Eskom

Attention: L Ward
Integrated Leak Rate Testing (ILRT)

Date:
29 June 2015

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Mmamotiti Rahube

Our Ref: DB2015-0020

Dear Mr Ward

SYSTEM DESIGN ENGINEERING ACCEPTANCE OF THE UNIT 1 ILRT (OUTAGE 121) STRUCTURAL INTERGRITY TESTS RESULTS

This memorandum serves to confirm that SDE has reviewed Outage 121, Unit 1 ILRT structural integrity measurements. The measurements (under cover of EdF report "Koeberg Unit 1 ILRT 14-18 April 2015- EDF-AMTNO-DTG Results and Comments") covered the following:

- Crack monitoring from 13 crack measuring devices. A number of cracks were observed to develop further and new cracks were observed particularly around the equipment hatch. The developed crack widths were acceptable except for those around the equipment hatch which measured up to 0.6 mm in width.
- Measurements of the EAU system at different times before, during and after the ILRT. The EAU system includes pendulums, invar wires and extensometers / strain gauges which produced very much the same results as were recorded in the previous ILRT of 2005. Furthermore, essentially linear behaviour of the containment structure was observed by EdF with acceptable hysteresis.
- The dynamometers however, indicated very much lower forces in 2 of the 4 ungrouted tendons compared to measurements in 2005. This observation is considered inconsistent with the EAU displacement measurements (pendulums, invar wires and extensometers). A reason for this discrepancy is requested from EdF.
- Equipment hatch deformation (displacement in axial and radial directions and deformation of the equipment hatch flange before and after the pressurisation test). The deformation of the hatch is considered acceptable.
- Visual inspection of the Containment Buildings (before pressurisation and at the 4 bar stage).

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The comments and concerns are attached as Appendix 1. The results of the ILRT will be accepted following a satisfactory explanation from EdF on the dynamometer readings.

Should you require any further information, please do not hesitate to contact us.

Yours sincerely

Babalwa Ndlovu
SYSTEM DESIGN ENGINEERING – PLANT SUPPORT MANAGER (ACTING)

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Attachment: Appendix 1: JN 411-NSE-ESK-L- 6081 Rev 0

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For Attention: Babalwa Ndlovu

Project No.	Your Ref.	Our Ref.	Date
JN 411		JN411-NSE-ESK-L-6081 Rev 0	29 June 2015

Assessment of EdF Report on Outage 121 ILRT

Dear Babalwa

I have reviewed the results of the ILRT on Unit 1 (Outage 121) as contained in the EdF presentation (no reference) and the EdF report dated 21 April 2015.

The criteria against which the structural measurements are judged comprise:

- Displacement measurements should demonstrate elastic behaviour.
- Significant cracks measured before pressurisation should not show any noticeable growth.

The leak rate is required to fall below both the following limits:

- 100% Leak rate: -0.165% / day of dry air mass or -16Nm^3/h leak flow.
- 75% Leak rate: -0.131% / day of dry air mass or -12.7Nm^3/h leak flow.

The conclusions made below are based on the EdF results but it recognised that the detailed results recorded by SITES (Report reference ADL 15 SA 187 Rev 0 dated 13 May 2015) must still be processed in the Eskom containment monitoring database. To this end, SITES should be requested for an electronic version of the data capture as agreed in the close out meetings after the ILRT.

1. Leak Rate:

A high leak rate was detected at end of the 1 bar stage and the hold period was extended. At the end of this hold period, the leakage was measured to be -0.101±0.027%/day or -3.8±1.0Nm^3/h. In 2005 the leakage was measured to be -4.1Nm^3/h. It was noted by EdF that leakage from containment to Steam Generator 3 was detected and hence, the need to extend the hold period.

At the end of 4 bar stage, the leak rate was high but acceptable (-0.067±0.014%/day). However, the 75% criterion between this ILRT and the previous ILRT in 2005 was not satisfied (Refer to Table 1).

The hold period at the 4 bar stage was extended by 4 hours as it was suspected that the temperatures had not stabilised (Refer Figure 1). Acceptable results were then obtained.

Table 1: Comparison of Leak Rates at 4 Bar

ILRT	Maximum Leak Rate (Nm^3/hr)
2015	-6.3±1.4 = -7.7
2005	-2.9

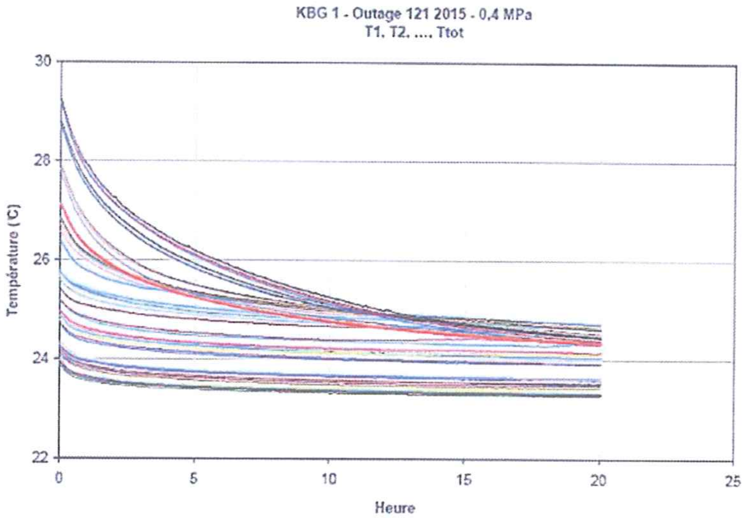

Figure 1: Temperature Evolution at 4 Bar

It may be interpreted from the results that the leak rate from containment is increasing (refer Page 24 of the EdF presentation).

2. Structural Deformation:

2.1 Pendulums:

- A maximum increase in diameter of 10.8 mm was measured from the pendulums. In contrast, the extensometers indicated an increase of 8.6 mm.
- Based on the graphs on Page 9 of the EdF presentation the horizontal increase in diameter appears to be close to linear. However, on inspection of the SITES results some variation of the linear trend is observed. The largest hysteresis of approximately 1.5 mm on a single pendulum occurs on pendulum 241 26 R P1B EAU112.
- The largest hysteresis of approximately 2 mm on diameter occurs on P3B – P1B and P3C-P1C.
- The difference in the pendulum data to the 2005 ILRT is very small (Refer Figure 2 & Table 2).

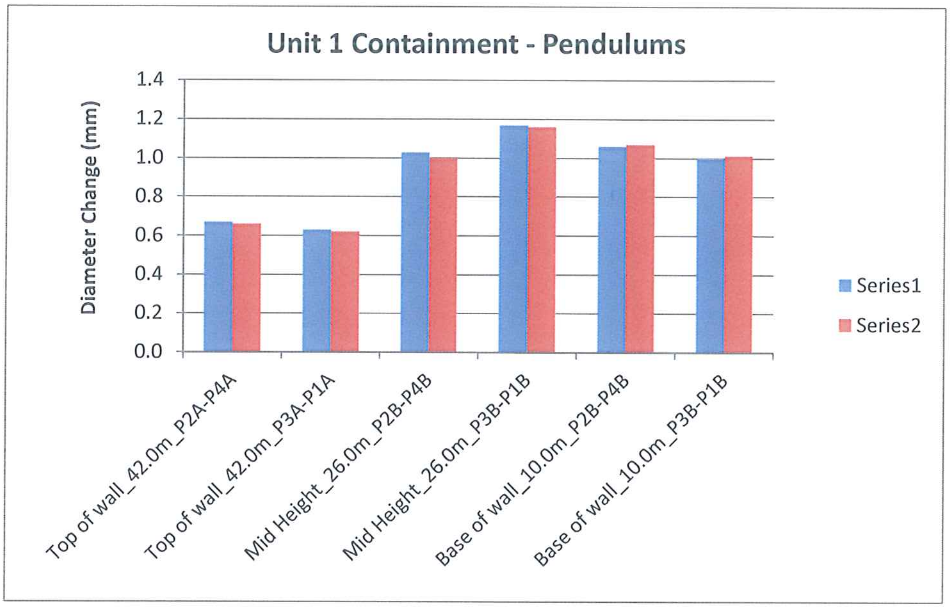

Figure 2: Comparison of pendulum data for Unit 1

Table 2: Comparison for pendulum data for Unit 1

Area	Level	Direction	Reference	ILRT_2005 (mm)	ILRT_2015 (mm)	Diff (mm)
Top of wall	42.0m	P2A-P4A	Top of wall_42.0m_P2A-P4A	6.7	6.6	-0.1
Top of wall	42.0m	P3A-P1A	Top of wall_42.0m_P3A-P1A	6.3	6.2	-0.1
Mid Height	26.0m	P2B-P4B	Mid Height_26.0m_P2B-P4B	10.3	10.0	-0.3
Mid Height	26.0m	P3B-P1B	Mid Height_26.0m_P3B-P1B	11.7	11.6	-0.1
Base of wall	10.0m	P2B-P4B	Base of wall_10.0m_P2B-P4B	10.6	10.7	0.1
Base of wall	10.0m	P3B-P1B	Base of wall_10.0m_P3B-P1B	10.0	10.1	0.1

2.2 Invar Wires:

- An average increase in height of 4.1 mm was measured by the invar wires. The extensometers indicated a 3.6 mm vertical deformation.
- Based on the graphs on Page 10 of the EdF presentation, the vertical behaviour under pressurisation appears to be linear although there is an aberration at the 1 bar hold point which would require further investigation. The depressurisation is linear on 2 wires but shows some non-linearity on the other two. The reason for this non-linearity should be investigated.
- Temperature appears to have an influence on the stiffness of the structure especially during depressurisation. Temperature was recorded as 13.2°C (0 to 1 bar stage) and 17.1°C (1 to 4 bar stage).
- The largest hysteresis of approximately 0.5 mm on height occurs on P1.
- The difference in the invar wire data to the 2005 ILRT is very small (Refer Table 3 & Figure 3).

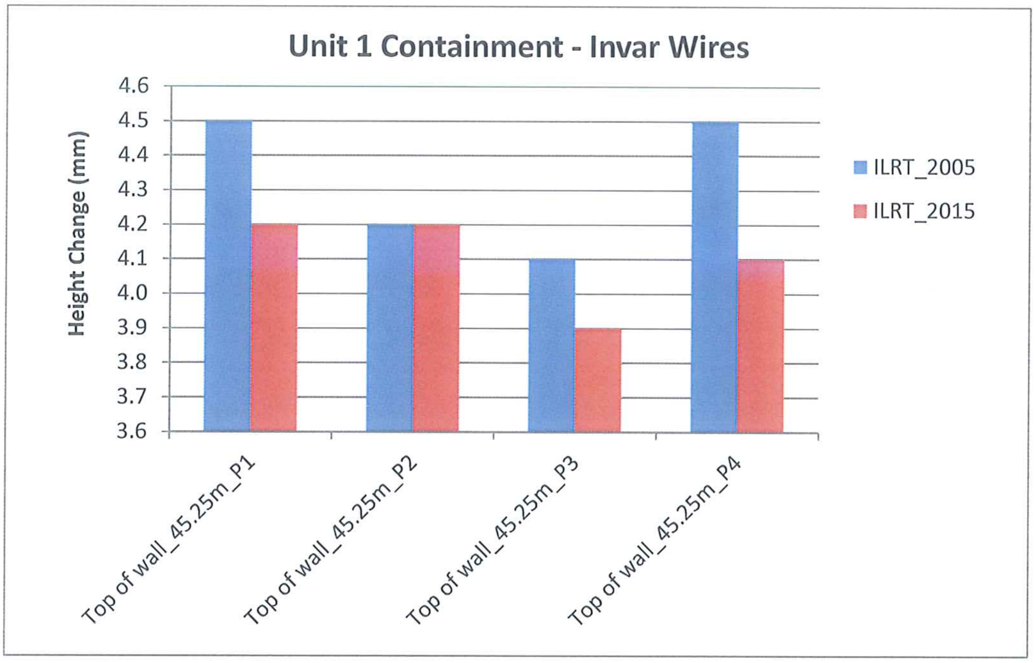

Figure 3: Comparison of invar wire data for Unit 1

Table 3: Comparison for invar wire data for Unit 1

Area	Level	Direction	Reference	ILRT 2005	ILRT 2015	Diff (mm)
Top of wall	45.25m	P1	Top of wall_45.25m_P1	4.5	4.2	-0.3
Top of wall	45.25m	P2	Top of wall_45.25m_P2	4.2	4.2	0.0
Top of wall	45.25m	P3	Top of wall_45.25m_P3	4.1	3.9	-0.2
Top of wall	45.25m	P4	Top of wall_45.25m_P4	4.5	4.1	-0.4

2.3 Dynamometers:

The dynamometer data in Table 4 indicates a relatively large residual force in the tendons after de-pressurisation. Further measurements should be taken in 1 month to check whether this residual force has reduced.

The comparison of dynamometer data with the 2005 ILRT shows rather large differences on cables 90 & 198 (Table 5 and Figure 4). Only 62% and 59% of the force recorded in 2005 for cables 90 & 198 respectively were reached during this ILRT. Measurements on cables 35 and 144 were within 90% of the forces measured in 2005. The average force in the ungrouted tendons was measured to be 22 kN as opposed to 28.75 kN measured in 2005.

It is recommended that reasons for the differences in dynamometer readings to those taken in 2005 as well as the relatively low forces in cables 90 and 198 during this ILRT be obtained given that the deformation measurements are close to those measured in 2005.

Table 4: Force history on the dynamometers during the ILRT

Cable	Start Force (kN)	Force at 4 bar (kN)	End Force (kN)
35	0	28	8
90	0	21	8
144	0	26	11
198	0	13	8

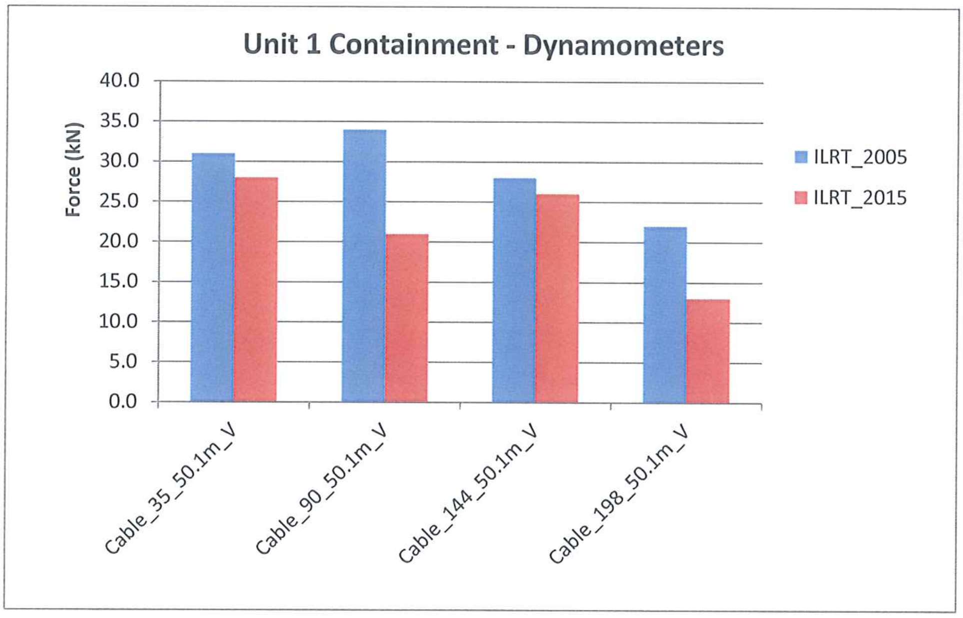

Figure 4: Comparison of dynamometer data for Unit 1

Table 5: Comparison of dynamometer data for Unit 1

Cable	Level	Direction	Reference	ILRT_2005	ILRT_2015	Diff (mm)
Cable_35	50.1m	V	Cable_35_50.1m_V	31	28	-3.0
Cable_90	50.1m	V	Cable_90_50.1m_V	34	21	-13.0
Cable_144	50.1m	V	Cable_144_50.1m_V	28	26	-2.0
Cable_198	50.1m	V	Cable_198_50.1m_V	22	13	-9.0

2.4 Crack Monitoring:

- 10 cracks were instrumented. The criteria for crack monitoring is that the length should be greater than 1 m and the width greater than 0.3 mm, or the length should be greater than 10 m.
- The maximum width of instrumented cracks was 0.3 mm.
- 1 No. instrumented crack evolved on equipment hatch to a maximum width of 0.5 mm.

- New cracks were detected as follows:
    - Dome: 1 No (Width < 0.1 mm);
    - Equipment Hatch: 20 No (Width < 0.6 mm);
    - Lower containment wall: 8 No (Width < 0.1 mm);
    - Steam penetration: 3 No (Width < 0.1 mm)

2.5 Extensometers:

- Essentially liner behaviour is noted but the dome does indicate a degree of non-linear behaviour.
- Detailed results are presented in the SITES report. Location of non-linear behaviour should be checked against the results of the finite element model.
- The following instruments indicate slight hysteresis (<25 μm): F7E VT 000 -4.25; H7E VT 000 -0.25; F5E VT 200 -4.25; H1I VT 200 -0.25; H5E VT 200 -0.25; F6E VT 300 -4.25; H6E VT 300 -0.25; H6E HT 300 -0.25; I3I HT 41 +22.89; I7E HT 41 +22.89; I4I HT 141 +22.89; I8E HT 141 +22.89; I1I HT 241 +22.89; I1I VT 241 +22.89; I5E VT 241 +22.89; I2I VT 341 +22.89; N1 HR 239 +49.80; N1 HT 239 +49.80; N3 HR 239 +50.70; N3 HT 239 +50.70; J4 HT 272 +45.60; N4 HR 272 +49.80; N4 HT 272 +49.80; N5 HR 272 +50.00; N5 HT 272 +50.00; N6 HT 272 +50.70;
- The following instruments indicate larger hysteresis (>40 μm): I5E HT 241 +22.89; I2I HT 341 +22.89; J2 VT 239 +45.60; N2 HT 239 +50.00; J4 VT 272 +45.60; J3 VT 272 +45.60; J2 HT DOME +56.90; J2 HR DOME +56.80;

EdF report the maximum hysteresis upon return to atmospheric pressure as follows. The hysteresis is considered acceptable in all cases.

Table 6: Maximum residual strains

Location	Maximum residual hysteretic strain ($\mu\varepsilon$)	Maximum residual expressed as a % of the total deformation
Raft	2	15%
Gusset	7	7%
Containment wall at mid height	17	7%
Dome	20	15%

A comparison is made between extensometer readings during the 2005 and 2015 ILRT's in Figure 5 to Figure 7. It is also clear from the plots and the data listed in Table 7 that the difference in strain measurements from 2005 to 2015 is very small.

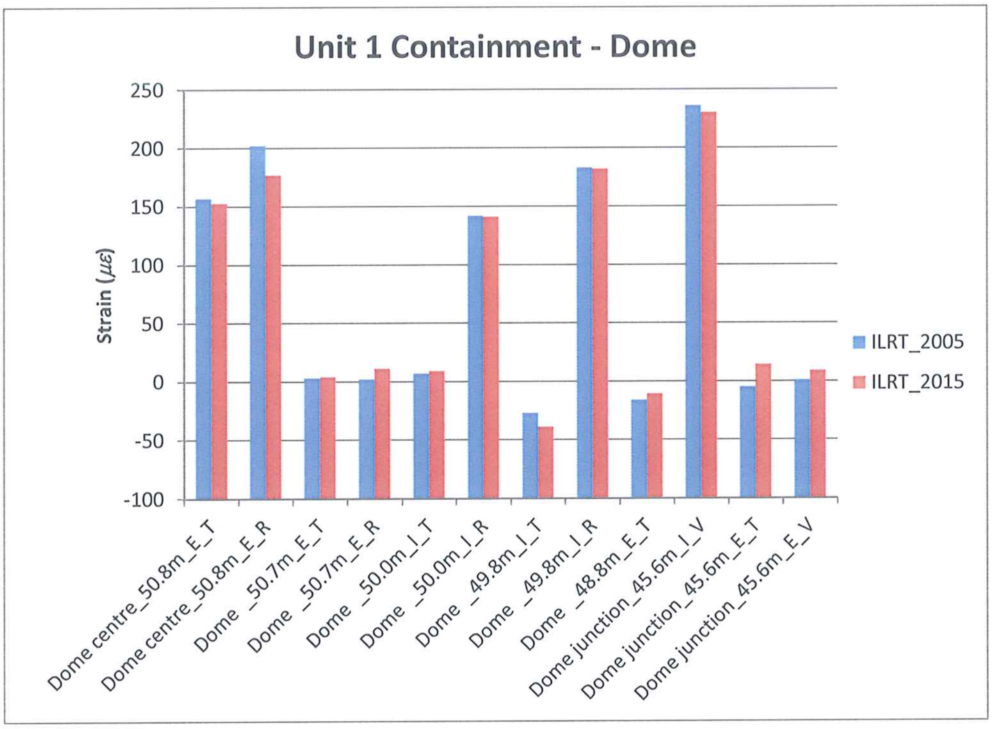

Figure 5: Comparison of extensometers in the Unit 1 Dome

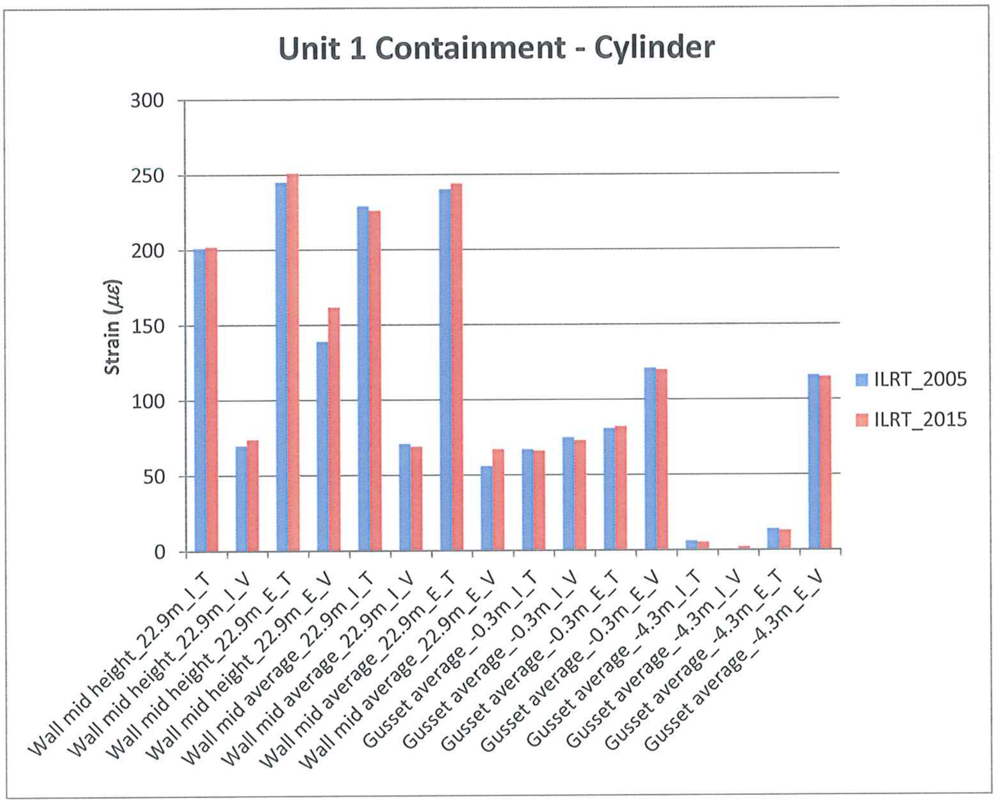

Figure 6: Comparison of extensometers in the Unit 1 Wall

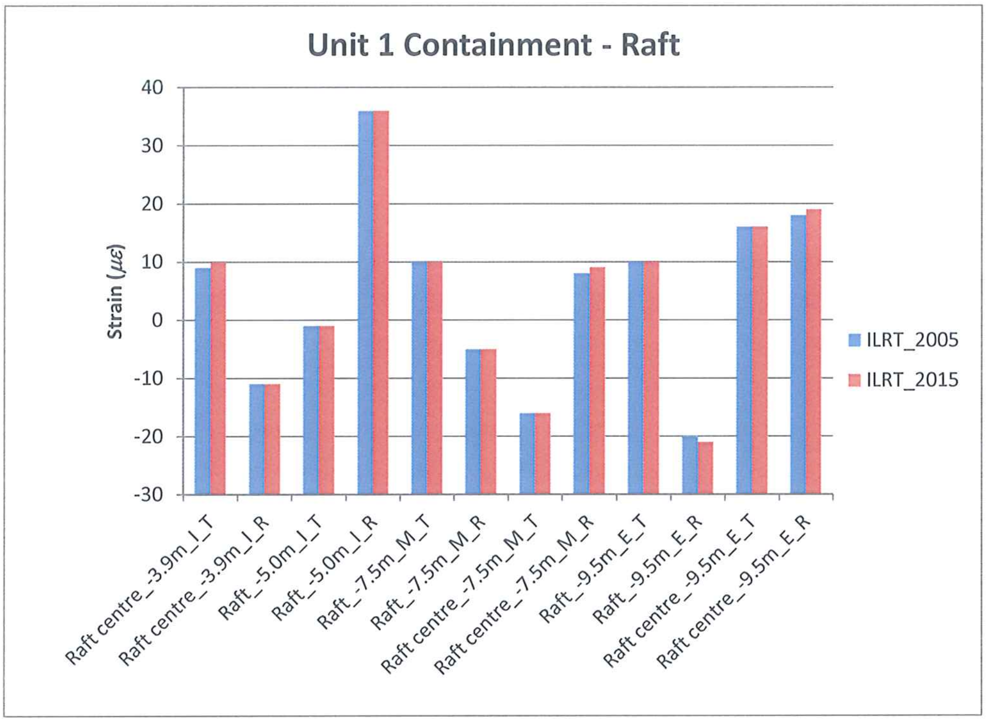

Figure 7: Comparison of extensometers in the Unit 1 Raft

Table 7: Comparison of extensometer data for Unit 1

Area	Level	Posi-tion	Direc-tion	Reference	ILRT 2005	ILRT 2015	Diff ($\mu\varepsilon$)
Dome centre	50.8m	E	T	Dome centre_50.8m_E_T	157	153	-4
Dome centre	50.8m	E	R	Dome centre_50.8m_E_R	202	177	-25
Dome	50.7m	E	T	Dome _50.7m_E_T	3	4	1
Dome	50.7m	E	R	Dome _50.7m_E_R	2	11	9
Dome	50.0m	I	T	Dome _50.0m_I_T	7	9	2
Dome	50.0m	I	R	Dome _50.0m_I_R	142	141	-1
Dome	49.8m	I	T	Dome _49.8m_I_T	-27	-39	-12
Dome	49.8m	I	R	Dome _49.8m_I_R	183	182	-1
Dome	48.8m	E	T	Dome _48.8m_E_T	-16	-11	5
Dome junction	45.6m	I	V	Dome junction_45.6m_I_V	236	230	-6
Dome junction	45.6m	E	T	Dome junction_45.6m_E_T	-5	14	19
Dome junction	45.6m	E	V	Dome junction_45.6m_E_V	1	9	8
Wall mid height	22.9m	I	T	Wall mid height_22.9m_I_T	201	202	1
Wall mid height	22.9m	I	V	Wall mid height_22.9m_I_V	70	74	4
Wall mid height	22.9m	E	T	Wall mid height_22.9m_E_T	245	251	6
Wall mid height	22.9m	E	V	Wall mid height_22.9m_E_V	139	162	23
Wall mid average	22.9m	I	T	Wall mid average_22.9m_I_T	229	226	-3
Wall mid average	22.9m	I	V	Wall mid average_22.9m_I_V	71	69	-2
Wall mid average	22.9m	E	T	Wall mid average_22.9m_E_T	240	244	4
Wall mid average	22.9m	E	V	Wall mid average_22.9m_E_V	56	67	11
Gusset average	-0.3m	I	T	Gusset average_-0.3m_I_T	67	66	-1

Area	Level	Posi-tion	Direc-tion	Reference	ILRT 2005	ILRT 2015	Diff ($\mu\varepsilon$)
Gusset average	-0.3m	I	V	Gusset average_-0.3m_I_V	75	73	-2
Gusset average	-0.3m	E	T	Gusset average_-0.3m_E_T	81	82	1
Gusset average	-0.3m	E	V	Gusset average_-0.3m_E_V	121	120	-1
Gusset average	-4.3m	I	T	Gusset average_-4.3m_I_T	6	5	-1
Gusset average	-4.3m	I	V	Gusset average_-4.3m_I_V	0	2	2
Gusset average	-4.3m	E	T	Gusset average_-4.3m_E_T	14	13	-1
Gusset average	-4.3m	E	V	Gusset average_-4.3m_E_V	116	115	-1
Raft centre	-3.9m	I	T	Raft centre_-3.9m_I_T	9	10	1
Raft centre	-3.9m	I	R	Raft centre_-3.9m_I_R	-11	-11	0
Raft	-5.0m	I	T	Raft_-5.0m_I_T	-1	-1	0
Raft	-5.0m	I	R	Raft_-5.0m_I_R	36	36	0
Raft	-7.5m	M	T	Raft_-7.5m_M_T	10	10	0
Raft	-7.5m	M	R	Raft_-7.5m_M_R	-5	-5	0
Raft centre	-7.5m	M	T	Raft centre_-7.5m_M_T	-16	-16	0
Raft centre	-7.5m	M	R	Raft centre_-7.5m_M_R	8	9	1
Raft	-9.5m	E	T	Raft_-9.5m_E_T	10	10	0
Raft	-9.5m	E	R	Raft_-9.5m_E_R	-20	-21	-1
Raft centre	-9.5m	E	T	Raft centre_-9.5m_E_T	16	16	0
Raft centre	-9.5m	E	R	Raft centre_-9.5m_E_R	18	19	1

Legend:

E = External
T = Tangential
R= Radial
V = Vertical
M = Middle

2.6 Equipment Hatch:

- Maximum radial displacement (in relation to the surface of the hatch) = 0.2 mm;
- Maximum axial displacement (in relation to the surface of the hatch) = 0.05 mm

3.0 EdF Summarised Results

- Elastic behaviour is generally observed with low hysteresis 8 hours after the end of the test.
- Negligible thermal effect is observed.
- The ILRT results for 2005 and 2015 are very close.
- A few new cracks and cracks which evolved during pressurisation were detected.

The EdF report expressed the following concerns regarding the Unit 1 measuring devices:

- Thermocouples: 18 No. or 17% of thermocouples were unavailable whilst 5 No. thermocouples have random operation.
- Extensometers: 13 No. or 12% of extensometers were unavailable.

4.0 Responsible Engineer Comments

It may be concluded that the structural response of the containment has not changed since the previous ILRT in 2005 despite the continued delamination of the surface concrete and corrosion of the horizontal rebar. The structural integrity and functionality of the Unit 1 containment at the current time is therefore demonstrated through test.

However, it is recommended that reasons for the differences in dynamometer readings to those taken in 2005 as well as the relatively low forces in cables 90 and 198 during this ILRT be obtained given that the deformation measurements are close to those measured in 2005.

Dynamometer measurements should be taken at the end of July 2015 to check whether the residual force has reduced.

The location of extensometers demonstrating non-linear behaviour should be checked against the results of the finite element model.

Yours Faithfully,

D E Lee (Pr Eng)

Koeberg Responsible Engineer (Civils)