



South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

January 6, 2003  
NOC-AE-02001439  
File No.: G25  
10CFR50.55a

U. S. Nuclear Regulatory Commission  
Attention: Document Control Desk  
One White Flint North  
11555 Rockville Pike  
Rockville, MD 20852

South Texas Project  
Units 1 and 2  
Docket Nos. STN 50-498, STN 50-499  
Response to Request for Additional Information Regarding  
Revised Request for Approval of an Alternative Approach for  
Containment Concrete and Tendon Surveillances (RR-ENG-37)

Reference: Letter, T. J. Jordan to NRC Document Control Desk, "Request for Approval of an Alternative Approach for Containment Tendon Surveillances (RR-ENG-37)"

In accordance with the provisions of 10CFR50.55a(a)(3)(i), the referenced letter from the South Texas Project requested approval of an alternative to ASME Section XI, paragraph IWL-2421(b). This specified the inservice inspection intervals to be applied in examination of containment concrete and unbonded post-tensioning systems, and IWL-2521, which describes the tendon selection process. This letter is in response to questions forwarded from the NRC requesting clarification of points presented previously. The requested information is attached.

If there are any questions, please contact either Mr. Philip Walker at 361-972-8392 or me at 361-972-7902.

T. J. Jordan  
Vice President,  
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PLW

Attachment: Response to Request for Additional Information Regarding Containment Tendon Surveillance Requirements

A047

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**SOUTH TEXAS PROJECT  
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION  
REGARDING CONTAINMENT TENDON SURVEILLANCE REQUIREMENTS**

**NRC REQUEST:**

*In reviewing the information in Figure 1 and Tables 1 and 2, it is unclear what the actual measured and predicted tendon forces are. The licensee is requested to provide Tables showing actual measured pre-stressing forces for each Unit in each direction together with the forces at installation, elastic shortening losses, and slippage, if any, for the tendons selected during each prior inspections.*

*In the Figure, the licensee is requested to show:*

- (1) The trend lines (separately, for each Unit, and for U and hoop tendons) based on the inspections performed,*
- (2) Actual measured forces as points above and below the trend lines, and*
- (3) Predicted average tendon forces at 40 years.*

*The licensee is also requested to provide a summary of the method used to construct the trend lines.*

**SOUTH TEXAS PROJECT RESPONSE:**

**Supplementary Tables**

As requested, supplementary tables are provided for each tendon group. The columns in these tables are as follows:

- (1) Tendon designation
- (2) Tendon end (S = "Shop end", F = "Field end")
- (3) Surveillance year (1, 5, or 10)
- (4) Initial liftoff force measured at installation (kips)
- (5) Predicted elastic loss (kips)
- (6) Predicted liftoff force at surveillance year (kips)
- (7) Measured liftoff force during surveillance.

Columns 8 through 11 are explained under the section on calculation of trend lines.

Slippage is not applicable to the buttonhead-type installation at the South Texas Project.

The supplementary tables also include the *average* initial liftoff and predicted end-of-life liftoff for each group. These averages are calculated as the average of all tendons in the group, not just the surveillance tendons.

**Figure 1 and Figure 2**

As read from top to bottom, respectively, on the right side of Figure 1, the four lines are:

- Unit 2 verticals (inverted "U"),
- Unit 1 verticals (inverted "U"),
- Unit 2 horizontals (hoop), and
- Unit 1 horizontals (hoop).

Tendon loss is typically presented on a semi-log plot, with prestress loss being linear with the log of time. STP prepared Figure 1 using a standard linear scale, resulting in nonlinear trend lines. The labels on the revised Figure 1 included with this response have been enhanced for greater clarity. (There is no change to the data presented in the figure.) Figure 2 has been added to show the same trends against the log of time.

The figures show *percent deviation* from the predicted value on the vertical axis. Although the request was to add the *actual measured forces* and end-of-life predicted average forces to the figure, the South Texas Project believes this information is more appropriately shown in the tables provided.

The South Texas Project believes that the information shown in revised Figure 1, Figure 2, and provided in the supplementary tables, while slightly different from the staff's request, meets the intent of the RAI.

### Construction of Trend Lines

The trend line is calculated using linear regression analysis. The trend is a straight line, represented by the equation:

$$Y = \alpha + \beta X,$$

where the variables  $X$  and  $Y$  are defined as:

$$X = \text{Log}(T), \text{ and } T = \text{time (measured in years), and}$$

$$Y = \text{Deviation from predicted prestress (measured in \%)}.$$

Data points currently available are from surveillances in years 1, 5, and 10. This means the three possible values of  $T$  are 1, 5, and 10, and the corresponding values of  $X$  are  $\text{Log}(1)$ ,  $\text{Log}(5)$ , and  $\text{Log}(10)$ , which are 0, 0.69897, and 1, respectively.

All tendons were installed using similar methods, but no two were tensioned to precisely the same force. The initial liftoff forces were recorded for all tendons immediately following installation. Additional disparity in tendon forces was introduced due to installation sequencing (elastic losses). The subsequent time-dependent losses (creep, shrinkage, relaxation) are stress-dependent. Since no two tendons have exactly the same stress, it follows that no two have exactly the same predicted time-dependent loss. Therefore, predicted liftoff force is calculated individually for each tendon. In order to make meaningful comparisons among tendons and assess trends, converting them to percentage deviation from predicted values normalizes the measured liftoff forces. For example, during the first year surveillance of Unit 1, tendon V126-S had a predicted liftoff force of 1376 kips and an actual measured liftoff at 1402 kips. This means the actual liftoff force was 1.89% higher than expected.  $[(1402 - 1376)/1376 = 0.0189 = 1.89\%]$ . Hence, for this case, the value of  $Y$  used in the regression analysis is 1.890. The corresponding value of  $X$  is 0.

The regression constants  $\alpha$  and  $\beta$  are calculated according to standard statistical formulas:

$$\alpha = \bar{y} - \beta \bar{x},$$

$$\beta = \frac{\sum_{i=1}^n x_i y_i - n \cdot \bar{x} \cdot \bar{y}}{\sum_{i=1}^n x_i^2 - n \cdot \bar{x}^2},$$

where  $\bar{x} = \frac{1}{n} \cdot \sum_{i=1}^n x_i$ ,  $\bar{y} = \frac{1}{n} \cdot \sum_{i=1}^n y_i$ , and  $n =$  number of data points in the group.

Columns 8 through 11 in the supplementary tables are defined as:

- (8)  $X = \text{Log}(\text{Time})$ ,
- (9)  $Y = \text{Deviation from predicted (expressed as \%)} \text{ where}$   
 $Y = 100 \times [(\text{col. 7}) - (\text{col. 6})]/(\text{col. 6})$
- (10)  $XY = (\text{col. 8}) \times (\text{col. 9})$
- (11)  $X^2 = (\text{col. 8}) \times (\text{col. 8})$

The sum of the terms in each of these columns is given at the bottom of each table. These sums are used to calculate the constants  $\alpha$  and  $\beta$  for each group, according to the formulas given above. Table 2 in the relief request presents the projected trends in tabular form. Using the Unit 1 horizontals as an illustration, the constant "alpha" was calculated as 2.464 and the constant "Beta" was  $-3.722$ . Therefore, the projected deviation from predicted (expressed as %) at year 40 is:

$$\begin{aligned} Y &= \alpha + \beta X \\ &= \alpha + \beta \text{Log}(T) \\ &= 2.464 + (-3.722)(\text{Log}(40)) \\ &= 2.462 + (-3.722)(1.602) \\ &= -3.50\%. \end{aligned}$$

This means that the Unit 1 horizontals, as a group, are trending toward 3.5% less than the predicted values at year 40. This is shown in Table 1 of the relief request. It is the least satisfactory trend of any of the four groups. To put this projection in perspective, the end-of-life containment design value for rated capacity is 56.5 psi, which is 37% above the 41.2 psi maximum calculated pressure resulting from a LOCA.

To date, STP has performed 116 tendon liftoff tests (38 verticals and 78 horizontals). These were distributed among the surveillances as follows:

- 52 at the first year,
- 40 at the fifth year, and
- 24 at the tenth year.

Each tendon has two ends, so the 116 liftoff tests convert to surveillances of 58 tendons.

**Supplementary Table S-1: Vertical Tendons (U1)**

Tendons		Time (yr)	Liftoff Force (Kips)				Regression Line Parameters				
Tendon	End		Initial	Elastic Loss	Predicted	Measured	$X_i$	$Y_i$	$X_i Y_i$	$X_i^2$	
1	2	3	4	5	6	7	8	9	10	11	
V126	S	1	1598	11	1376	1402	0	1.890	0	0	
V126	F	1	1621	11	1391	1439	0	3.451	0	0	
V144	S	1	1642	22	1401	1400	0	-0.071	0	0	
V144	F	1	1567	22	1352	1343	0	-0.666	0	0	
V227	S	1	1553	22	1345	1336	0	-0.669	0	0	
V227	F	1	1556	22	1346	1325	0	-1.560	0	0	
V245	S	1	1591	34	1366	1363	0	-0.220	0	0	
V245	F	1	1565	34	1349	1326	0	-1.705	0	0	
V126	S	5	1598	11	1350	1385	0.69897	2.593	1.81214	0.48856	
V126	F	5	1621	11	1370	1406	0.69897	2.628	1.83671	0.48856	
V214	S	5	1598	1	1358	1380	0.69897	1.620	1.13245	0.48856	
V214	F	5	1631	1	1378	1392	0.69897	1.016	0.71013	0.48856	
V242	S	5	1603	5	1363	1381	0.69897	1.321	0.92307	0.48856	
V242	F	5	1608	5	1367	1397	0.69897	2.195	1.53495	0.48856	
V248	S	5	1603	9	1354	1359	0.69897	0.369	0.25811	0.48856	
V248	F	5	1608	9	1359	1382	0.69897	1.692	1.18395	0.48856	
V126	S	10	1598	11	1348	1340	1	-0.593	-0.59347	1	
V126	F	10	1621	11	1362	1380	1	1.322	1.32159	1	
V129	S	10	1533	47	1286	1290	1	0.311	0.31104	1	
V129	F	10	1609	47	1333	1320	1	-0.975	-0.97524	1	
V230	S	10	1638	-2	1379	1380	1	0.073	0.07252	1	
V230	F	10	1596	-2	1354	1430	1	5.613	5.61300	1	
			<b>1596</b>	-- Average Initial			<b>11.592</b>	<b>19.632</b>	<b>15.139</b>	<b>9.908</b>	
			<b>1350</b>	-- Average Predicted (End-of-Life)			Number of liftoff tests: N = 22				

See page 1 of this attachment for an explanation of columns 1 through 7, and page 3 of this attachment for an explanation of columns 8 through 11.

Supplementary Table S-2: Vertical Tendons (U2)

Tendons		Time (yr)	Liftoff Force (Kips)				Regression Line Parameters				
Tendon	End		Initial	Elastic Loss	Predicted	Measured	$X_i$	$Y_i$	$X_i Y_i$	$X_i^2$	
1	2	3	4	5	6	7	8	9	10	11	
V110	S	1	1605	25	1380	1421	0	2.971	0	0	
V110	F	1	1605	25	1380	1377	0	-0.217	0	0	
V120	S	1	1580	18	1359	1403	0	3.238	0	0	
V120	F	1	1630	18	1402	1400	0	-0.143	0	0	
V202	S	1	1630	15	1402	1432	0	2.140	0	0	
V202	F	1	1640	15	1410	1422	0	0.851	0	0	
V236	S	1	1605	4	1396	1382	0	-1.003	0	0	
V236	F	1	1520	4	1338	1370	0	2.392	0	0	
V110	S	5	1605	25	1348	1412	0.69897	4.748	3.31855	0.48856	
V110	F	5	1605	25	1348	1362	0.69897	1.039	0.72593	0.48856	
V203	S	5	1610	13	1360	1415	0.69897	4.044	2.82672	0.48856	
V203	F	5	1620	13	1361	1407	0.69897	3.380	2.36243	0.48856	
V221	S	5	1580	-2	1351	1479	0.69897	9.474	6.62237	0.48856	
V221	F	5	1630	-2	1394	1452	0.69897	4.161	2.90820	0.48856	
V233	S	5	1580	29	1343	1348	0.69897	0.372	0.26023	0.48856	
V233	F	5	1540	29	1309	1338	0.69897	2.215	1.54852	0.48856	
			<b>1595</b> - - Average Initial				<b>5.592</b>	<b>39.661</b>	<b>20.573</b>	<b>3.908</b>	
			<b>1350</b> - - Average Predicted (End-of-Life)				Number of liftoff tests: N = 16				

See page 1 of this attachment for an explanation of columns 1 through 7, and page 3 of this attachment for an explanation of columns 8 through 11.

**Supplementary Table S-3: Hoop Tendons (U1)**

Tendons		Time (yr)	Liftoff Force (Kips)				Regression Line Parameters			
Tendon	End		Initial	Elastic Loss	Predicted	Measured	X <sub>i</sub>	Y <sub>i</sub>	X <sub>i</sub> Y <sub>i</sub>	X <sub>i</sub> <sup>2</sup>
1	2	3	4	5	6	7	8	9	10	11
1H091	S	1	1550	5	1326	1380	0	4.072	0	0
1H091	F	1	1612	5	1367	1378	0	0.805	0	0
1H106	S	1	1579	73	1302	1345	0	3.303	0	0
1H106	F	1	1607	73	1321	1354	0	2.498	0	0
1H130	S	1	1638	55	1368	1383	0	1.096	0	0
1H130	F	1	1582	55	1331	1360	0	2.179	0	0
2H051	S	1	1539	99	1259	1297	0	3.018	0	0
2H051	F	1	1643	99	1329	1321	0	-0.602	0	0
2H054	S	1	1582	24	1335	1376	0	3.071	0	0
2H054	F	1	1589	24	1340	1363	0	1.716	0	0
2H078	S	1	1643	22	1376	1423	0	3.416	0	0
2H078	F	1	1632	22	1369	1373	0	0.292	0	0
2H111	S	1	1607	70	1338	1386	0	3.587	0	0
2H111	F	1	1577	70	1318	1336	0	1.366	0	0
3H005	S	1	1579	53	1315	1402	0	6.616	0	0
3H005	F	1	1562	53	1304	1356	0	3.988	0	0
3H032	S	1	1545	65	1285	1345	0	4.669	0	0
3H032	F	1	1632	65	1343	1365	0	1.638	0	0
1H091	S	5	1550	5	1310	1312	0.69897	0.153	0.10671	0.48856
1H091	F	5	1612	5	1386	1329	0.69897	-4.113	-2.87455	0.48856
1H112	S	5	1579	55	1318	1281	0.69897	-2.807	-1.96221	0.48856
1H112	F	5	1542	55	1280	1270	0.69897	-0.781	-0.54607	0.48856
2H093	S	5	1607	90	1294	1276	0.69897	-1.391	-0.97229	0.48856
2H093	F	5	1589	90	1302	1270	0.69897	-2.458	-1.71790	0.48856
2H129	S	5	1558	68	1293	1345	0.69897	4.022	2.81102	0.48856
2H129	F	5	1553	68	1289	1213	0.69897	-5.896	-4.12116	0.48856
2H036	S	5	1637	10	1359	1384	0.69897	1.840	1.28582	0.48856
2H036	F	5	1644	10	1364	1381	0.69897	1.246	0.87115	0.48856
2H048	S	5	1643	11	1364	1380	0.69897	1.173	0.81991	0.48856
2H048	F	5	1620	11	1345	1338	0.69897	-0.520	-0.36378	0.48856
1H043	S	10	1634	2	1356	1330	1	-1.917	-1.91740	1
1H043	F	10	1553	2	1306	1320	1	1.072	1.07198	1
1H049	S	10	1610	31	1325	1270	1	-4.151	-4.15094	1
1H049	F	10	1567	31	1298	1330	1	2.465	2.46533	1
1H091	S	10	1550	5	1303	1310	1	0.537	0.53722	1
1H091	F	10	1612	5	1341	1280	1	-4.549	-4.54884	1
2H129	S	10	1558	68	1287	1320	1	2.564	2.56410	1
2H129	F	10	1553	68	1284	1265	1	-1.480	-1.47975	1
1H130	S	10	1638	55	1345	1330	1	-1.115	-1.11524	1
1H130	F	10	1582	55	1310	1290	1	-1.527	-1.52672	1
1H127	S	10	1610	6	1356	1340	1	-1.180	-1.17994	1
1H127	F	10	1542	6	1314	1310	1	-0.304	-0.30441	1
			<b>1590</b>	-- Average Initial			<b>20.388</b>	<b>27.611</b>	<b>-16.248</b>	<b>17.863</b>
			<b>1316</b>	-- Average Predicted (End-of-Life)	Number of liftoff tests: N =42					

See page 1 of this attachment for an explanation of columns 1 through 7, and page 3 of this attachment for an explanation of columns 8 through 11.



### Supplementary Table S-4: Hoop Tendons (U2)

Tendons		Time (yr)	Liftoff Force (Kips)				Regression Line Parameters				
Tendon	End		Initial	Elastic Loss	Predicted	Measured	X <sub>i</sub>	Y <sub>i</sub>	X <sub>i</sub> Y <sub>i</sub>	X <sub>i</sub> <sup>2</sup>	
1	2	3	4	5	6	7	8	9	10	11	
1H094	S	1	1535	55	1289	1283	0	-0.465	0	0	
1H094	F	1	1620	55	1345	1335	0	-0.743	0	0	
1H112	S	1	1535	56	1305	1274	0	-2.375	0	0	
1H112	F	1	1580	56	1343	1303	0	-2.978	0	0	
1H124	S	1	1580	55	1343	1312	0	-2.308	0	0	
1H124	F	1	1580	55	1343	1337	0	-0.447	0	0	
2H033	S	1	1520	49	1292	1216	0	-5.882	0	0	
2H033	F	1	1550	49	1302	1354	0	3.994	0	0	
2H075	S	1	1600	43	1344	1394	0	3.720	0	0	
2H075	F	1	1600	43	1344	1398	0	4.018	0	0	
2H105	S	1	1540	39	1309	1418	0	8.327	0	0	
2H105	F	1	1580	39	1327	1400	0	5.501	0	0	
3H005	S	1	1580	101	1296	1355	0	4.552	0	0	
3H005	F	1	1550	101	1271	1375	0	8.183	0	0	
3H029	S	1	1585	97	1300	1392	0	7.077	0	0	
3H029	F	1	1550	97	1271	1319	0	3.777	0	0	
3H056	S	1	1570	65	1319	1361	0	3.184	0	0	
3H056	F	1	1580	65	1311	1346	0	2.670	0	0	
1H055	S	5	1550	3	1310	1325	0.69897	1.145	0.80035	0.48856	
1H055	F	5	1540	3	1301	1298	0.69897	-0.231	-0.16118	0.48856	
1H106	S	5	1580	56	1304	1308	0.69897	0.307	0.21441	0.48856	
1H106	F	5	1570	56	1295	1251	0.69897	-3.398	-2.37488	0.48856	
2H018	S	5	1540	10	1301	1421	0.69897	9.224	6.44707	0.48856	
2H018	F	5	1620	10	1353	1352	0.69897	-0.074	-0.05166	0.48856	
2H045	S	5	1540	47	1278	1356	0.69897	6.103	4.26601	0.48856	
2H045	F	5	1570	47	1295	1300	0.69897	0.386	0.26987	0.48856	
2H075	S	5	1600	43	1320	1324	0.69897	0.303	0.21181	0.48856	
2H075	F	5	1600	43	1320	1338	0.69897	1.364	0.95314	0.48856	
3H050	S	5	1610	64	1312	1336	0.69897	1.829	1.27860	0.48856	
3H050	F	5	1630	64	1337	1323	0.69897	-1.047	-0.73191	0.48856	
2H033	S	10	1520	49	1258	1196	1	-4.928	-4.92846	1	
2H033	F	10	1550	49	1277	1280	1	0.235	0.23493	1	
2H036	S	10	1600	13	1329	1290	1	-2.935	-2.93454	1	
2H036	F	10	1570	13	1311	1310	1	-0.076	-0.07628	1	
2H030	S	10	1550	12	1299	1280	1	-1.463	-1.46266	1	
2H030	F	10	1570	12	1311	1320	1	0.686	0.68650	1	
			<b>1583</b>	-- Average Initial			<b>14.388</b>	<b>47.233</b>	<b>2.641</b>	<b>11.863</b>	
			<b>1316</b>	-- Average Predicted (End-of-Life)			Number of liftoff tests: N = 36				

See page 1 of this attachment for an explanation of columns 1 through 7, and page 3 of this attachment for an explanation of columns 8 through 11.

**Supplementary Table S-5: TREND SUMMARY**

	<b>GROUP</b>			
	<b>U1-Hoop</b>	<b>U1-Vert</b>	<b>U2-Hoop</b>	<b>U2-Vert</b>
<b>Sum X<sub>i</sub></b>	20.388	11.592	14.388	5.592
<b>Sum Y<sub>i</sub></b>	27.611	19.632	47.233	39.661
<b>Sum X<sub>i</sub>Y<sub>i</sub></b>	-16.248	15.139	2.641	20.573
<b>Sum X<sub>i</sub><sup>2</sup></b>	17.863	9.908	11.863	3.908
<b>N</b>	42	22	36	16
<b>X-Mean</b>	0.485	0.527	0.400	0.349
<b>Y-Mean</b>	0.657	0.892	1.312	2.479
<b>Beta</b>	-3.722	1.262	-2.656	3.435
<b>Alpha</b>	2.464	0.228	2.374	1.279
<b>Trend* (Yr.)</b>	<b>% DEVIATION FROM PREDICTED LIFTOFF</b>			
<b>1</b>	2.46	0.23	2.37	1.28
<b>5</b>	-0.14	1.11	0.52	3.68
<b>10</b>	-1.26	1.49	-0.28	4.71
<b>15</b>	-1.91	1.71	-0.75	5.32
<b>20</b>	-2.38	1.87	-1.08	5.75
<b>25</b>	-2.74	1.99	-1.34	6.08
<b>30</b>	-3.03	2.09	-1.55	6.35
<b>35</b>	-3.28	2.18	-1.73	6.58
<b>40</b>	-3.50	2.25	-1.88	6.78
<b>*Trend Line: X = Log(time)</b>				
<b>Y = Alpha + (Beta)(X)</b>				

Revised Figure 1: Trend Lines of Lift-Off Test Results (Years 1, 5, and 10)

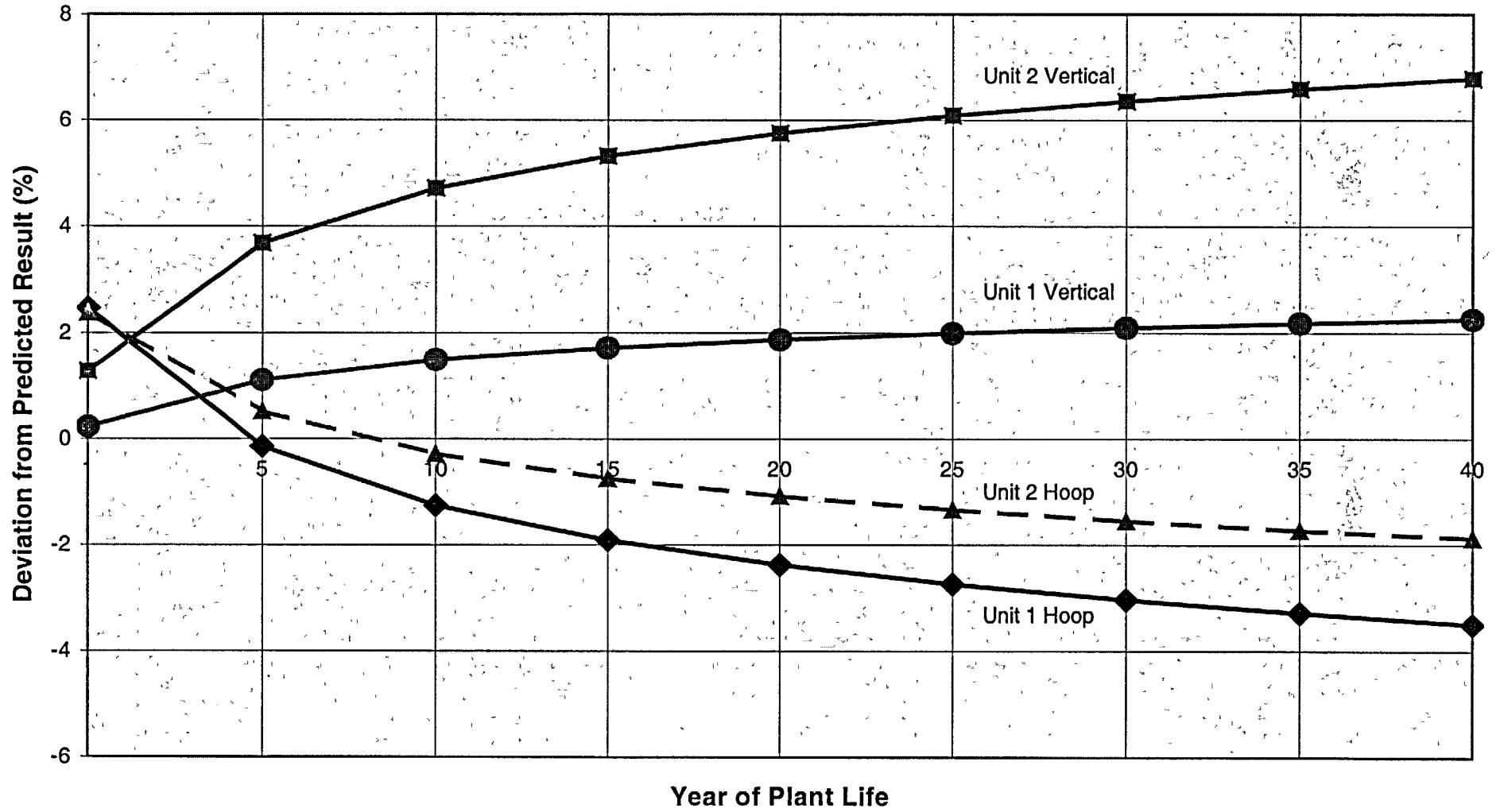


Figure 2: Trendlines of Lift-Off Test Results (Years 1, 5, and 10)

