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ADDENDUM TO "TORSIOGRAPH TESTS OF EMERGENCY DIESEL GENERATORS, DIVISIONS 1 AND 2, AT PERRY NUCLEAR POWER PLANT - UNIT 1" ON CYLINDER IMBALANCE

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INTRODUCTION

A torsiograph test of the emergency diesel generators Unit 1 Division 1 (U1D1) and Unit 1 Division 2 (U1D2) at Perry Nuclear Power Plant was performed to measure the angular displacements of the gear train end of the crankshaft. Data was obtained during steady state, transient (startup and coastdown), and cylinder imbalance conditions. This supplement report deals only with the cylinder imbalance test. This test was conducted to determine the response of the engine should a cylinder imbalance occur during normal operation. The effect of imbalance is typically greatest in the half order response. Since the 4th order critical speed (436 rpm) at Perry is close to the normal operating speed of 450 rpm, the response of the 4th order under cylinder imbalance conditions was also determined. The equipment and procedure used for this test along with the results of the steady-state and transient tests were addressed in a separate report [1].

Cylinder Imbalance Response

The imbalance test was performed with the fuel to cylinder five left bank disabled. This cylinder was chosen because analyses show that the largest increase in stress due to imbalance is produced by disabling this cylinder. The engines were operated for two to five minutes at rated speed (450 rpm) with no load and then with a 3500 kW load (50% of rated load), while the torsiograph output was recorded. The effect of imbalance was observed at no load and at 50% of rated load. The analytical model developed by Failure Analysis Associates for the TDI Diesel Generator Owners' Group was used to extrapolate the effect of imbalance to full load (7000 kW). This model uses the modal superposition technique to perform a dynamic analysis of a crankshaft. A discussion of the results at 100% load is noted below in item 5 and the test results at 50% load are sumamrized in Table 1. The results of similar steady-state conditions with normal cylinder balance are included in this table for comparison.

The following conclusions and comments can be made from the results of the imbalance tests:

1) Emergency diesel generator Unit 1 Division 2 is better balanced (i.e., the pressure vs. time curve is close to the same for each cylinder) than engine Unit 1 Division 1. This is indicated by the lower half order response of U1D2 during both normal and imbalanced steady state tests. The half order response for both engines was within the normal range.

2) The total response during the cylinder imbalance tests with no load is essentially the same as the response during normal balanced operation with no load.

3) During the imbalance tests, the half order response increased as expected.

4) The added imbalance of disabling a cylinder imparts a rigid body vibration to the crankshaft. This rigid body vibration does not induce any stress in the crankshaft. This rigid body vibration accounts for the significant increase in the half order during the imbalance tests.

5) During the cylinder imbalance tests performed at 50% of rated load, the total response and single order response for significant orders increased. Analytical results indicate that at rated load (7000 kW) the maximum amplitude of nominal stresses would increase from 5330 psi to 6910 psi due to this imbalanced condition. This increase is not large enough to affect the adequacy of the crankshaft in either engine.

6) The presence of the fourth order in the V-16 engine is caused by both the difference in timing and imbalance between the left and right banks., which is a normal condition for these engines. The fourth order response showed a small increase in engine U1D1 and a large increase in engine U1D2. The difference in fourth order response between the two engines is due to the different balance between left and right banks in the two engines. The magnitude of the fourth order

is not large enough to affect the adequacy of the crankshaft in either engine.

References

1 "Torsiograph Tests of Emergency Diesel Generators, Divisions 1 and 2, At Perry Nuclear Power Plant - Unit 1," FaAA-85-4-1, May 1985.

Table 1: Imbalance Test Response

Unit 1 Division 1

Order	Amplitude of Free-End Vibration (degrees)			
	No Load		3500 kW	
	No Imbalance	5 LB* Disabled	No Imbalance	5 LB Disabled
0.5	.022	.103	.095	.378
1.0	.002	.002	.005	.004
1.5	.043	.045	.103	.093
2.0	.012	.014	.006	.016
2.5	.064	.072	.130	.138
3.0	.002	.008	.002	.020
3.5	.072	.085	.133	.161
4.0	.094	.073	.095	.104
4.5	.016	.015	.027	.028
5.0	.002	.002	.003	.005
5.5	.005	.005	.009	.008
6.0	.003	.004	.007	.008
TOTAL	.225	.235	.368	.645

Unit 1 Division 2

Order	Amplitude of Free-End Vibration (degrees)			
	No Load		3500 kW	
	No Imbalance	5 LB Disabled	No Imbalance	5 LB Disabled
0.5	.007	.053	.013	.268
1.0	.003	.003	.003	.006
1.5	.041	.042	.098	.096
2.0	.011	.012	.005	.013
2.5	.068	.072	.138	.154
3.0	.004	.009	.008	.024
3.5	.069	.077	.129	.163
4.0	.088	.065	.080	.169
4.5	.075	.015	.029	.033
5.0	.001	.001	.001	.005
5.5	.005	.005	.010	.009
6.0	.004	.004	.008	.010
TOTAL	.215	.198	.330	.605

* LB denotes Left Bank.