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April 25, 1991

Philadelphia Electric Company
Limerick Generating Station
P.O. Box A
Sanatoga, PA 19464

Attn: Tom Strawley — SM engineer

Subject: Limerick
Standby Diesel Generators
Air Start Distributor Information

Enclosure: (1) Coltec Engineering Report R-5.08-0312
(2) Coltec 10CFR21 Evaluation, dated 4/24/91

Gentlemen:

This letter is written to provide you service information relative to the air start distributor shaft driven by the overspeed governor shaft.

Per enclosure (1), it is recommended that the air start distributor shaft be inspected to verify proper alignment. The following utilities are affected:

Utility	Site
Alabama Power	Farley
Detroit Edison	Fermi 2
Northeast Utilities	Millstone 2 (875022 only)
Philadelphia Electric	Limerick

Please note that per enclosures (1) and (2), a safety hazard does not exist.

If you have any questions or require additional information, please contact the writer at (608) 364-8424.

Very Truly Yours,

Ted Stevenson

T.M. Stevenson
Nuclear Sales

cc: C. Ankrum
W. Martin
M. Horinka
J. Moriarty
T. Stull
Bill McFarland - PECO
955-965 Chesterbrook Blvd
Wayne, PA 19087

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SUBSTANTIAL SAFETY HAZARD EVALUATION
10CFR21 STANDARD PRACTICE 714.00

1. Part Numbers Involved: 16204000 - Shaft, Air Start Distributor
16204001 - Shaft, Overspeed Governor

2. Problem Description: Air Start Distributor shaft and Overspeed Governor shaft deformed at point of engagement. 4/22/91

3. FMED Notified by: Philadelphia Electric (Limerick Site)

4. Customers affected (by engine application): PECo (LIMERICK); ALABAMA POWER (Farley 2); Detroit Edison (Fermi); Northeast Utilities (Millstone 2-875022 only) WESTINGHOUSE ANGRA (206122 CONTR.) & PHILADELPHIA ELECTRIC (700036 CONTRACT) 4/24/91

5. Engineering Evaluation (list any/all attachments): The above-units are the only OP engines with dual starting air distributors. The second distributor is driven off of the overspeed governor shaft. Each distributor is capable of starting the engine in less than 10 seconds. No "failures" of the second distributor have been seen. Also no failures to start have been seen, even with deformed shafts. See Engineering Report R-5.08-6312 (13 March 1991).

6. ☐ A substantial safety hazard exists
☒ A substantial safety hazard does not exist

7. _____ Engineering Review — 4/23/91 Date

_____ Quality Assurance Review — 4/24/91 Date

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ENGINEERING REPORT

Fairbanks Morse
Engine Division

SHEET OF	PAGE NO. 1
FILE NUMBER	R-5.08-0312
SUBJECT	STANDBY DIESEL GENERATOR SETS - PHILADELPHIA ELECTRIC COMPANY - LIMERICK STATION - S.O. 700000
DATE	March 13, 1991
PREPARED BY	W. A. Brill
REPORT TITLE	ANALYSIS OF DEFORMATION OF AIR START DISTRIBUTOR DISTRIBUTOR DRIVE COMPONENTS
APPROVED BY	3/25/91

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Introduction and Summary

The auxiliary air start distributor on this and several other nuclear standby units is driven by the right-hand camshaft. The overspeed governor shaft, which bolts to the end of the camshaft, has a tang end which pilots into a slot on the end of the distributor shaft.

On 7/7/89, PECO discovered this tang and slot on their #D-13 unit were in deformed condition. The tang was twisted and had rounded corners, while the slot showed the imprint of the tang corners. See photos attached to this report. Subsequent investigation revealed this condition to exist in their other seven engines as well. The deformed parts from D-13 were returned to Beloit along with photos from the site.

After some initial sorting out, the investigation settled down to answering two questions:

(a) By what mechanism were such large forces developed that would cause the observed deformations?

(b) What were the limits and characteristics of the axial engagement of the tang in the groove?

Investigation of the second question also was along two main themes, (a) of how the length of engagement could vary over time for a single set of parts, and (b) of how the length of engagement could vary depending on the stack-up of tolerances and clearances.

Comparison of the deformed air distributor tang drive also was made to the successful (and similar) governor tang drive.

Conclusions and Recommendations

1. It is concluded that the large forces are the result of rotation of the tang joint with the shaft axes out of alignment, and that proper alignment will eliminate these forces.
2. It is concluded that deformation of the tang corners is enhanced by the very short engagement that results from the stack-up of tolerances.
3. It is recommended that provision be made for alignment of the distributor shaft with the overspeed governor shaft. Specific suggestions are included in the discussion which follows.
4. It is recommended that provision be made for assuring an adequate length of tang engagement. Specific suggestions are included in the discussion which follows.
5. It is recommended that a discussion of the shaft alignment procedure be provided in the instruction manual.

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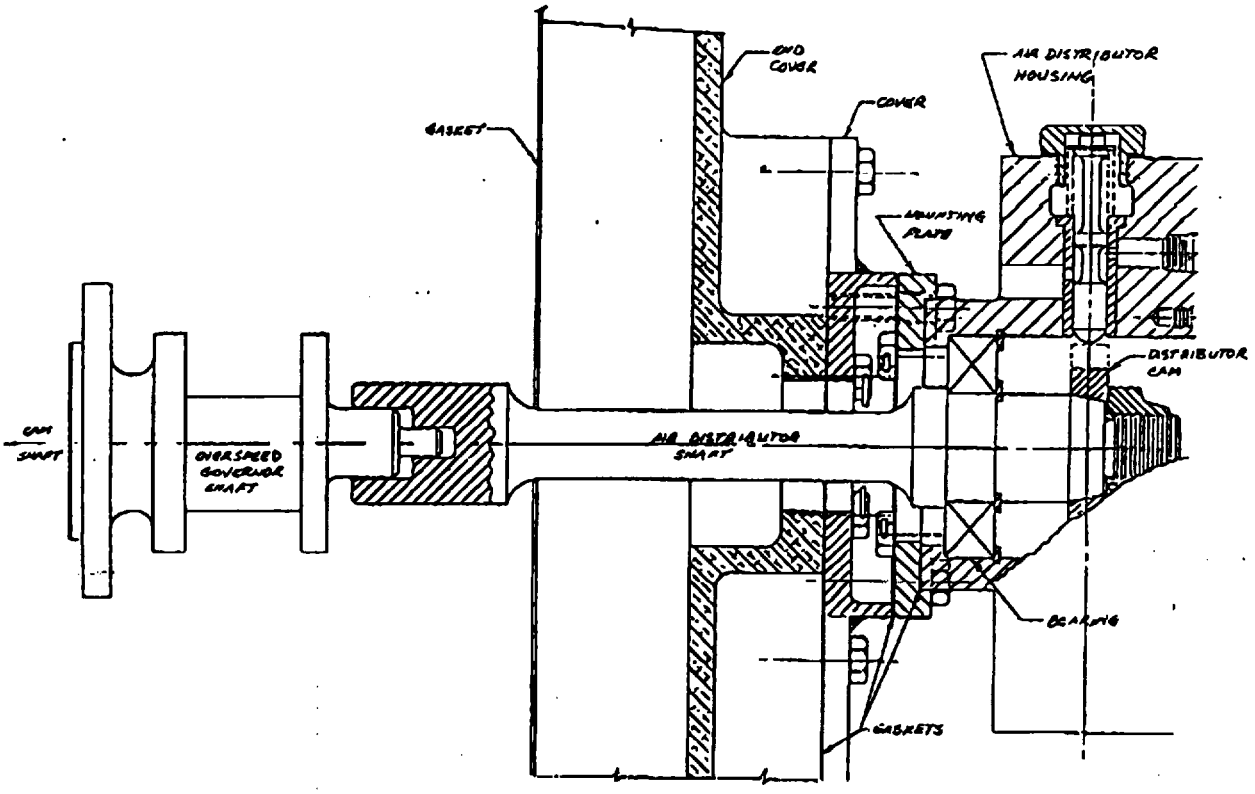
Discussion

A sketch of the subject air distributor follows. Since the distributor has little inertia and turns freely on the ball bearing, the source of resistance against which the deforming torques could develop was a mystery. Even during the start sequence when the valve stems contact the distributor cam, only very small resistance torques are generated.



It was subsequently discovered that large deforming forces can be generated within the tang/groove joint if the adjoining shaft axes are not closely aligned. This can be seen as follows. The bearing has two rows of balls on a spherical seat, and thus will allow for a small angle between the axes of inner and outer races. The distributor application involves bolted-on covers and housings with bolt hole clearances, dimensioning tolerances, etc. These produce some uncertainty as to the location of the shaft center in the plane of the bearing. The result is that the distributor shaft can be at an angle to the overspeed governor shaft.

FILE NUMBER R-5.08-0312

SUBJECT: STANDBY DIESEL GENERATOR SETS - PHILADELPHIA ELECTRIC COMPANY - LIMERICK STATION - S.O. 700000

DATE: March 13, 1991

PREPARED BY: W. A. Brill

REPORT TITLE: ANALYSIS OF DEFORMATION OF AIR START DISTRIBUTOR DISTRIBUTOR DRIVE COMPONENTS

APPROVED BY: C. Lawrence 3/25/91

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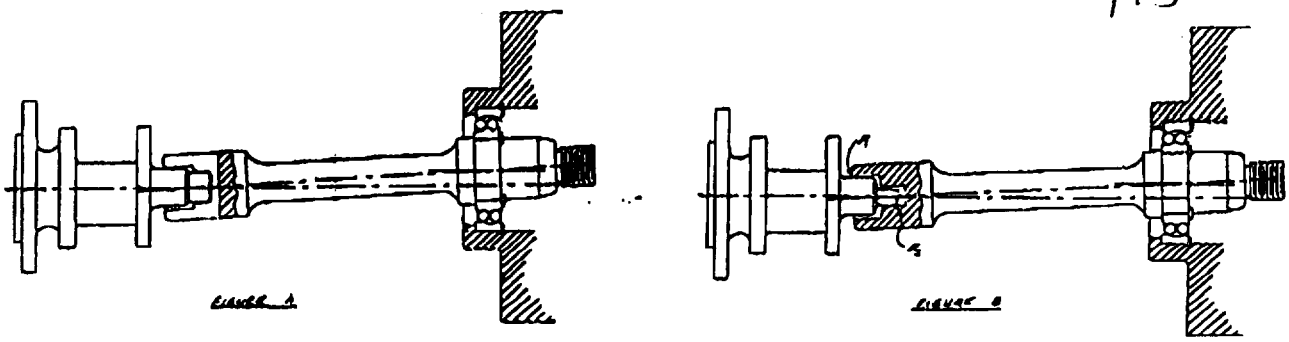

This angle causes no problem if the slot and tang are in the same plane as the shaft axes (Figure A). But rotating the shafts 90° causes pinching at P_1 and P_2 (Figure B). When torque on the overspeed shaft is the load driving the assembly into this interference position, the leading corner of the tang takes the brunt of the force and thus yields or smears. An impression of the corner in the groove would also be made. These theoretical deformations correlate closely with the actual pieces, as can be seen in the photos. It is noted that increasing the tang-to-groove and pilot-to-bore clearances would reduce such pinching.

An early Change Order (#8461, 3/28/73) describes a problem with "binding to the extent that the shaft would not turn freely". At that time, however, the misalignment problem was not recognized. The "binding" was attributed to a length-type interference, so the obvious solution was to shorten the air distributor shaft.

Unfortunately, this may have contributed to the second part of the problem by reducing the length of engagement of the tang in the slot. As part of the current investigation, a detailed examination was made of the allowable lengths of all the individual components affecting tang engagement. Since the cam shaft thrust bearing is at the engine drive end, this examination involved components for the full length of the engine. The result of this for the original design was an engagement of .702 to .203 inches with the assumption of zero compression of the gaskets. The change order shortened the shaft, reducing engagement by 0.24 inches, and giving a range of engagement from .462 to -.037 (gap) inches. The four gaskets have a total thickness of 7/32 inches. Compression of these gaskets could result in another 0.12 inches or so of tang engagement, depending on joint tightnesses.

The result of these tolerances is that the tang "engagement" may vary from zero to .582", the latter being an interference condition. To this writer, it appears essential that either a provision be added to set proper tang engagement of each individual assembly, or the design be modified to ensure adequate engagement over the existing range of tolerances.

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The deformed shafts from Limerick D-13 "fit" together with about 0.1" engagement. But a PECO photograph taken prior to disassembly clearly shows an increase in engagement of 0.28". The smeared corner surfaces of the tang also show two facets (see attached photo), as if the assembly ran with two different engagement lengths. This may be explained at least in part by the gaskets. The assembly could have initially run with short engagement and gaskets not compressed much. Then, perhaps following an inspection, the joints were retorqued, the gaskets compressed and the engagement increased. Camshaft end float (.007 to .022 inches), distributor shaft end float (.003 to .018 inches), and differential thermal growth of camshaft versus cylinder block (.001 inches per 1°F) are not thought to be major contributors to this effect. In total then, we can account for about half of the variation in engagement length observed at Limerick.

An early in situ inspection of the spare engine being produced for Philadelphia Electric's Peach Bottom plant disclosed an adequate tang engagement of approximately 3/8 inch. No tang deformation was seen, but the joint was not disassembled for close inspection. We were not able to bar the engine, so we did not check for binding. The engine had not been run yet at the time of this inspection. A second more recent inspection of this engine was made following contract testing. Twisting deformation of the tang was clearly visible. Tang engagement was satisfactory, and appeared essentially unchanged from the earlier inspection.

All 8-1/8 O.P. engines have a similar tang-and-groove drive to the main governor. This has an essentially trouble-free history. Comparison of the auxiliary air distributor drive with the governor drive discloses the following differences. The governor drive has:

(a) A wider tang.

(b) A higher yield strength material in the tang.

(c) An adequate and more closely controlled length of engagement.

(d) A tighter clearance on the pilot diameter.

It is also normal practice for FMED mechanics to check that the governor drive shaft remains "free" while slowly barring the engine. They do this by twisting the shaft back and forth by hand and feeling or hearing the "play". This procedure is not in the instruction manual.

Finally, the question is, what should be done to alleviate the situation seen at Limerick? The following are suggestions to address both (a) the alignment of the shafts, and (b) the attainment of adequate tang engagement.

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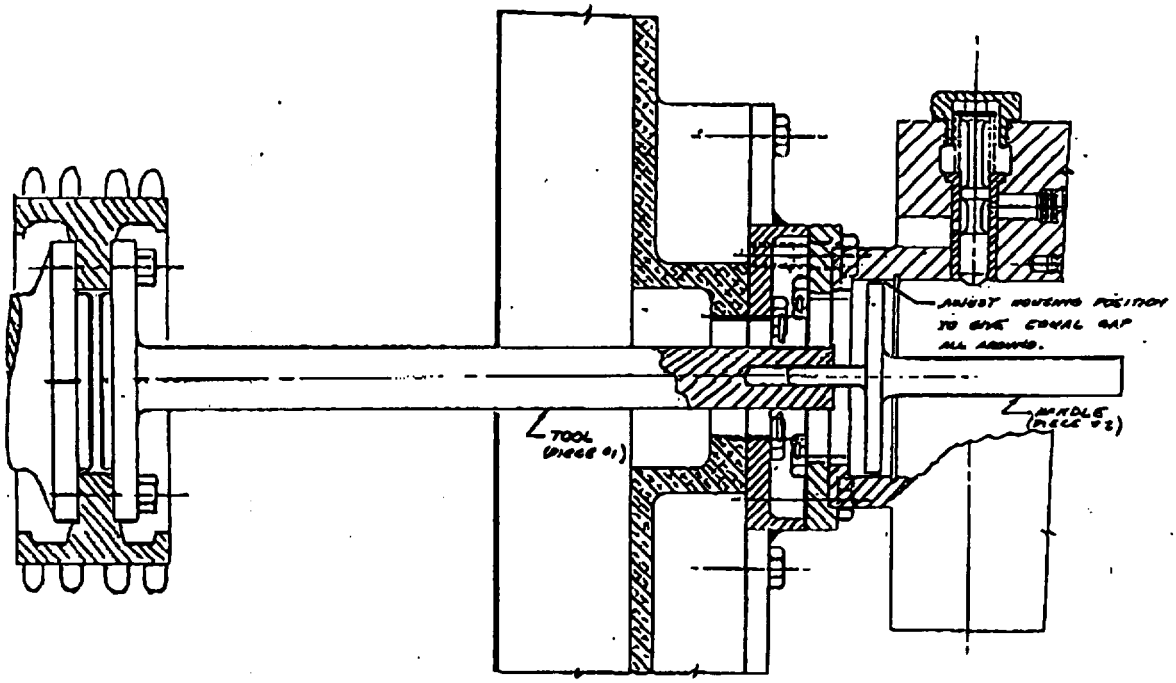
The best way to insure alignment is to check that the distributor shaft does not bind while the engine is barred, as is currently done with the main governor shaft. In addition, a tool should be designed to mount on the camshaft that would indicate correct positioning of the air distributor housing (see for example the following sketch). Following alignment, it is suggested that locating pins (a) between the end cover and the distributor support cover, and (b) between the distribution support cover and the mounting plate, be added to maintain the alignment. The tang also should be redesigned to the full 1 inch width, and the clearances increased to tolerate the remaining misalignment.



A straightforward method of assuring adequate length tang engagement is to lengthen the tang and slot design to accommodate the range of tolerances. This is the suggested fix.

Attachments