



# DIEHL ENGINEERING COMPANY

## CONDITION REPORT No.

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DIEHL ENG. CO. REP: Rob Diehl, P.E.	REPORT DATE: June 11, 2011
VESSEL: 110 Foot Coast Guard Patrol Boat	SUBJECT: STARBOARD MAIN PROPULSION SHAFT BEARING BORE-SIGHT.
CUSTOMER: xxxxx Shipyard	
PROJECT MANAGER: Keith xxxxxx	REFERENCES: 1. DEC Report xxxxxx. 2.
P.O. No: xxxxxx	
LOCATION: xxxxx Harbor, xxxxx	

### SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS:

The boresight data indicates that the Bulkhead Bearing is aligned within a satisfactory tolerance relative to the Reduction Gear Centerline, while the Forward and Aft Strut Bearings are significantly out of alignment in both the vertical and horizontal planes.

Realignment of the Forward and Aft Strut Bearings should be considered, but is not necessarily recommended.

1. **DIEHL ENGINEERING COMPANY** (DEC) measured the alignment of the Starboard Propulsion Shaft, relative to the Reduction Gear Shaft Coupling, while afloat on June 2, 2011, at the xxxxx Shipyard (Reference 1). These measurements indicated the possibility of significant tailshaft bearing misalignment.
2. **BORESIGHT PROCEDURE:** The vessel was dry-docked and the starboard shafting was removed. DEC performed a boresight alignment check during the early morning hours of June 11, 2011. The boresight procedure was as follows:
  - a. A Hamar Laser, Model L-706, was mounted and centered into a concentric circular disc mounted into the aft end of the aft strut bearing. The disc was made to press into the Cutlass bearing bore. The laser projected a beam pointed to the reduction gear output shaft coupling.
  - b. A Hamar 4-Axis Laser Target, Model T-261A, was mounted up to Reduction Gear Output Shaft Coupling Flange Face via a circular disc adapter made to fit the register on the reduction gear output shaft coupling on one side, and the target on the other side, so that the target center axis was on the gear shaft center axis. This target has the capability of measuring both concentricity and angle of the laser beam relative to the target center axis.
  - c. The laser beam angle was adjusted until it was centered ( $\pm 0.001"$ ) in the target on the reduction gear coupling flange face, and the relative angle of the beam to the target center axis was recorded. The gear shaft (and target) was rotated 180 degrees, and the angle data was again recorded. By averaging the two sets of readings, any mounting errors are canceled out, and the relative angle between the gear shaft centerline and a line extending from the coupling face center to the aft strut bearing bore center can be determined. Ideally, there should be no angular difference between these two lines: the projected centerline of the gear shaft should intersect the center of the strut bearing bore.



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- d. Concentric target holders were made to tightly fit into the ends of each Cutlass bearing. A Hamar 2-Axis Laser Target, Model T-218, was placed into the target holders, to measure the offset position of the bearing bores, relative to the Laser Line Of Sight (LLOS). The vertical and horizontal offsets of the targets, relative to the LLOS, were recorded at each end of each bearing. Ideally, all bearing offsets should be close to zero, both vertically and horizontally.
- e. The boresight data yielded the following offsets at each bearing and at the center of the gear shaft coupling flange face:

<u>BEARING</u>	<u>Vertical Offset</u>	<u>Horizontal Offset</u>
<u>Gear Shaft Coupling, Angle</u>	<u>+0.0016 in/in (B/O)</u>	<u>+0.0006 in/in (P/O)</u>
<u>Gear Shaft Coupling, Center</u>	<u>0.000" (Cntr)</u>	<u>0.000" (Cntr)</u>
<u>Bulkhead, Fwd End</u>	<u>-0.085" (Low)</u>	<u>-0.027" (to Port)</u>
<u>Bulkhead, Aft End</u>	<u>-0.075" (Low)</u>	<u>-0.052" (to Port)</u>
<u>Fwd Strut, Fwd End</u>	<u>0.000" (Cntr)</u>	<u>+0.024" (to Stbd)</u>
<u>Fwd Strut, Aft End</u>	<u>+0.026" (High)</u>	<u>+0.006" (to Stbd)</u>
<u>Aft Strut, Fwd End</u>	<u>+0.018" (High)</u>	<u>+0.015" (to Stbd)</u>
<u>Aft Strut, Aft End</u>	<u>0.000" (Cntr)</u>	<u>0.000" (Cntr)</u>

- f. **FIGURE 1** attached depicts a graphical estimate of the fair-curvature of the shaft resulting from the measured bearing offsets, and for the bearing positions relative to the gear shaft centerline.  
(Note: Bearing offset scale is exaggerated for affect.)

### 3. FWD & AFT STRUT BEARING ALIGNMENT ANALYSIS:

- a. The graphical layout shows a severe offset error in both the forward and aft struts, in both the vertical and horizontal planes, relative to the gear shaft centerline.
- b. The aft strut would have to be lowered approximately 1/2", and moved to port approximately 3/16", to bring it into alignment with the gear shaft centerline.
- c. The forward strut would have to be lowered approximately 5/16", and moved to port approximately 1/8", to bring it into alignment.
- d. In their current alignment, both struts have a relatively close alignment with respect to the fair-curve of the shaft. That is, the skew of the bores, fore to aft, relative to the shaft slope through the bearings, is less than the design clearance of 0.020". That means that the shaft will not tend to bind up in these bearings.

### 4. BULKHEAD BEARING ALIGNMENT ANALYSIS:

- a. The Bulkhead Bearing is aligned relatively close to the projected centerline of the gear shaft in both the vertical and horizontal planes. As a result, the fair-curve of the shaft should result in very small face gap differences when the shaft is installed. This agrees with the



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before-afloat coupling alignment measurements (Ref. 1).

- b. In the un-coupled condition, the tailshaft would tend to spring to Port relative to the gear shaft. This is consistent with the before-afloat coupling alignment measurements (Ref. 1).

### 5. SHAFT SYSTEM ALIGNMENT ANALYSIS:

- a. The measured bearing offsets were used to calculate the estimated bearing loads for the existing alignment condition, and compared to the loads that would result if all bearings were set on the reduction gear shaft centerline (i.e. a Straight Line Alignment):

<u>BEARING POSITION</u>	<u>S.L. Load</u>	<u>Est'd Vertical</u>	<u>Est'd Horizontal</u>
<u>Gear Shaft Coupling</u>	280 lbs	480 lbs	+120 lbs
<u>Bulkhead Bearing</u>	430 lbs	30 lbs	-220 lbs
<u>Forward Strut Bearing</u>	210 lbs	450 lbs	+130 lbs
<u>After Strut Bearing</u>	1210 lbs	1150 lbs	-40 lbs

- b. The Before-Afloat Alignment measurements indicated a shaft load of 470 lbs will be supported by the gear shaft coupling (Ref. 1). This is within 2% of the load predicted using the measured bearing offsets.
- c. The current alignment condition results in a very nearly unloaded (vertically) bulkhead bearing. If not for the considerable horizontal misalignment, resulting in a significant horizontal load at the bulkhead bearing, the shaft would be at risk of whirling or lateral vibration due to the lightly loaded bearing.
- d. The current alignment results in estimated peak bending stresses occurring in two places: 2000 psi at the aft strut bearing, and 1600 psi at the bulkhead bearing. The bending stress at the aft stern bearing is due primarily to the overhung weight of the propeller, and is not influence significantly by the bearing alignment. The bending stress at the bulkhead bearing is strongly influenced by the bearing alignment condition, and could be significantly reduced by re-aligning the two strut bearings.
- e. DEC normally recommends limiting marine shaft bending stresses to at or below 2000 psi in order to minimize the risk of bending fatigue failure. However, this limit is primarily used for shafts subject to corrosion, and as this shaft is made out of corrosion resistant material, this limit is not so critical.

### 6. CONCLUSIONS AND RECOMMENDATIONS:

- a. The current alignment does not conform to the requirement for all bearings to be on an extension of the gear shaft centerline, within a reasonable tolerance. In order to achieve this alignment criteria, the forward and aft strut bearings would require significant realignment. This action would entail the breaking loose of the struts from their Chockfast connections to the hull, optically positioning the two struts onto the gear shaft centerline, and re-pouring Chockfast to hold the realigned bearing positions.

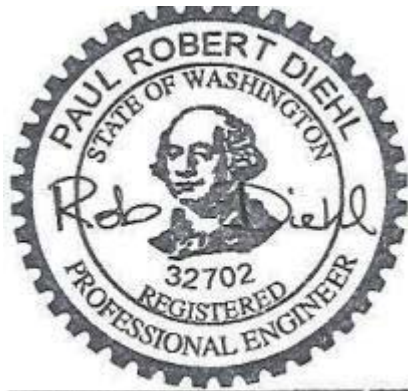


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- b. The current vertical alignment would result in a nearly unloaded bulkhead bearing, if not for the corresponding horizontal misalignment on that bearing.
- c. The decision as to re-align the strut bearings, or not, is not an easy one to make. The considerable cost to re-align must be weighted against the risk of doing nothing. The vessel has presumably been running with the current alignment for some time, without any know complaints with regards to excessive shaft noise or vibration coming from the starboard shaft. On the other hand, the current alignment has some potential for developing lateral shaft vibration, especially as bearing clearances increase due to wear. Also, the relatively high shaft bending stresses could eventually lead to a shaft failure, but this risk is considered rather low.
- d. Our recommendation to re-align the two strut bearings is therefore neutral. The decision to realign should be made by the USCG after weighing all of the costs versus risks and benefits.



EXPIRES: 4-16-13

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