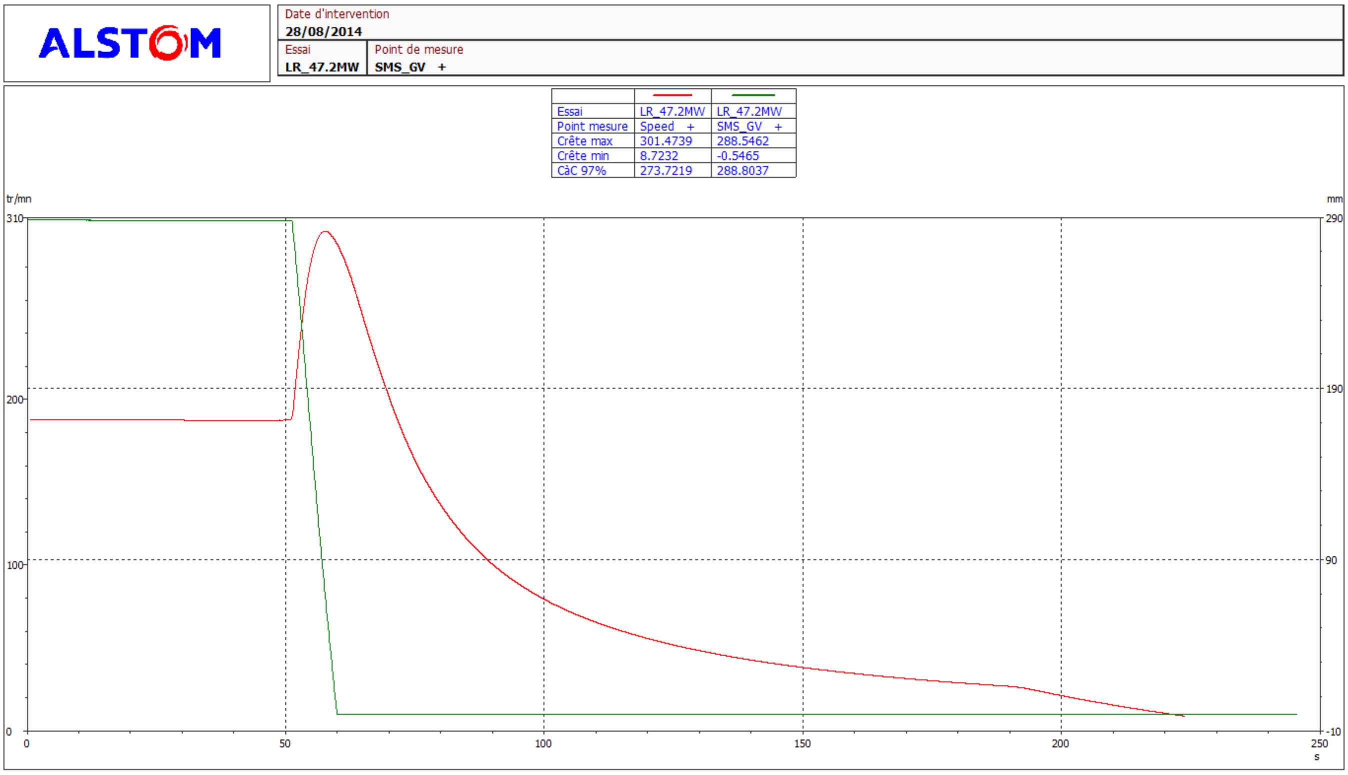
4.2 Empuje hidráulico máximo sobre el rodete con sellos sin desgaste : 163.1 t

4.3 Empuje hidráulico máximo posible sobre el rodete cuando el claro original de los sellos haya 280.0 t

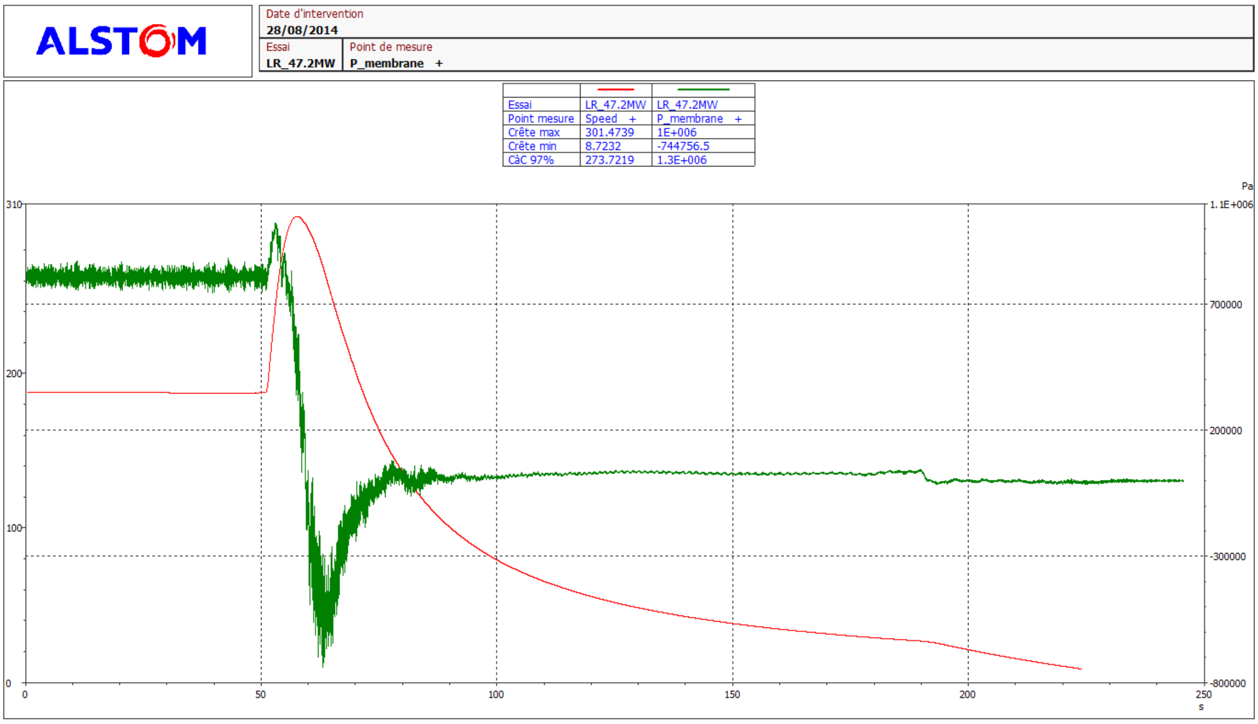
Steady state value before the load rejection:

Angostura U3 Steady state parameters before load rejection		
parameter	value	unit
Servomotor stroke	288	mm
Wicket gate opening	36	°
Generator output power	47.2	MW
Net head (from index tests)	52.24	m

Temporal raw signals



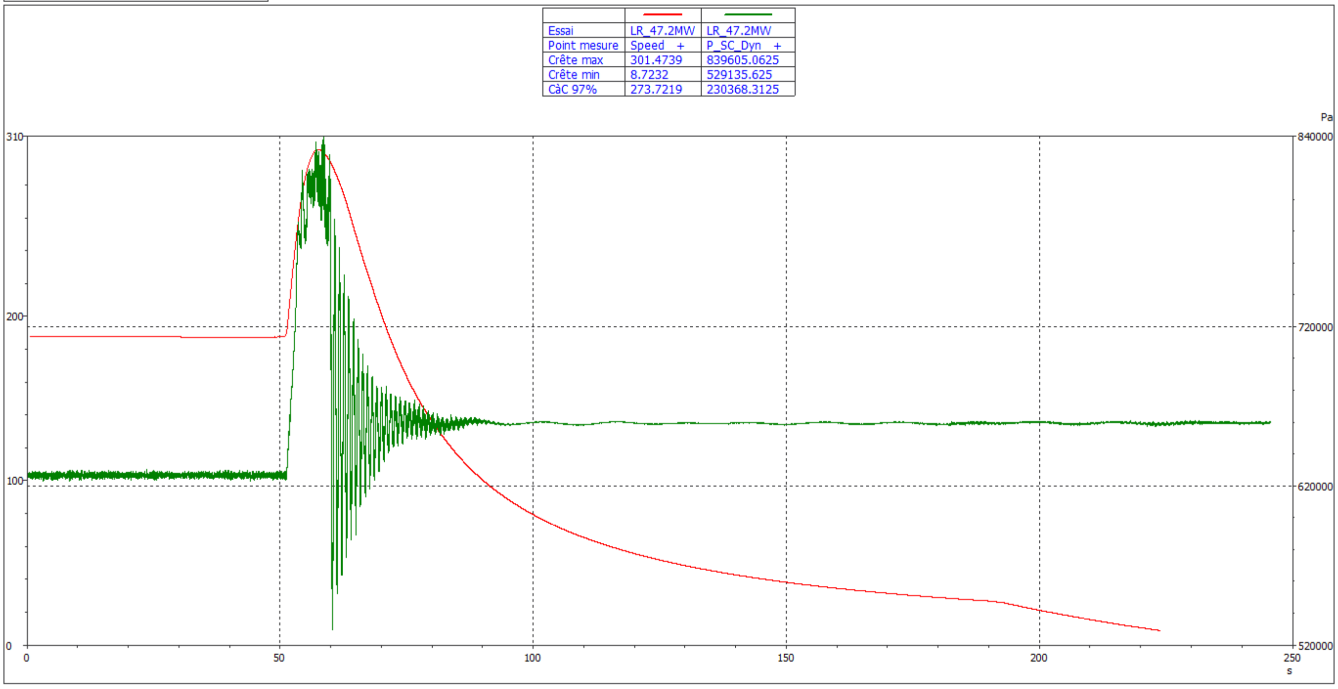
We reached an overspeed of 301.5 rpm.



The mean axial thrust "P_membrane" before and after load rejection are respectively, 806935 and -4628 Pa. Those results neither take into account the wait of the rotating parts nor the Archimedes upthrust.

ALSTOM

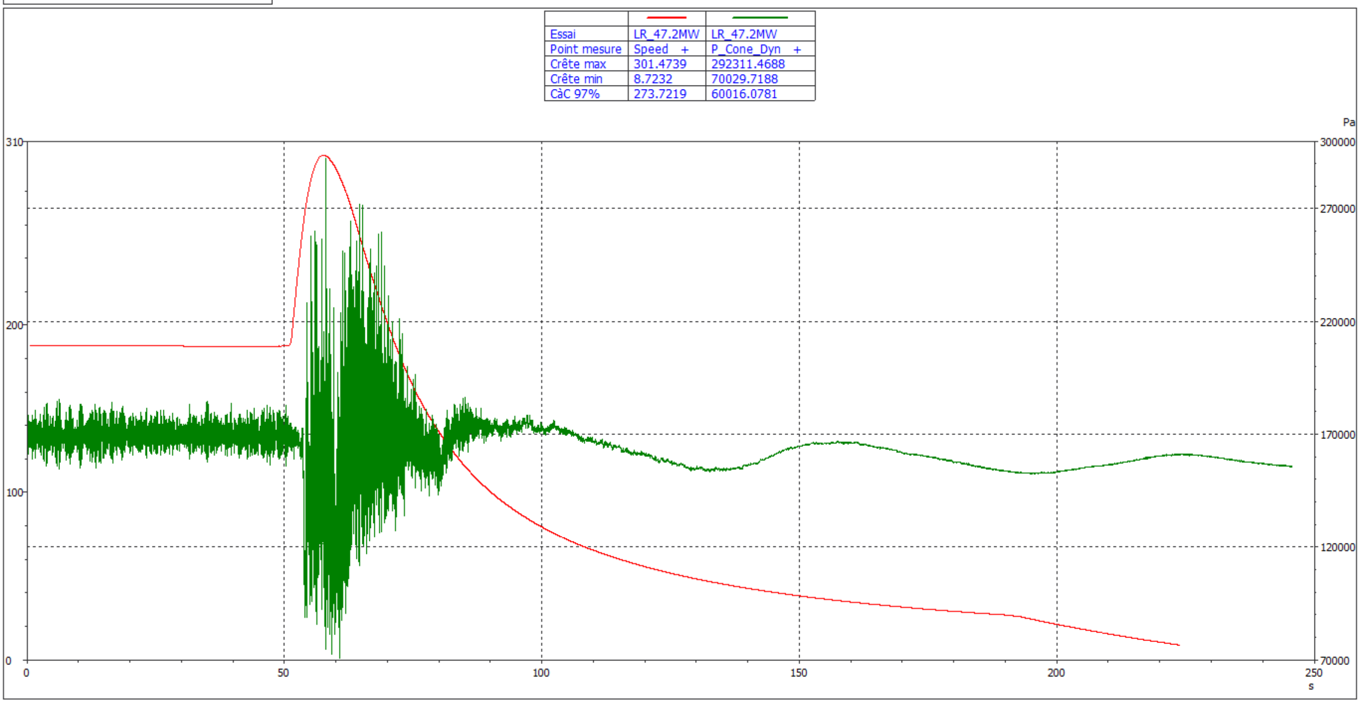
Date d'intervention
28/08/2014
Essai: LR_47.2MW | Point de mesure: P_SC_Dyn +



The maximum pressure reached in the spirale case entrance is 839605Pa abs, which is approximatively equal to 74 mCA. **The guaranty of 84 mCA maximum in the spiral case is fulfilled.**

ALSTOM

Date d'intervention
28/08/2014
Essai: LR_47.2MW | Point de mesure: P_Cone_Dyn +



The minimum pressure reached in the draft tube is 70029Pa abs, which is approximatively equal to -2.8mCA. **The guaranty of -6 mCA minimum in the draft tube cone is fulfilled.**

8. Conclusions

In terms of turbine performances, Angostura **Unit 3 fulfill the guaranties.** We reached 48.6 MW when only unit 3 was running and 45.92MW with the 3 units running.

In terms of hydromechanical behaviour, **we fit with the guaranties** and ISO standards (ISO7919, ISO10816). Except on the generator upper bearing, it hasn't been possible to compare displacement with the ISO10816, due to a track default on S1Y.

The bottom ring air injection has a huge impact on the bearings vibrations (up to twice lower) and in a less significant way, on the shaft displacement, noise and pressure pulsations. The configuration 3 shall be used for loads lower than 40% of the maximum load to reduce the stress on the machine.

9. Appendix

Appendix 1 : List of Tests
Appendix 2 : Unit bearing running clearances
Appendix 3 : Instrumentation and pictures
Appendix 4 : Sensors calibrations
Appendix 5 : Axial thrust calculation
Appendix 6 : Topographic manual records

9.1. Appendix 1 : List of tests

	Test name	Date	Hour
1	Startup->43MW	28/08/2014	1:31:00
2	43MW	28/08/2014	1:33:38
3	Shutdown	28/08/2014	14:34:56
4	point_zero1	28/08/2014	15:10:48
5	point_zero2	28/08/2014	15:12:14
6	Startup->FSNL	28/08/2014	15:33:40
7	FSNL_not_excited	28/08/2014	15:37:42
8	NotExcited->Excited	28/08/2014	15:39:42
9	FSNL_excited	28/08/2014	15:41:40
10	4.7MW1	28/08/2014	15:55:54
11	4.7MW2	28/08/2014	16:01:24
12	4.7MW3	28/08/2014	16:10:04
13	9.3MW1	28/08/2014	16:24:24
14	9.3MW2	28/08/2014	16:27:54
15	9.3MW3	28/08/2014	16:32:02
16	9->14MW	28/08/2014	16:37:08
17	14.1MW1	28/08/2014	16:48:06
18	14.1MW2	28/08/2014	16:52:34
19	14.1MW2->3	28/08/2014	16:55:00
20	14.1MW3	28/08/2014	17:09:06
21	14.1MW3->4	28/08/2014	17:11:14
22	14.1MW4	28/08/2014	17:13:58
23	14->19MW	28/08/2014	17:18:08
24	19MW1	28/08/2014	17:29:46
25	19MW2	28/08/2014	17:33:34
26	19MW3	28/08/2014	17:38:22
27	19->23MW	28/08/2014	17:42:58
28	23MW1	28/08/2014	17:52:28
29	23MW2	28/08/2014	17:57:20
30	23MW3	28/08/2014	18:02:02
31	23->28MW	28/08/2014	18:06:14
32	28MW1	28/08/2014	18:14:24
33	28MW2	28/08/2014	18:17:42
34	28MW3	28/08/2014	18:23:08
35	28->33MW	28/08/2014	18:27:42
36	33MW1	28/08/2014	18:37:00
37	33MW2	28/08/2014	18:42:14
38	33MW3	28/08/2014	18:47:30
39	33->38MW	28/08/2014	18:51:24
40	37MW1	28/08/2014	19:04:42
41	37MW2	28/08/2014	19:09:16
42	37MW12	28/08/2014	19:11:14
43	37MW22	28/08/2014	19:13:26
44	37MW3	28/08/2014	19:17:36
45	37->42MW	28/08/2014	19:23:02
46	LR_42MW	28/08/2014	19:26:02
47	42MW1	28/08/2014	20:52:48
48	42MW2	28/08/2014	20:57:08
49	42MW31	28/08/2014	21:02:06
50	42MW32	28/08/2014	21:05:24
51	42->43.5MW	28/08/2014	21:09:48
52	43MW1	28/08/2014	21:19:50
53	43MW2	28/08/2014	21:24:20
54	43MW31	28/08/2014	21:29:54
55	43MW32	28/08/2014	21:31:54
56	43->46MW	28/08/2014	21:38:56
57	46MW1	28/08/2014	21:43:30
58	46MW21	28/08/2014	21:46:50
59	46MW22	28/08/2014	21:48:44
60	U3=47.2MW_U1Shutdov	28/08/2014	22:28:14
61	Before LR 47.2MW	28/08/2014	22:58:36
62	LR_47.2MW	28/08/2014	22:58:36
63	point_zero3	28/08/2014	23:02:14

9.2. ***Appendix 2 : Unit bearings running clearances***

Radial running clearance:

	Unit 1 & 2		Unit 3	
	Theoretical	Site Adjustement	Theoretical	Site Adjustement
Upper generator guide bearing	0.3mm	0.3mm	0.22mm	0.22mm
Generator combined bearing	0.5mm	0.5mm	0.4mm	-
Turbine bearing	0.3mm	0.3mm	0.3mm	0.3mm

9.3. Appendix 3 : Instrumentation and pictures :

9.3.1. Sensors list

	Measured points	Description
1	S1X	Generator upper bearing displacement on X axis
2	S1Y	Generator upper bearing displacement on Y axis
3	S1Z	Generator upper bearing displacement on Z axis
4	S2X	Combined thrust and guide bearing displacement on X axis
5	S2Y	Combined thrust and guide bearing displacement on Y axis
6	S3X	Turbine guide bearing displacement on X axis
7	S3Y	Turbine guide bearing displacement on Y axis
8	1X	Generator upper bearing vibration on X axis
9	1Y	Generator upper bearing vibration on Y axis
10	3X	Turbine guide bearing vibration on X axis
11	3Y	Turbine guide bearing vibration on Y axis
12	3Z	Turbine guide bearing vibration on Z axis
13	2X	Combined thrust and guide bearing vibration on X axis
14	2Y	Combined thrust and guide bearing vibration on Y axis
15	2Z	Combined thrust and guide bearing vibration on Z axis
16	Vib_ConeX	Draft tube cone vibration on X axis
17	Vib_ConeY	Draft tube cone vibration on Y axis
18	P_SC_Dyn	Spiral case inlet pressure pulsation
19	P_Cone_Dyn	Draft tube cone pressure pulsation
20	P_HC3	Head cover pressure 3
21	P_HC1	Head cover pressure 1
22	P_HC2	Head cover pressure 2
23	Axial_valve_pos	Axial valve air injection stroke
24	P_WK_Client	Colbun Winter-Kennedy differential pressure
25	P_membrane	Thrust membrane pressure
26	Speed	Key phasor
27	P_Up_After	Collected pressure after the convergent
28	P_Down	Draft tube outlet pressure
29	Cone_Noise	Draft tube cone noise
30	P_Up_Before	Collected pressure before the convergent
31	SMS_GV	Guide vane servomotor stroke
32	GV_Opening	Guide vane opening angle
33	P_WK	Alstom Site Winter-Kennedy differential pressure
34	Power	Turbine power from the turbine governor

Inputs

	Label	Component	Node	Direction	Type	Transducer	Physical qty.	Sensitivity	Range pk	External Gain	Polarity	Offset comp.	Coupling
Input 1	S1X	None	0	Scalar	Translation	S1_X	Displacement	1 k(V)/(m)	10.0 mm	1	Normal	0 V	DC
Input 2	S1Y	None	0	Scalar	Translation	S1_Y	Displacement	1 k(V)/(m)	10.0 mm	1	Normal	0 V	DC
Input 3	S1Z	None	0	Scalar	Translation	S1Z_X	Displacement	1.1296 k(V)/(m)	8.85 mm	1	Normal	-1.0737 V	DC
Input 4	S2X	None	0	Scalar	Translation	S2_X	Displacement	1 k(V)/(m)	10.0 mm	1	Normal	0 V	DC
Input 5	S2Y	None	0	Scalar	Translation	S2_Y	Displacement	1 k(V)/(m)	10.0 mm	1	Normal	0 V	DC
Input 6	S3X	None	0	Scalar	Translation	S3_X	Displacement	1.1098 k(V)/(m)	9.01 mm	1	Normal	-1.0681 V	DC
Input 7	S3Y	None	0	Scalar	Translation	S3_Y	Displacement	1.1764 k(V)/(m)	8.5 mm	1	Normal	-977.1 mV	DC
Input 8	1X	None	0	Scalar	Translation	DYNAE_B4220	Acceleration	52.495 m(V)/(m/s²)	190 m/s²	1	Normal	0 V	ICP
Input 9	1Y	None	0	Scalar	Translation	DYNAE_B4219	Acceleration	49.868 m(V)/(m/s²)	201 m/s²	1	Normal	0 V	ICP
Input 10	3X	None	0	Scalar	Translation	DYNAE_B4221	Acceleration	52.868 m(V)/(m/s²)	189 m/s²	1	Normal	0 V	ICP
Input 11	3Y	None	0	Scalar	Translation	DYNAE_B4218	Acceleration	50.632 m(V)/(m/s²)	198 m/s²	1	Normal	0 V	ICP
Input 12	3Z	None	0	Scalar	Translation	DYNAE_B4215	Acceleration	51.505 m(V)/(m/s²)	194 m/s²	1	Normal	0 V	ICP
Input 13	2X	None	0	Scalar	Translation	DYNAE_B3061	Acceleration	49.887 m(V)/(m/s²)	200 m/s²	1	Normal	0 V	ICP
Input 14	2Y	None	0	Scalar	Translation	DYNAE_B3060	Acceleration	52.819 m(V)/(m/s²)	189 m/s²	1	Normal	0 V	ICP
Input 15	2Z	None	0	Scalar	Translation	DYNAE_B4216	Acceleration	50.559 m(V)/(m/s²)	198 m/s²	1	Normal	0 V	ICP
Input 16	Vib_ConeX	None	0	Scalar	Translation	DYNAE_B4224	Acceleration	53.048 m(V)/(m/s²)	189 m/s²	1	Normal	0 V	ICP
Input 17	Vib_ConeY	None	0	Scalar	Translation	DYNAE_B4223	Acceleration	49.365 m(V)/(m/s²)	203 m/s²	1	Normal	0 V	ICP
Input 18	P_SC_Dyn	None	0	Scalar	Translation	PTX_631_1669792	Pressure	3.1938E-06 (V)/(N/m²)	3130000 N/m²	1	Normal	-1.996 V	DC
Input 19	P_Cone_Dyn	None	0	Scalar	Translation	PTX631_1605429	Pressure	16.03E-06 (V)/(N/m²)	624000 N/m²	1	Normal	-1.9913 V	DC
Input 20	P_HC3	None	0	Scalar	Translation	PTX_631_2926858	Pressure	3.1944E-06 (V)/(N/m²)	3130000 N/m²	1	Normal	-1.9938 V	DC
Input 21	P_HC1	None	0	Scalar	Translation	PTX_631_2919186	Pressure	3.1924E-06 (V)/(N/m²)	3130000 N/m²	1	Normal	-1.9924 V	DC
Input 22	P_HC2	None	0	Scalar	Translation	PTX_631_2962348	Pressure	3.1929E-06 (V)/(N/m²)	3130000 N/m²	1	Normal	-1.9929 V	DC
Input 23	Axial_valve_pos	None	0	Scalar	Translation	Default Voltmeter	Voltage	1 (V)/(V)	10 V	1	Normal	0 V	DC
Input 24	P_WK_Client	None	0	Scalar	Translation	P_WK_Client	Pressure	200E-06 (V)/(N/m²)	50000 N/m²	1	Normal	0 V	DC
Input 25	P_membrane	None	0	Scalar	Translation	P_membrane_Client	Pressure	625E-09 (V)/(N/m²)	16000000 N/m²	1	Normal	0 V	DC
Input 26	not_used1	None	0	Scalar	Translation	Default Voltmeter	Voltage	1 (V)/(V)	10 V	1	Normal	0 V	DC
Input 27	not_used2	None	0	Scalar	Translation	Default Voltmeter	Voltage	1 (V)/(V)	10 V	1	Normal	0 V	DC
Input 28	Speed	None	0	Scalar	Translation	Default Voltmeter	Voltage	1 (V)/(V)	10 V	1	Normal	0 V	DC
Input 29	P_Up_After	None	0	Scalar	Translation	PTX_631_1774816	Pressure	3.1991E-06 (V)/(N/m²)	3130000 N/m²	1	Normal	-1.9539 V	DC
Input 30	P_Down	None	0	Scalar	Translation	PTX_631_2192271	Pressure	16.042E-06 (V)/(N/m²)	623000 N/m²	1	Normal	-2.0112 V	DC
Input 31	Cone_Noise	None	0	Scalar	Translation	4189_A_2749242	Acoustic pressure	53.887E-03 (V)/(Pa)	139.3 dB	1	Normal	0 V	ICP
Input 32	P_Up_Before	None	0	Scalar	Translation	PTX_1400_135/14	Pressure	7.9955E-06 (V)/(N/m²)	1250000 N/m²	1	Normal	-1.9676 V	DC

9.3.2. Sensors pictures

Generator upper bearing vibration 1Y

Generator upper bearing vibration 1X

Generator upper bearing displacement S1Y

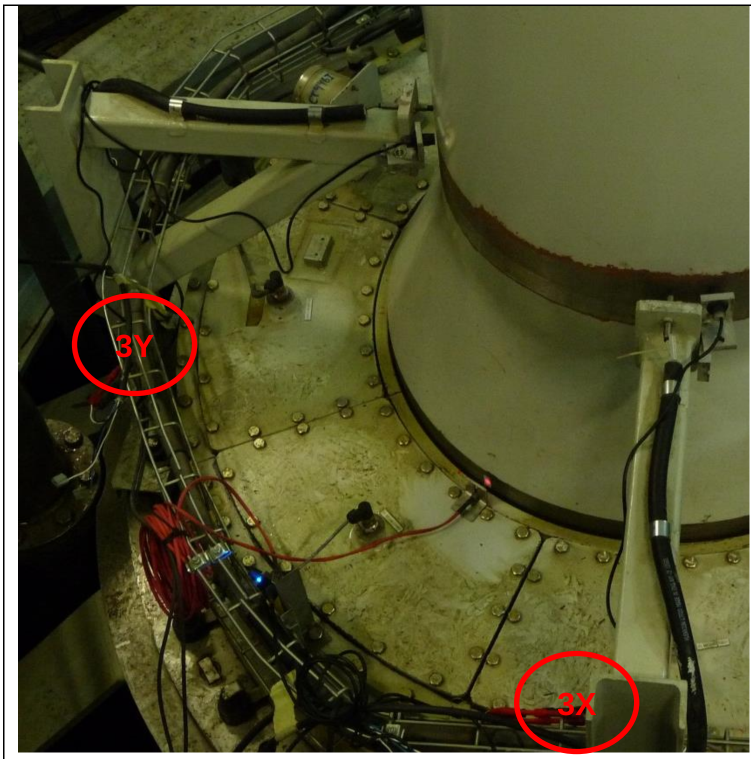
Generator upper bearing displacement S1X


Combined thrust and guide bearing vibration 2X


Combined thrust and guide bearing vibration 2Y


Combined thrust and guide bearing vibration 2Z

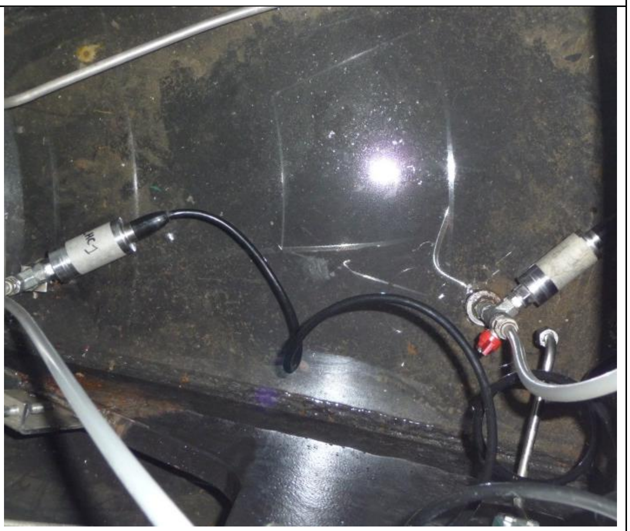

Combined thrust and guide bearing displacement S2X



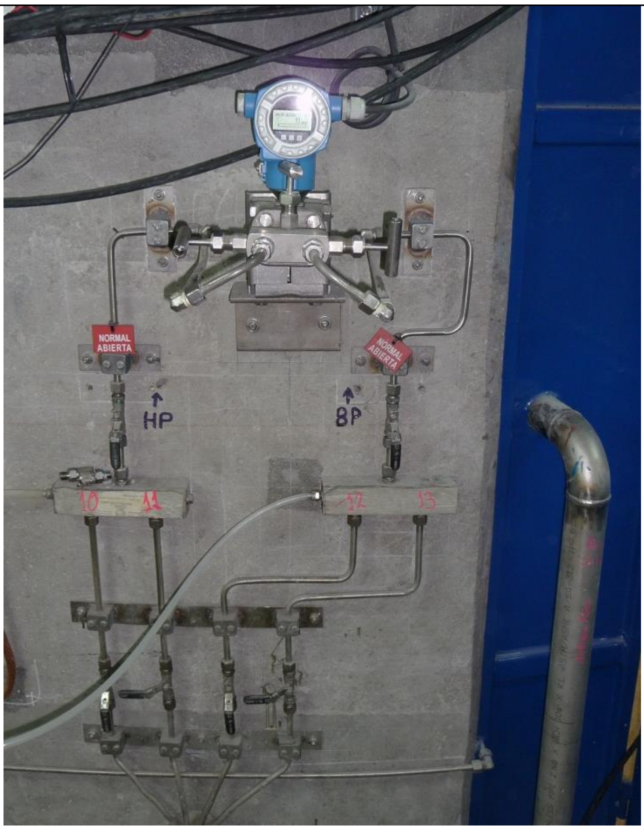
Turbine bearing displacements, vibrations, key phasor


Turbine bearing vibration 3Y

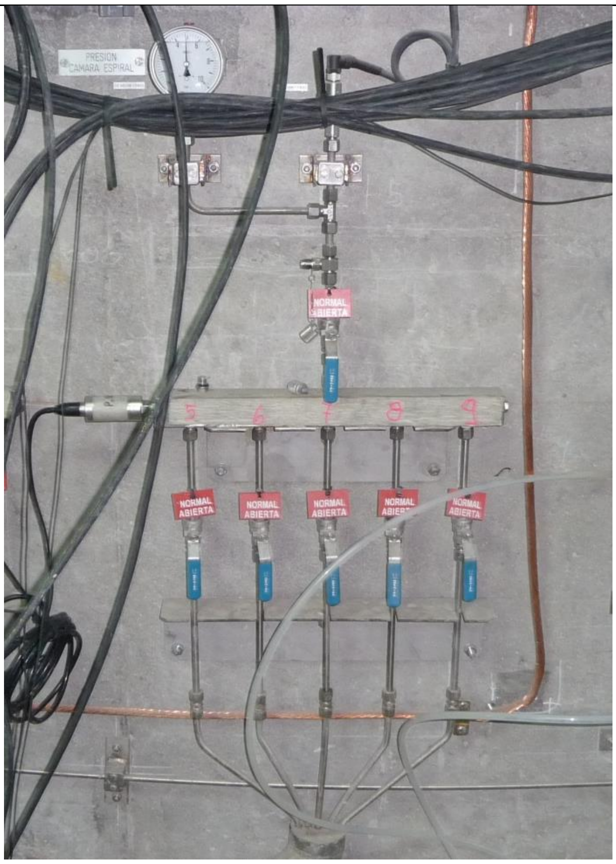

Guide vane servomotor stroke


Head cover pressure P_HC1 and P_HC2

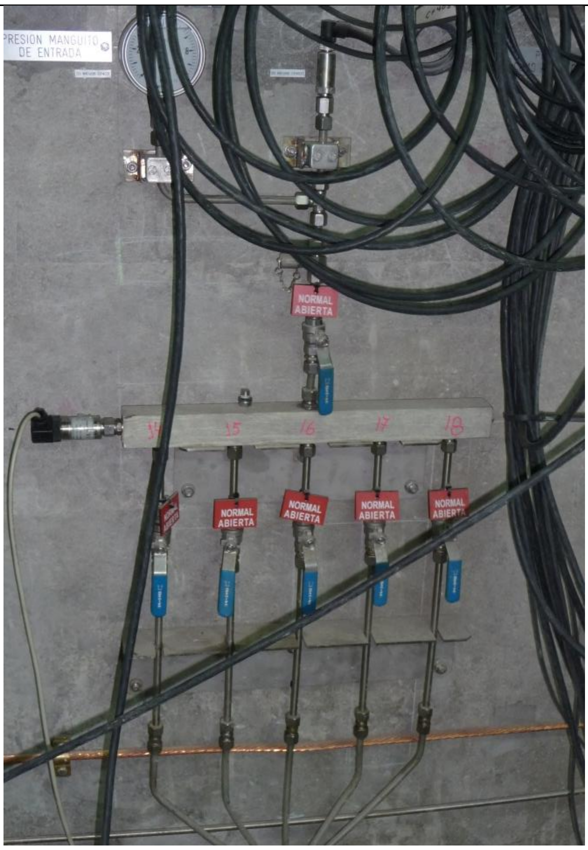
Head cover pressure P_HC3



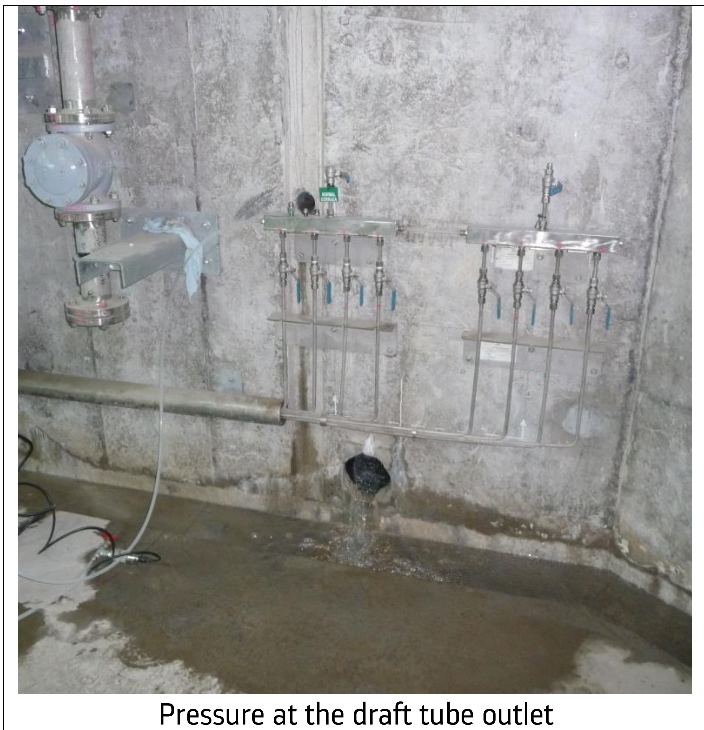
Winter Kennedy differential pressure



Pressure after the convergent

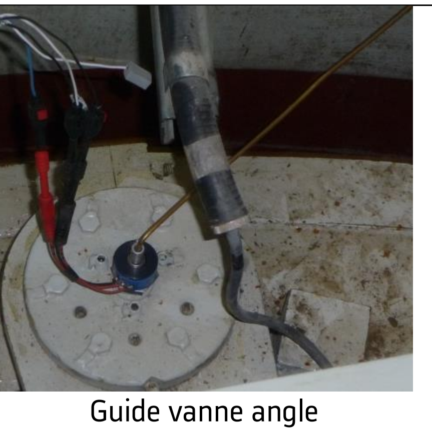


Pressure before the convergent


Pressure at the draft tube outlet


Pressure pulsation at the spiral case entrance


Draft tube cone pressure pulsation


Guide vanne angle


Draft tube cone vibration

9.4. Appendix 4 : Sensors calibrations

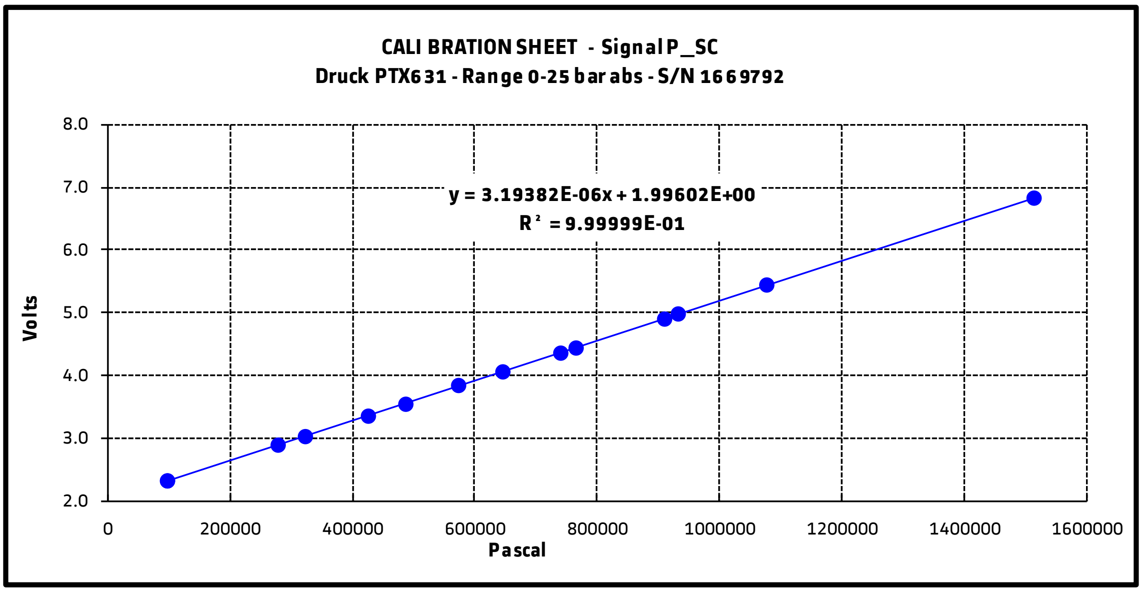
ALSTOM

CALIBRATION SHEET - Signal P_SC
Druck PTX631 - Range 0-25 bar abs - S/N 1669792

Signal	P_SC	Operator	X.CORNUT
Transducer	Druck PTX631	Project	ANGOSTURA
Range	0-25 bar abs	Date	12/08/2014
S/N	1669792	Calibrator	Druck DPI 605
Ambient pressure			
input n° (box, box_in,	1, 1, 18	S/N	60505093

Sensitivity	3.193815E-06	*Volts / Pascal*
Offset	1.996018E+00	*Volts*

	Druck DPI 605 *Pascal*	DRUCK *Volts*	Calcul *Volt*	Error PE *%*
1	98722	2.31040	2.311	0.013%
2	278439	2.88420	2.885	0.016%
3	425319	3.35488	3.354	0.007%
4	574232	3.83136	3.830	0.020%
5	740748	4.36140	4.362	0.006%
6	910215	4.90335	4.903	0.004%
7	1077020	5.43526	5.436	0.008%
8	934354	4.98126	4.980	0.016%
9	767115	4.44521	4.446	0.012%
10	647477	4.06403	4.064	0.001%
11	486195	3.54989	3.549	0.015%
12	324263	3.03434	3.032	0.039%
13	98730	2.30917	2.311	0.032%
14	1514004	6.83047	6.831	0.015%
			Averaged	**0.015%**

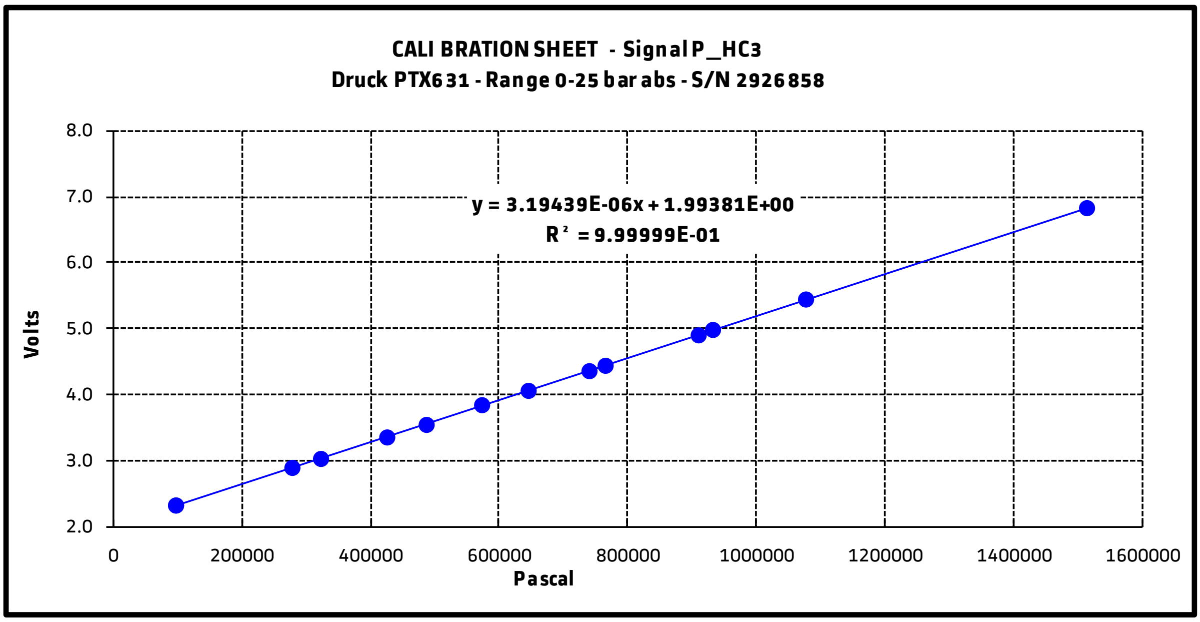


ALSTOM CALI BRATION SHEET - Signal P_HC3
Druck PTX631 - Range 0-25 bar abs - S/N 2926858

Signal	P_HC3	Operator	X.CORNUT
Transducer	Druck PTX631	Project	ANGOSTURA
Range	0-25 bar abs	Date	12/08/2014
S/N	2926858	Calibrator	Druck DPI 605
Ambient pressure			
input n° (box, box_in,	1, 2, 20	S/N	60505093

Sensitivity	3.194394E-06	*Volts / Pascal*
Offset	1.993812E+00	*Volts*

	Druck DPI 605 *Pascal*	DRUCK *Volts*	Calcul *Volt*	Error PE *%*
1	98722	2.30832	2.309	0.012%
2	278439	2.88098	2.883	0.033%
3	425319	3.35510	3.352	0.039%
4	574232	3.82870	3.828	0.008%
5	740748	4.35949	4.360	0.008%
6	910215	4.90015	4.901	0.018%
7	1077020	5.43189	5.434	0.034%
8	934354	4.97848	4.979	0.000%
9	767115	4.44573	4.444	0.021%
10	647477	4.06187	4.062	0.003%
11	486195	3.54846	3.547	0.023%
12	324263	3.03113	3.030	0.022%
13	98730	2.30819	2.309	0.015%
14	1514004	6.83098	6.830	0.012%
			Averaged	0.018%



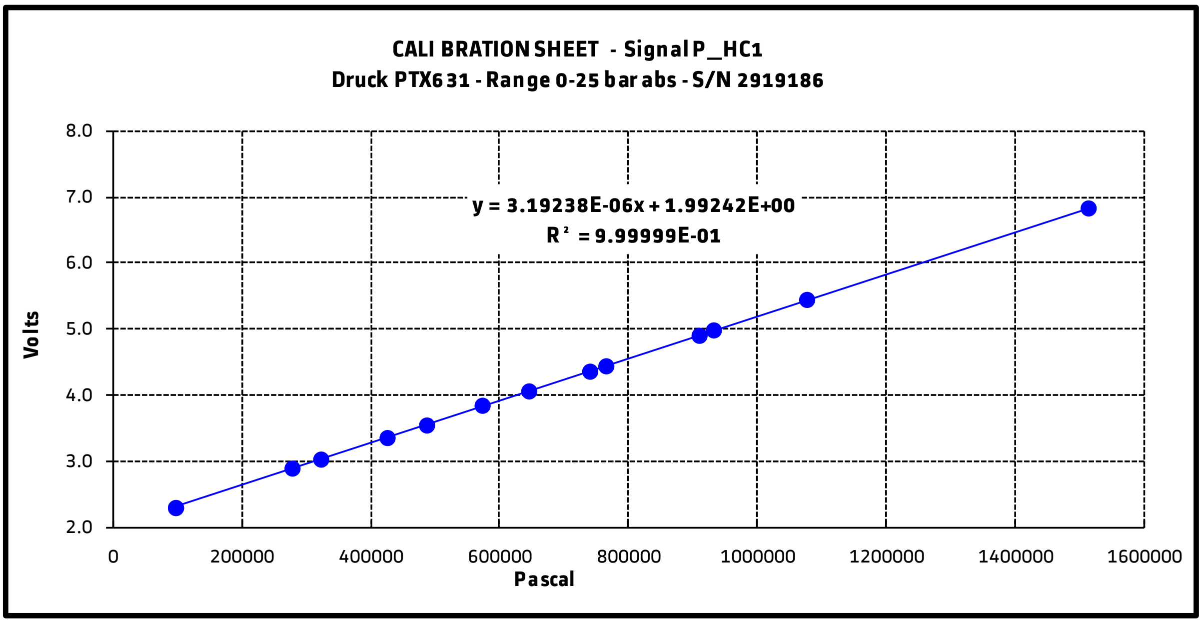
ALSTOM

CALI BRATION SHEET - Signal P_HC1
Druck PTX631 - Range 0-25 bar abs - S/N 2919186

Signal	**P_HC1**	**Operator**	**X.CORNUT**
Transducer	**Druck PTX631**	**Project**	**ANGOSTURA**
Range	**0-25 bar abs**	**Date**	**12/08/2014**
S/N	**2919186**	**Calibrator**	**Druck DPI 605**
Ambient pressure			
input n° (box, box_in,	**1, 3, 21**	**S/N**	**60505093**

Sensitivity	**3.192377E-06**	*Volts / Pascal*
Offset	**1.992421E+00**	*Volts*

	Druck DPI 605 *Pascal*	**DRUCK** *Volts*	**Calcul** *Volt*	**Error PE** *%*
1	98722	2.30548	2.308	0.031%
2	278439	2.88016	2.881	0.017%
3	425319	3.35137	3.350	0.017%
4	574232	3.82779	3.826	0.032%
5	740748	4.35742	4.357	0.004%
6	910215	4.89761	4.898	0.008%
7	1077020	5.42973	5.431	0.014%
8	934354	4.97450	4.975	0.011%
9	767115	4.44184	4.441	0.007%
10	647477	4.05996	4.059	0.008%
11	486195	3.54472	3.545	0.003%
12	324263	3.02973	3.028	0.031%
13	98730	2.30650	2.308	0.016%
14	1514004	6.82528	6.826	0.006%
			Averaged	**0.015%**



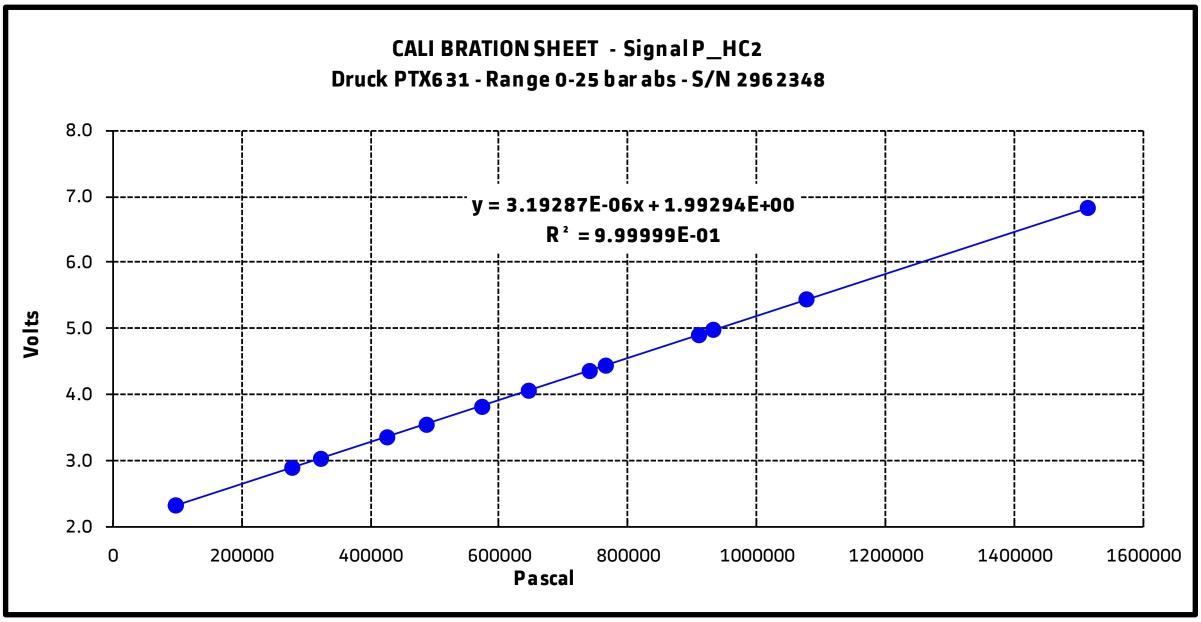
ALSTOM

CALI BRATION SHEET - Signal P_HC2
Druck PTX631 - Range 0-25 bar abs - S/N 2962348

Signal	**P_HC2**	**Operator**	**X.CORNUT**
Transducer	**Druck PTX631**	**Project**	**ANGOSTURA**
Range	**0-25 bar abs**	**Date**	**12/08/2014**
S/N	**2962348**	**Calibrator**	**Druck DPI 605**
Ambient pressure			
input n° (box, box_in,	**1, 4, 22**	**S/N**	**60505093**

Sensitivity	**3.192867E-06**	*Volts / Pascal*
Offset	**1.992945E+00**	*Volts*

	Druck DPI 605 *Pascal*	DRUCK *Volts*	Calcul *Volt*	Error PE *%*
1	98722	2.30716	2.308	0.015%
2	278439	2.87957	2.882	0.035%
3	425319	3.35311	3.351	0.032%
4	574232	3.82704	3.826	0.010%
5	740748	4.35851	4.358	0.007%
6	910215	4.89857	4.899	0.008%
7	1077020	5.43132	5.432	0.006%
8	934354	4.97460	4.976	0.024%
9	767115	4.44226	4.442	0.000%
10	647477	4.06157	4.060	0.019%
11	486195	3.54656	3.545	0.018%
12	324263	3.02977	3.028	0.022%
13	98730	2.30694	2.308	0.018%
14	1514004	6.82679	6.827	0.002%
			Averaged	**0.015%**



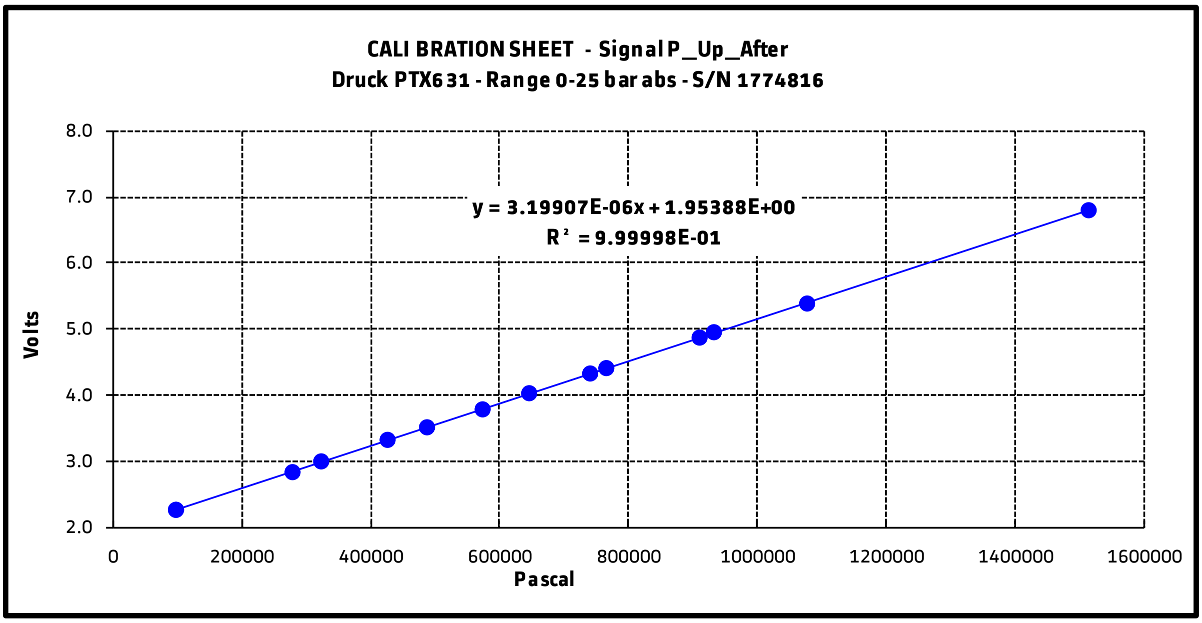
ALSTOM

CALI BRATION SHEET - Signal P_Up_After
Druck PTX631 - Range 0-25 bar abs - S/N 1774816

Signal	P_Up_After	Operator	X.CORNUT
Transducer	Druck PTX631	Project	ANGOSTURA
Range	0-25 bar abs	Date	12/08/2014
S/N	1774816	Calibrator	Druck DPI 605
Ambient pressure			
input n° (box, box_in,	1, 5, 29	S/N	60505093

Sensitivity	3.199069E-06	*Volts / Pascal*
Offset	1.953883E+00	*Volts*

	Druck DPI 605 *Pascal*	DRUCK *Volts*	Calcul *Volt*	Error PE *%*
1	98722	2.26785	2.270	0.027%
2	278439	2.84133	2.845	0.049%
3	425319	3.31478	3.315	0.004%
4	574232	3.79044	3.791	0.007%
5	740748	4.32167	4.324	0.028%
6	910215	4.86497	4.866	0.011%
7	1077020	5.39824	5.399	0.016%
8	934354	4.94466	4.943	0.025%
9	767115	4.40968	4.408	0.026%
10	647477	4.02736	4.025	0.032%
11	486195	3.51139	3.509	0.031%
12	324263	2.99409	2.991	0.042%
13	98730	2.26936	2.270	0.005%
14	1514004	6.79615	6.797	0.017%
			Averaged	0.023%



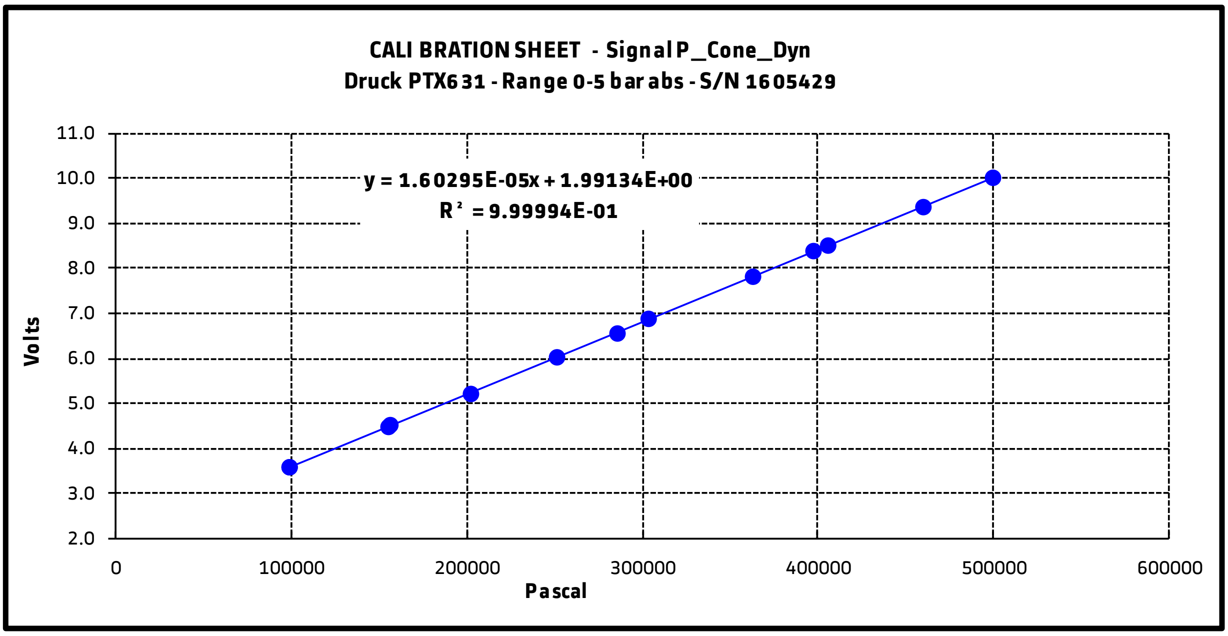
ALSTOM

CALI BRATION SHEET - Signal P_Cone_Dyn
Druck PTX631 - Range 0-5 bar abs - S/N 1605429

Signal	P_Cone_Dyn	Operator	X.CORNUT
Transducer	Druck PTX631	Project	ANGOSTURA
Range	0-5 bar abs	Date	12/08/2014
S/N	1605429	Calibrator	Druck DPI 605
Ambient pressure			
input n° (box, box_in,	1, 6,19	S/N	60505093

Sensitivity	1.602953E-05	*Volts / Pascal*
Offset	1.991337E+00	*Volts*

	Druck DPI 605 *Pascal*	DRUCK *Volts*	Calcul *Volt*	Error PE *%*
1	98804	3.57800	3.575	0.029%
2	155275	4.47963	4.480	0.007%
3	202160	5.22636	5.232	0.055%
4	251531	6.01790	6.023	0.054%
5	303168	6.86429	6.851	0.133%
6	363410	7.81980	7.817	0.032%
7	405502	8.49355	8.491	0.022%
8	460511	9.37267	9.373	0.004%
9	499975	9.99852	10.006	0.072%
10	397565	8.36622	8.364	0.021%
11	285767	6.57124	6.572	0.008%
12	156737	4.49955	4.504	0.042%
13	98802	3.57562	3.575	0.005%
			Averaged	0.037%



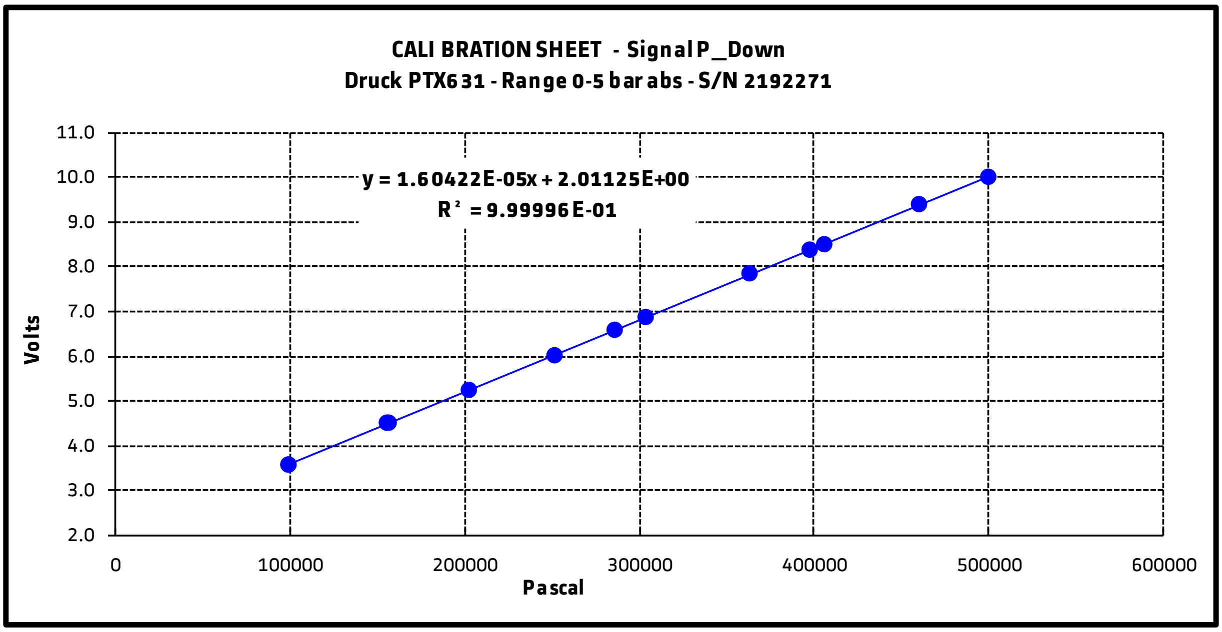
ALSTOM

CALI BRATION SHEET - Signal P_Down
Druck PTX631 - Range 0-5 bar abs - S/N 2192271

Signal	P_Down	Operator	X.CORNUT
Transducer	Druck PTX631	Project	ANGOSTURA
Range	0-5 bar abs	Date	12/08/2014
S/N	2192271	Calibrator	Druck DPI 605
Ambient pressure			
input n° (box, box_in,	1, 7, 30	S/N	60505093

Sensitivity	1.604225E-05	*Volts / Pascal*
Offset	2.011249E+00	*Volts*

	Druck DPI 605 *Pascal*	DRUCK *Volts*	Calcul *Volt*	Error PE *%*
1	98804	3.59580	3.596	0.005%
2	155275	4.50303	4.502	0.008%
3	202160	5.24927	5.254	0.051%
4	251531	6.04049	6.046	0.059%
5	303168	6.88515	6.875	0.104%
6	363410	7.84726	7.841	0.061%
7	405502	8.51842	8.516	0.020%
8	460511	9.39659	9.399	0.023%
9	499975	10.02655	10.032	0.054%
10	397565	8.38960	8.389	0.005%
11	285767	6.59568	6.596	0.001%
12	156737	4.52321	4.526	0.024%
13	98802	3.59795	3.596	0.017%
			Averaged	**0.033%**



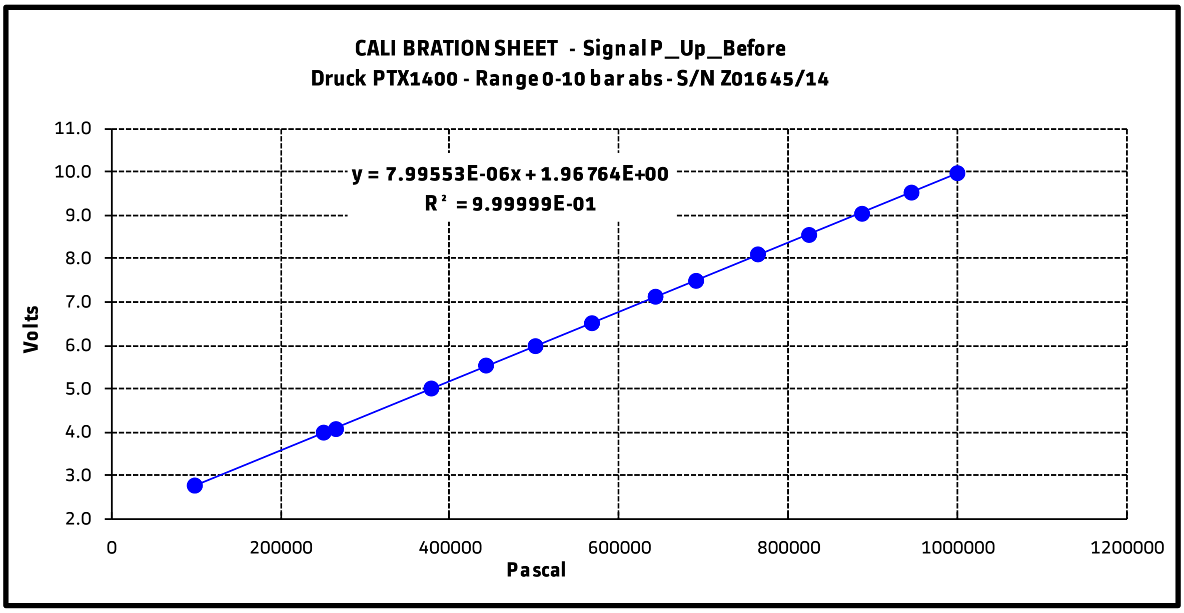
ALSTOM

CALI BRATION SHEET - Signal P_Up_Before
Druck PTX1400 - Range 0-10 bar abs - S/N Z01645/14

Signal	P_Up_Before	Operator	X.CORNUT
Transducer	Druck PTX1400	Project	ANGOSTURA
Range	0-10 bar abs	Date	12/08/2014
S/N	Z01645/14	Calibrator	Druck DPI 605
Ambient pressure			
input n° (box, box_in,	2, 4, 32	S/N	60505093

Sensitivity	7.995531E-06	Volts / Pascal
Offset	1.967635E+00	Volts

	Druck DPI 605 Pascal	DRUCK Volts	Calcul Volt	Error PE %
1	98184	2.75198	2.753	0.007%
2	251417	3.97590	3.978	0.020%
3	378816	5.00187	4.996	0.054%
4	500748	5.97335	5.971	0.020%
5	642683	7.10646	7.106	0.002%
6	764716	8.08064	8.082	0.013%
7	887093	9.05669	9.060	0.037%
8	1001198	9.97135	9.973	0.014%
9	945762	9.53021	9.530	0.007%
10	824516	8.56065	8.560	0.006%
11	691562	7.49841	7.497	0.014%
12	567773	6.50867	6.507	0.014%
13	443428	5.51610	5.513	0.030%
14	265079	4.08356	4.087	0.035%
15	98252	2.75114	2.753	0.021%
			Averaged	0.020%



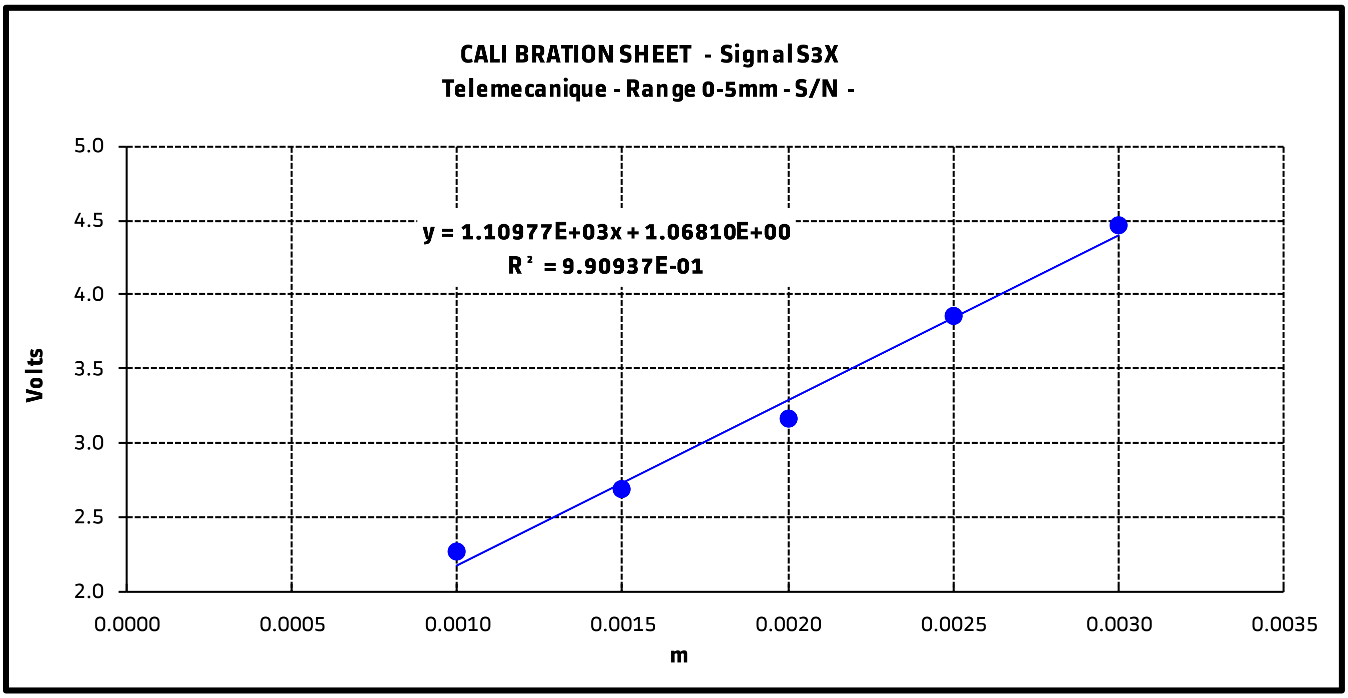
ALSTOM

CALI BRATION SHEET - Signal S3X
Telemecanique - Range 0-5mm - S/N -

Signal	S3X	Operator	X.CORNUT
Transducer	Telemecanique	Project	ANGOSTURA
Range	0-5mm	Date	22/08/2014
S/N	-	Calibrator	juego de calas
Ambient pressure			
input n° (box, box_in,		S/N	-

Sensitivity	1.109772E+03	*Volts / m*
Offset	1.068102E+00	*Volts*

	juego de calas *m*	DRUCK *Volts*	Calcul *Volt*	Error PE *%*
1	0.0010	2.26865	2.178	2.064%
2	0.0015	2.68702	2.733	1.040%
3	0.0020	3.17068	3.288	2.660%
4	0.0025	3.85058	3.843	0.183%
5	0.0030	4.46130	4.397	1.453%
			Averaged	**1.480%**

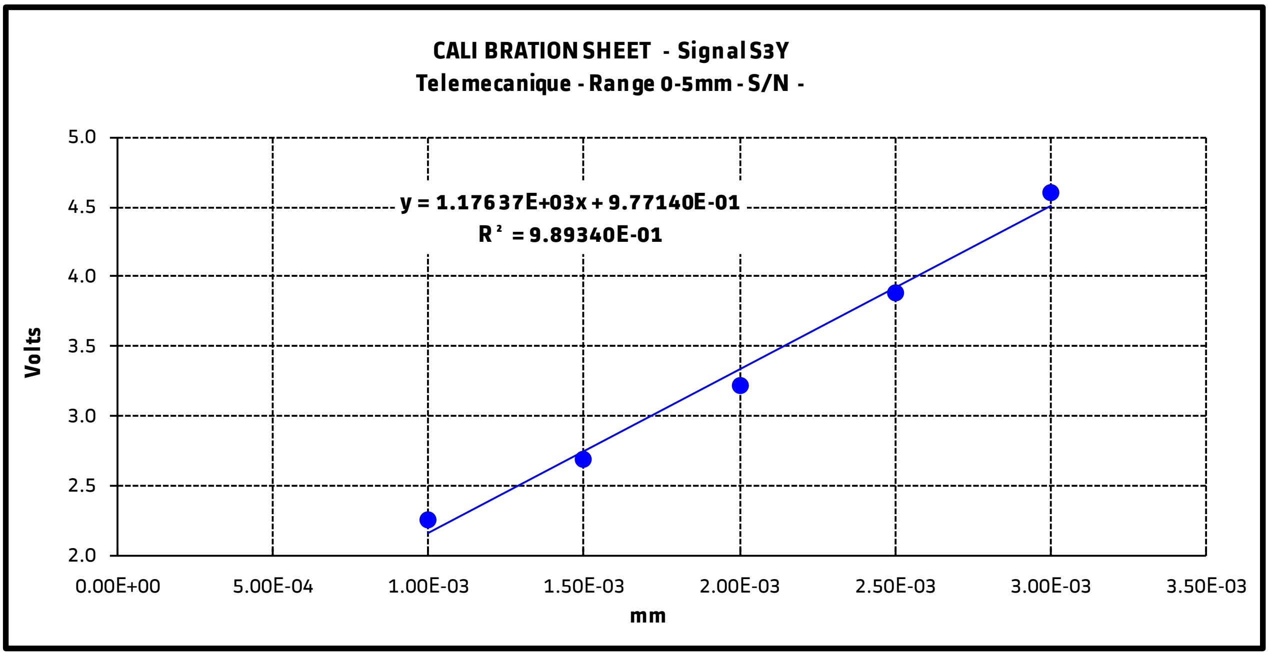


CALI BRATION SHEET - Signal S3Y
Telemecanique - Range 0-5mm - S/N -

Signal	S3Y	Operator	X.CORNUT
Transducer	Telemecanique	Project	ANGOSTURA
Range	0-5mm	Date	22/08/2014
S/N	-	Calibrator	juego de calas
Ambient pressure			
input n° (box, box_in,		S/N	-

Sensitivity	1.176372E+03	*Volts / m*
Offset	9.771400E-01	*Volts*

	juego de calas *m*	DRUCK *Volts*	Calcul *Volt*	Error PE *%*
1	0.0010	2.25771	2.154	2.312%
2	0.0015	2.69139	2.742	1.116%
3	0.0020	3.21461	3.330	2.558%
4	0.0025	3.88275	3.918	0.784%
5	0.0030	4.60296	4.506	2.146%
			Averaged	**1.783%**



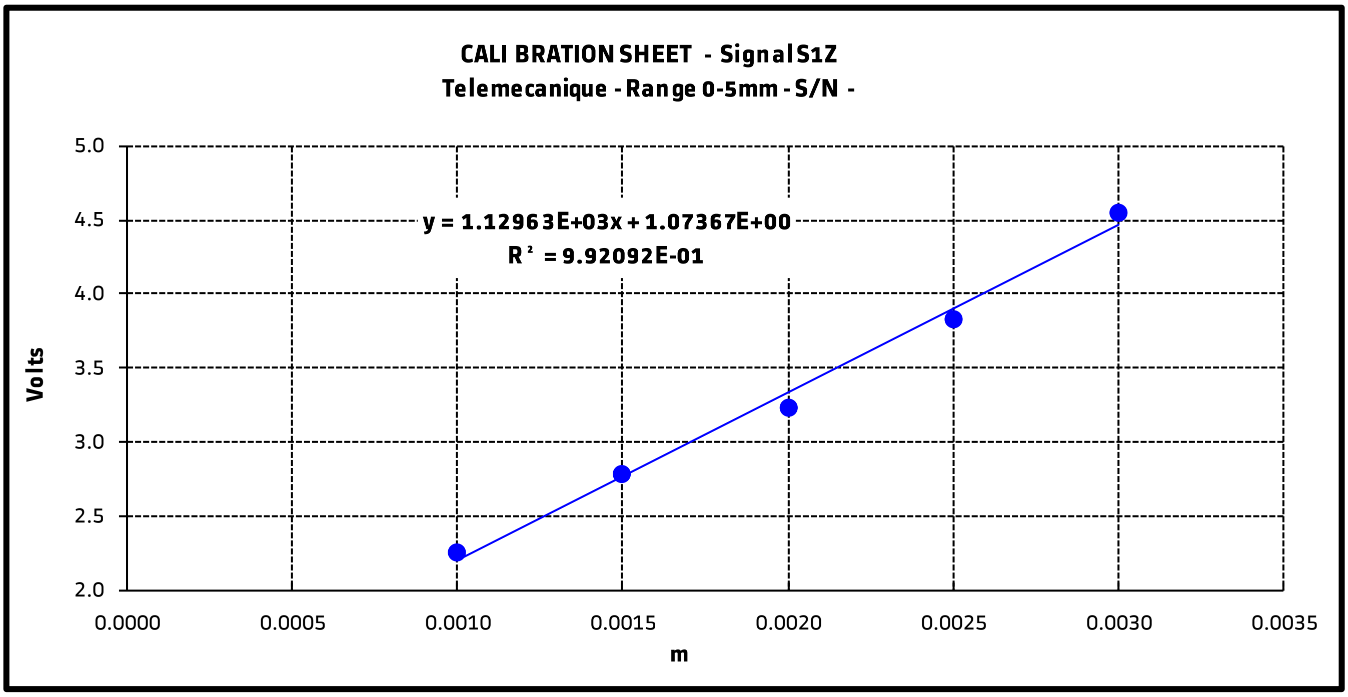
ALSTOM

CALI BRATION SHEET - Signal S1Z
Telemecanique - Range 0-5mm - S/N -

Signal	S1Z	Operator	X.CORNUT
Transducer	Telemecanique	Project	ANGOSTURA
Range	0-5mm	Date	22/08/2014
S/N	-	Calibrator	juego de calas
Ambient pressure			
input n° (box, box_in,		S/N	-

Sensitivity	1.129632E+03	*Volts / m*
Offset	1.073668E+00	*Volts*

	juego de calas *m*	DRUCK *Volts*	Calcul *Volt*	Error PE *%*
1	0.0010	2.25461	2.203	1.150%
2	0.0015	2.78707	2.768	0.425%
3	0.0020	3.23355	3.333	2.227%
4	0.0025	3.83441	3.898	1.419%
5	0.0030	4.55502	4.463	2.072%
			Averaged	**1.459%**



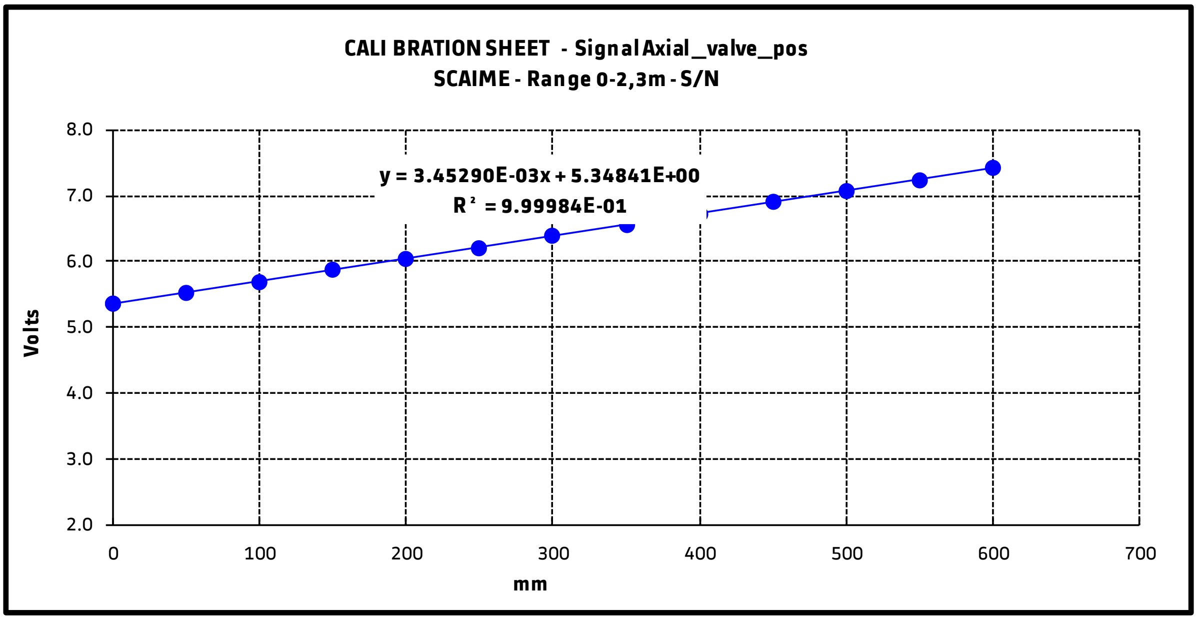
ALSTOM

CALI BRATION SHEET - Signal Axial_valve_pos
SCAIME - Range 0-2,3m - S/N

Signal	Axial_valve_pos	Operator	X.CORNUT
Transducer	SCAIME	Project	ANGOSTURA
Range	0-2,3m	Date	05/09/2014
S/N		Calibrator	metro
Ambient pressure			
input n° (box, box_in,	2, 1, 23	S/N	

Sensitivity	3.452905E-03	*Volts / mm*
Offset	5.348405E+00	*Volts*

	metro *mm*	DRUCK *Volts*	Calcul *Volt*	Error PE *%*
1	0	5.35100	5.348	0.035%
2	100	5.68800	5.694	0.077%
3	200	6.03500	6.039	0.054%
4	300	6.38300	6.384	0.017%
5	400	6.73000	6.730	0.006%
6	500	7.07500	7.075	0.002%
7	600	7.41800	7.420	0.029%
8	550	7.24600	7.248	0.020%
9	450	6.90600	6.902	0.051%
10	350	6.56000	6.557	0.041%
11	250	6.21500	6.212	0.045%
12	150	5.86600	5.866	0.005%
13	50	5.52200	5.521	0.013%
14	0	5.34900	5.348	0.008%
			Averaged	**0.029%**



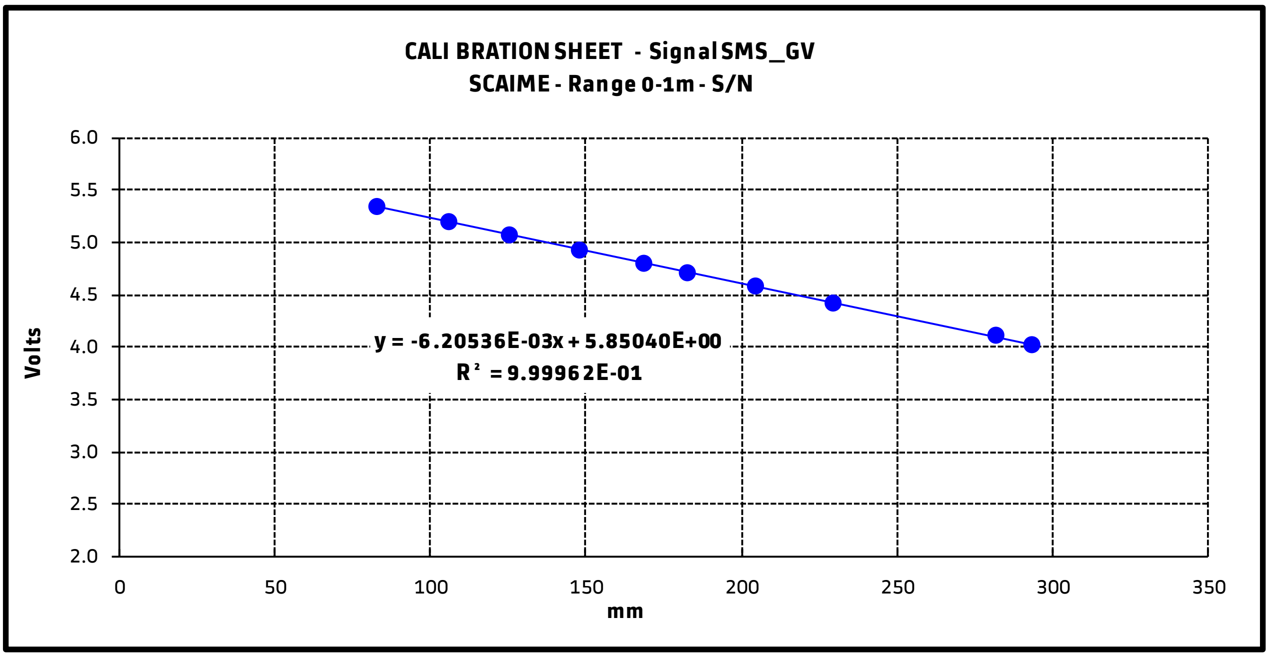
ALSTOM

CALI BRATION SHEET - Signal SMS_GV
SCAIME - Range 0-1m - S/N

Signal	SMS_GV	Operator	X.CORNUT
Transducer	SCAIME	Project	ANGOSTURA
Range	0-1m	Date	18/09/2014
S/N		Calibrator	ruler
Ambient pressure			
input n° (box, box_in,	2, 5, 1	S/N	

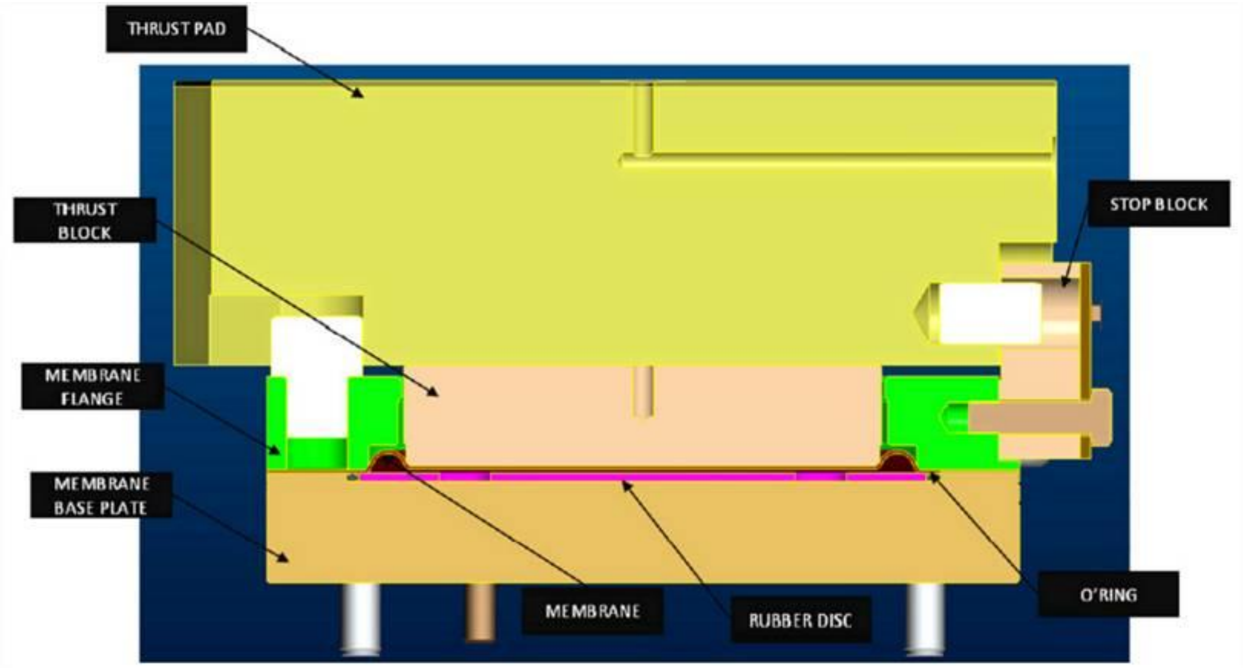
Sensitivity	-6.205357E-03	*Volts / mm*
Offset	5.850395E+00	*Volts*

	ruler *mm*	DRUCK *Volts*	Calcul *Volt*	Error PE *%*
1	83	5.3378	5.338	0.000%
2	106	5.1954	5.195	0.006%
3	126	5.0733	5.071	0.043%
4	148	4.9346	4.934	0.003%
5	169	4.8044	4.804	0.005%
6	183	4.713	4.717	0.080%
7	205	4.5776	4.581	0.059%
8	230	4.429	4.426	0.063%
9	282	4.1067	4.103	0.070%
10	294	4.0258	4.028	0.050%
			Averaged	**0.038%**

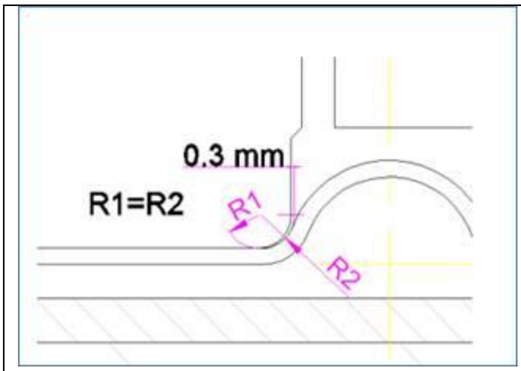


9.5. Appendix 5: Axial thrust calculation

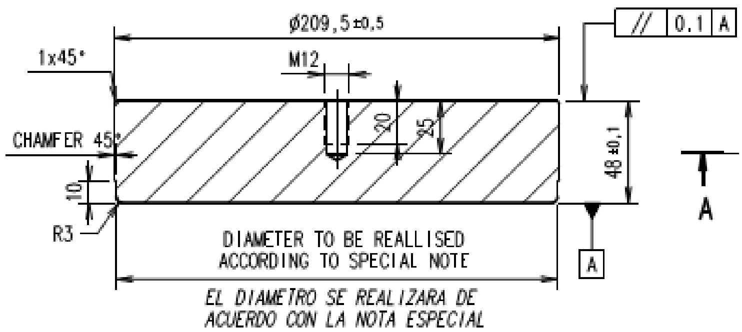
Hereafter the cutaway view of a thrust pad:



Here on the drawing, the thrust pad transmit the load on the membrane through the thrust block. If we enlarge the corner of the thrust block, we can see that the folding radius of the membrane isn't in contact with the thrust bock. Therefore we will only consider the flat surface of the thrust block in the thrust calculation.



Thrust block edge



Thrust block dimension

Hereafter the thrust block surface to be considered in the thrust calculation :

Thrust block number	12	-
Thrust block diameter	203.5	mm
Thrust block surface	32525.1051	mm2
Total thrust blocks surface	390301.261	mm2
Total thrust blocks surface	0.39030126	m2

$$S_{bt} = n \times \frac{(\pi \times D_b)}{4}$$

So that the dynamic axial thrust equal $F_Z = \frac{(P_{membrane} - LS)}{S_{bt}}$

9.6. Appendix 6: Topographic manual records

9.6.1. Measurement locations

1)Medición a 5 m aprox AAr del portal del tunel de Descarga.
2)Medición en la salida del Portal de descarga.
3)Medición a la mitad del canalon de salida.
4)Medición al final de camellon de piedra en la descarga.

ALSTOM	PROJECT : CLIENT :	ANGOSTURA UNIT 3 COLBUN	ALSTOM Hydro France N° DOCUMENT : LTESS-14507
Study N° :	Contract N°	N° O.E. :	Page : 87

9.6.2. Manual records

		Medidciones de Nivel												
Unidad	N° de medición	1	2	3	4	DCS	Nivel Embalse	QU1	QU2	QU3	Qtotal	Potencia Unidad en Prueba[MW]	Fecha	Hora
U3	1	267.11	266.86	266.60	266.33	266.70	316.78	308	317	0	625	Detenida	28/08/2014	09:15
U3	2	267.08	266.84	266.51	266.66	266.80	317.78	308	317		625	Detenida	28/08/2014	09:28
U3	3	267.06	266.86	266.59	266.86	266.70	316.78	305	317	0	622	Detenida	28/08/2014	09:23
U3	4	267.14	266.87	266.65	266.88	266.76	316.78	306	315	33	654	SNL	28/08/2014	09:33
U3	5	267.20	266.96	266.82	266.95	267.06	316.78	306	315	33	654	SNLE	28/08/2014	09:40
U3														
U3	1	267.18	266.94	266.83	266.07	266.80	316.78	307	315	37	659	4.7	28/08/2014	09:50
U3	2	267.22	267.00	266.91	266.98	266.76	316.78	308	315	39	662	4.7	28/08/2014	09:58
U3	3	267.22	267.08	266.86	267.02	266.87	316.76	307	315	39	661	4.7	28/08/2014	10:08
U3														
U3	1	267.26	267.15	267.00	267.09	267.00	316.76	307	315	44	666	9.4	28/08/2014	10:15
U3	2	267.28	267.06	266.93	267.08	267.00	316.75	307	315	44	666	9.4	28/08/2014	10:26
U3	3	267.27	267.10	267.02	267.15	267.00	316.75	308	315	44	667	9.4	28/08/2014	10:31
U3														
U3	1	267.30	267.12	267.01	267.14	267.05	316.75	310	316	50	676	14	28/08/2014	10:37
U3	2	267.31	267.16	267.02	267.17	267.04	316.75	311	315	51	677	14	28/08/2014	10:48
U3	3	267.28	267.15	267.00	267.27	267.01	317.75	308	316	50	674	14	28/08/2014	10:55
U3	4	267.31	167.18	266.96	267.16	266.90	317.73	309	314	50	673	14	28/08/2014	11:12
U3														
U3	1	267.36	267.19	267.07	267.32	267.12	316.73	309	316	59	684	18.8	28/08/2014	11:19
U3	2	267.36	267.27	267.13	267.36	266.97	316.72	308	316	59	683	18.8	28/08/2014	11:30
U3	3	267.38	267.24	267.09	267.24	267.09	316.72	309	317	57	683	18.8	28/08/2014	11:36
U3														
U3	1	267.37	267.26	267.20	267.28	267.12	316.71	309	315	65	689	23.5	28/08/2014	11:44
U3	2	267.41	267.27	267.12	267.27	267.00	316.70	312	315	65	692	23.5	28/08/2014	11:53
U3	3	267.42	267.25	267.13	267.20	267.02	316.70	309	260	65	634	23.5	28/08/2014	12:00
U3														
U3	1	266.55	266.30	266.00	266.30	266.00	316.71	212	218	71	501	28.3	28/08/2014	12:08
U3	2	266.40	266.18	265.81	266.17	266.00	316.72	212	216	71	499	28.5	28/08/2014	12:15
U3	3	266.24	266.11	265.77	266.11	266.00	317.73	211	219	71	501	28.5	28/08/2014	12:20
U3														
U3	1	265.75	265.67	265.29	265.66	265.70	317.73	169	169	79	417	33	28/08/2014	12:20
U3	2	265.66	265.61	265.17	265.54	265.48	317.75	169	172	79	420	33.2	28/08/2014	12:39
U3	3	265.58	265.54	265.17	265.63	265.48	317.78	172	172	79	423	33.5	28/08/2014	12:43
U3														
U3	1	265.66				265.50	316.78	168	170	87	425	37.7	28/08/2014	12:55
U3	2	265.66	265.56	265.16	265.62	265.56	316.80	166	174	87	427	37.6	28/08/2014	13:06
U3	1'	265.65	265.61	265.25	265.59	265.52	316.81	169	169	87	425	37.6	28/08/2014	13:10
U3	3	265.71	265.60	265.17	265.61	265.45	316.81	169	173	87	429	37.7	28/08/2014	13:14
U3														
U3	1	265.60	265.64	265.32	265.66	265.48	316.84	166	170	95	431	42.5	28/08/2014	13:24
U3	1'	267.61	267.51	267.45	267.47	267.24	316.98	308	317	99	724	42.5	28/08/2014	14:50
U3	2	267.65	267.49	267.39	267.42	267.24	316.98	307	315	99	721	42.5	28/08/2014	14:53
U3	3	267.66	267.49	267.53	267.56	267.24	316.98	310	315	99	724	42.2	28/08/2014	15:00
U3														
U3	1	267.64	267.58	267.43	267.55	267.20	316.94	310	315	103	728	43.5	28/08/2014	15:10
U3	2	267.61	267.47	267.41	267.41	267.14	316.93	309	317	103	729	43.5	28/08/2014	15:22
U3	3	267.63	267.47	267.45	267.56	267.27	316.93	310	315	103	728	43.5	28/08/2014	15:28
U3														
U3	1	267.56	267.63	267.63	267.49	267.18	316.92	310	315	111	736	46.2	28/08/2014	15:40
U3	2	267.58	267.50	267.50	267.55	267.32	316.90	310	315	111	736	46	28/08/2014	15:45
U3	3	266.98				266.14	316.91	0	310	111	421		28/08/2014	
U3	4	266.36	266.00	265.65	265.73	265.50	316.92	0	310	109	419	47.4	28/08/2014	16:16
U3	5	265.03	264.89	264.23	264.72	263.55	31.95	0	0	107	107	47.2	28/08/2014	16:20
U3	6	264.21	264.33	263.51	264.48	262.84	317.02	0	0	105	105	47.2	28/08/2014	16:45
U3	7	264.21				262.70	317.07	0	0	105	105	47.2	28/08/2014	16:53