NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

April 21, 2015

MATERIALS LABORATORY FACTUAL REPORT | Report No. 15-037

1. ACCIDENT

Place	:	Brunswick, GA
Date	:	March 24, 2015
Vehicle	:	Piper PA-44-180, N923RS
NTSB No.	:	ERA14FA168
Investigator	:	Shawn Etcher, AS-ERA

2. COMPONENTS EXAMINED

Rapco Vacuum Pump 215CC
Rapco Vacuum Pump 216CW

3. DETAILS OF THE EXAMINATION

On March 24, 2014, about 1745 eastern daylight time, a Piper PA-44-180, N923RS, was destroyed following an inflight breakup and subsequent impact in a waterway in a marsh area near Brunswick, Georgia. The two private pilots were fatally injured. The airplane had departed from the Concord Regional Airport (JQF), Concord, North Carolina, about 1551 EDT and had an intended destination of Jacksonville Executive Airport at Craig (CRG), Jacksonville, Florida. Several eyewitnesses reported hearing a "thud" or "explosion" and observed debris falling.

Two vacuum pumps from the aircraft engines (Lycoming O-360-E1A6D) were retained by the NTSB for further examination.[1] Examination of the pumps found both drive shafts sheared. According to the maintenance logs, the left engine vacuum pump (P/N 215CC, S/N 132402) had accumulated 1207.8 total hours since overhaul and was installed on May 13, 2011. The right engine vacuum pump (P/N 216CW, S/N 155135) had accumulated 172.5 total hours.

3.1. Left Vacuum Pump

The left vacuum pump is shown in Figure 1, as received. The pump exhibited no external damage to the housing (see Figure 1 and Figure 2). However, the outlet side tube exhibited buckling on the inside on the elbow, consistent with bending forces towards that direction. When handled or moved, the pump exhibited a rattling sound from the inside.

[1] The Lycoming O-360 series are a family of four-cylinder, direct-drive, horizontally opposed, air-cooled, piston aircraft engines.

Granular material was observed falling out through the drive side input port tube. The drive end coupling could be turned, which created a rattling or grinding sound.

The pump was disassembled to reveal the condition of the internal components (see Figure 3). The interior of the pump contained a white brittle material on most of the drive end surfaces. This material was consistent with salt deposits from evaporated salt or brackish water that infiltrated the pump after the accident. Upon opening the pump housing, the rotor was found fractured in multiple locations (see Figure 4). The pieces of the rotor were carefully reassembled, as shown Figure 5. The rotor flanges and slots were labeled 1 through 6, clockwise, for the purposes of this report. Cracks were apparent on the rotor at slots numbered 1, 3, 4, and 5. A transverse crack was present across the hole on rotor flange #2.

The forward (inlet flange end) and aft (discharge flange end) faces of the rotor were examined for wear marks indicative of rotor motion in contact with the housing. As exemplified in Figure 6, these rotor faces exhibited dents and wear consistent with non-rotational or stationary contact with adjacent components (the housing).

Circumferential score marks were observed on the interior surface of the rotor center hole (Figure 7). The location of a prominent score mark in Figure 7 (arrow) was located at a location on the rotor fracture surface consistent with the fracture initiation on this fragment. The interior surface also exhibited longitudinal and angled wear marks.

The vanes were removed from the pump housing and rotor slots, and they are illustrated in Figure 8 and Figure 9. All of the vanes were intact—none had cracked or fractured. The widths of the vanes recovered from this pump were measured using digital calipers and are listed in Table I. Horizontal and vertical sliding marks were present on the faces of the vanes. These marks were consistent with similar marks on the inside faces of the rotor vane slots. The horizontal marks were consistent with sliding of the vanes that occurred during rotational operation of the rotor. Each of the vanes exhibited one flat vertical face and one rounded vertical face.

The interior of the drive end pump housing is shown in Figure 10. This surface exhibited the white brittle material consistent with salt deposits found on the opposite interior of the pump. The pattern of the white material was consistent with the resting position of the rotor and vanes after the airplane accident and recovery.

The interior of the circular housing is illustrated in Figure 11 and Figure 12. These surfaces also show the white deposits found on the other interior surfaces. These deposits were most prevalent at regular positions consistent with the rest position of the vane slots in the rotor. Circumferential wear marks, consistent with contact during rotation, were present.

3.2. Right Vacuum Pump

The right vacuum pump is shown in Figure 13, as received. The pump exhibited no external damage to the housing (see Figure 14). The drive-side coupling end could not be turned. The fracture surface of the plastic coupling exhibited rotational river patterns, consistent with overstress fracture in torsion.

The pump was disassembled to reveal the condition of the internal components (see Figure 15). Similar to the left pump interior, a white brittle material was found on most of the interior surfaces. The rotor was wedged in position with the interior housing surfaces, even though it had fractured in multiple locations. The rotor and forward housing interior exhibited orange-colored oxidation that was consistent with rust found on the interior nut.

Figure 16 shows the multiple fracture locations of the rotor, found upon opening. The pieces of the rotor were reassembled as shown Figure 17. As with the left pump, the rotor flanges and slots were labeled 1 through 6 clockwise for the purposes of this report. Upon opening, cracks were found on the rotor at slots numbered 1, 2, and 4.

Circumferential score marks were observed on the interior surface of the rotor center hole (Figure 18). The fracture surfaces of the rotor were consistent with brittle overstress fracture. The patterns of the fracture surfaces adjacent to the center bore were consistent with multiple crack initiation locations. However, no indications of progressive fracture were observed.

The faces of a portion of the right pump rotor are illustrated in Figure 19. These faces exhibited primarily circumferential wear marks. The outlet side exhibited some chatter and salt deposition (see Figure 19a). No indications of longitudinal contact with the mating surfaces were observed.

The vanes were removed from the pump housing and rotor slots, as illustrated in Figure 20 and Figure 21. The widths of the vanes recovered from this pump were again measured and listed in Table I. Vanes 1 and 2 were cracked in multiple locations, and Vane 1 had shattered completely. As such, the widths of these two vanes were not measured. The dimensions of these vanes were not consistent with those of the left pump.

Horizontal and vertical sliding marks were present on the faces of the vanes. These marks were consistent with similar marks on the machined inside faces of the rotor pieces. The horizontal marks were consistent with sliding of the vanes that occurred during rotational operation of the rotor. Each of the vanes exhibited one flat vertical face and one rounded vertical face.

The interior of the drive end pump housing is shown in Figure 22. This surface exhibited the white brittle material consistent with salt deposits found on the opposite interior of the pump. The pattern of the white material was consistent with the resting position of the rotor and vanes in the pump.

The interior of the circular housing is illustrated in Figure 23 and Figure 24. These surfaces show the white deposits found on the other interior surfaces. These deposits were most prevalent at regular positions consistent with the rest position of the vane slots in the rotor. Scraping was present on the inside wall of the housing, predominantly at the location of the #1 vane slot. This was the location of the crushed vane (#1) and a crack in the rotor.

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Table I – Widths of the vanes from the left vacuum pump and the right vacuum pump.

Vane No.	LH Vane Width (in)	Notes	RH Vane Width (in)	Notes
1	0.5215	Appeared bent	N/A	Shattered
2	0.5505		N/A	End was fractured
3	0.5585		0.8515	
4	0.5580		0.8510	
5	0.5570		0.8520	
6	0.5565		0.8515	

Figure 1 – The left vacuum pump, as received, showing the serial and part number markings on the side. The arrow denotes the partially collapsed outlet tube, consistent with excessive bending stresses.

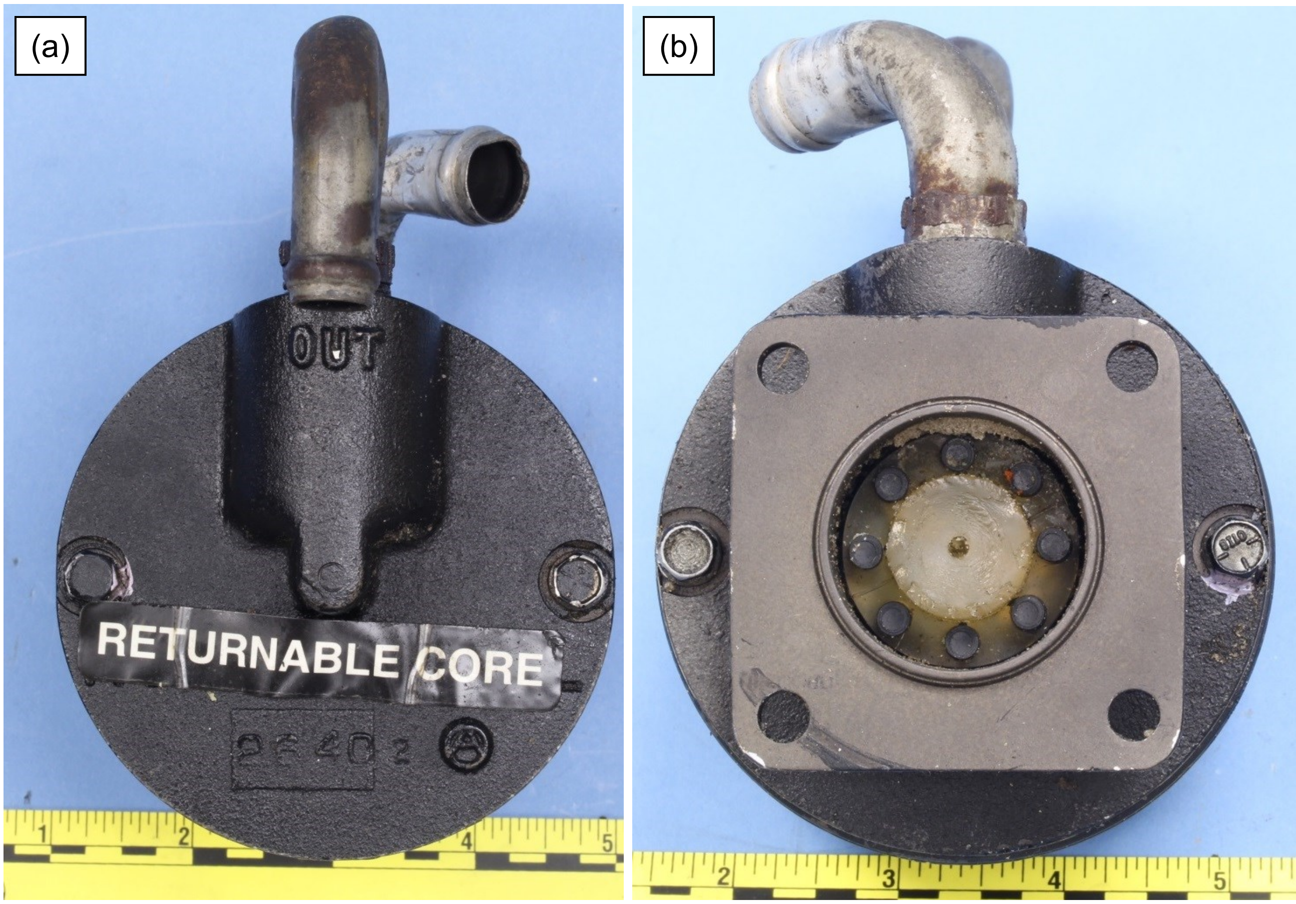

Figure 2 – The left vacuum pump, as received, shows (a) the outlet side and (b) the drive side.

Figure 3 – The interior of the left vacuum pump after removing the outlet side housing cover.

Figure 4 – Closer view of the left vacuum pump rotor, after removal of the outlet housing cover. The rotor had fractured in multiple locations.

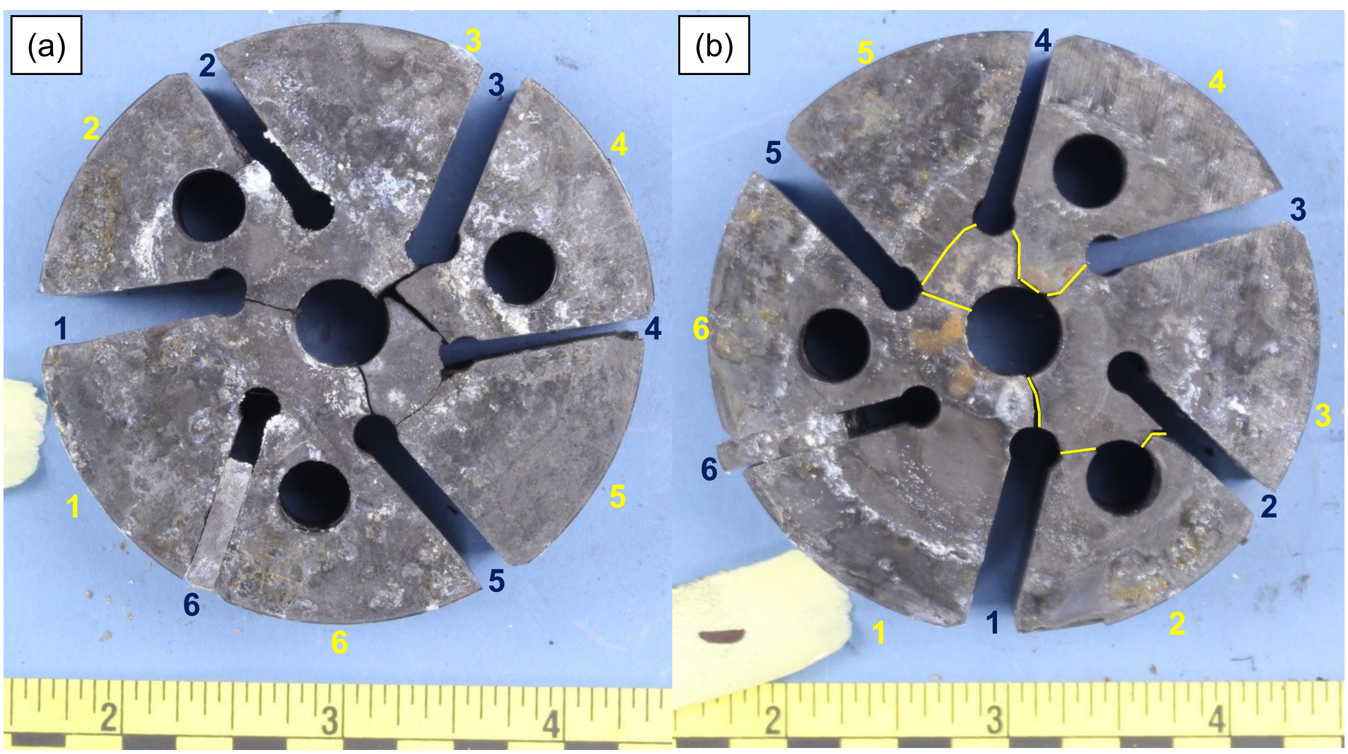

Figure 5 – The fractured rotor from the left vacuum pump, after removal from the housing from (a) the outlet side and (b) the opposite drive side. The rotor prongs are labeled 1 – 6 in yellow, and the vane slots are labeled 1 – 6 in dark blue (vane 6 was still in slot 6). The fracture locations are highlighted with the cracks in yellow.

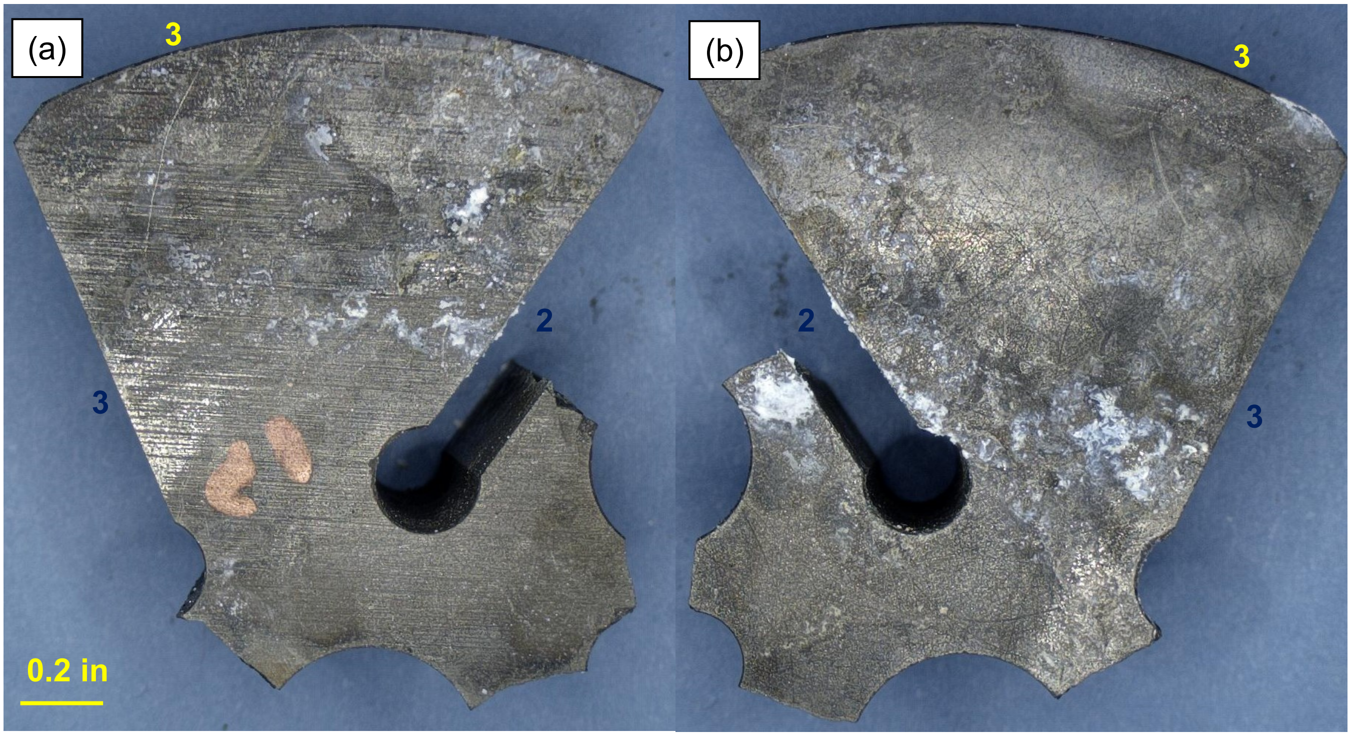

Figure 6 – The (a) drive side and (b) outlet side faces of the left pump rotor, showing longitudinal wear marks.

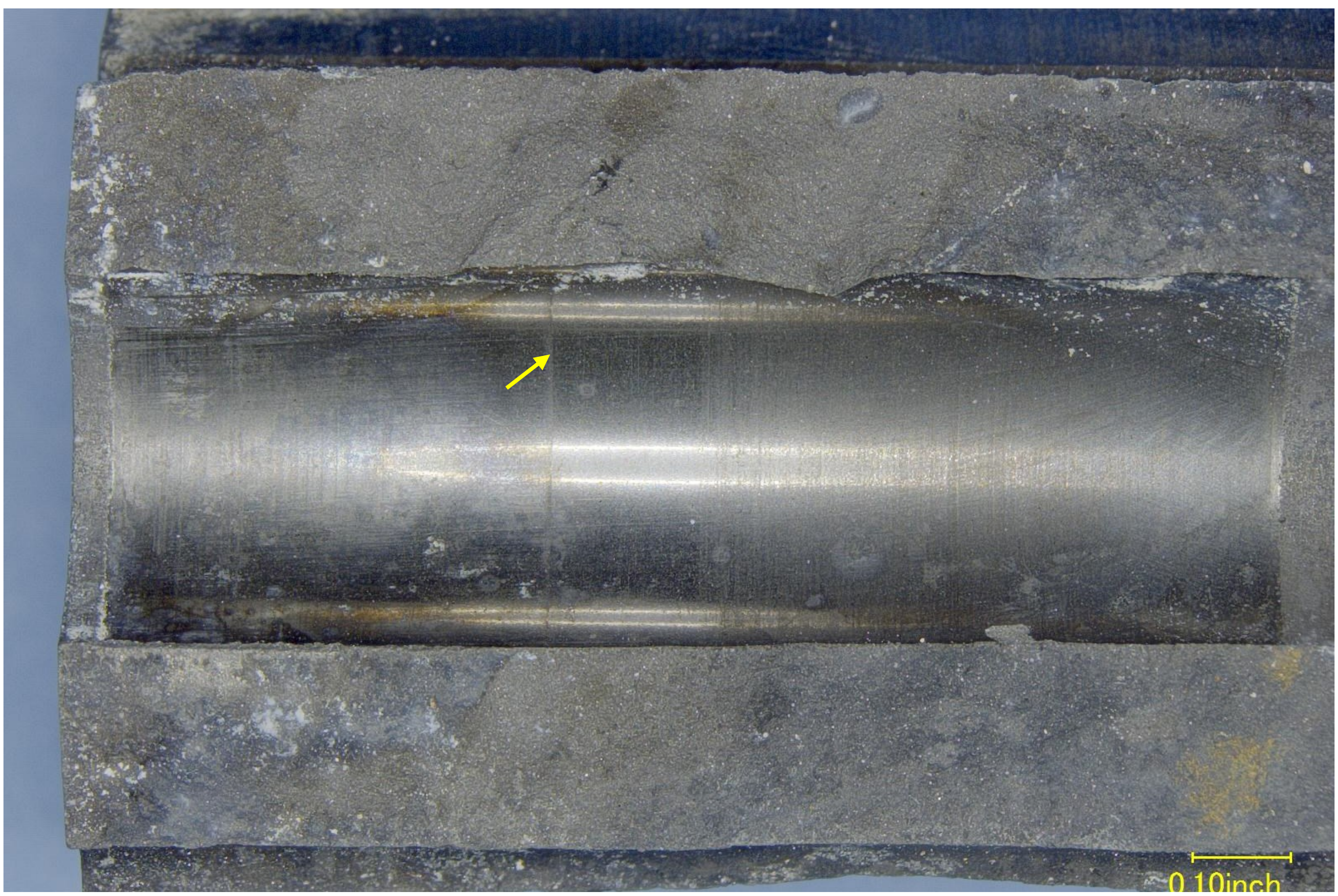

Figure 7 – The inside bore of the left pump rotor fragment 3, showing circumferential and curving longitudinal wear marks on the bore. A notable wear mark was present (arrow).

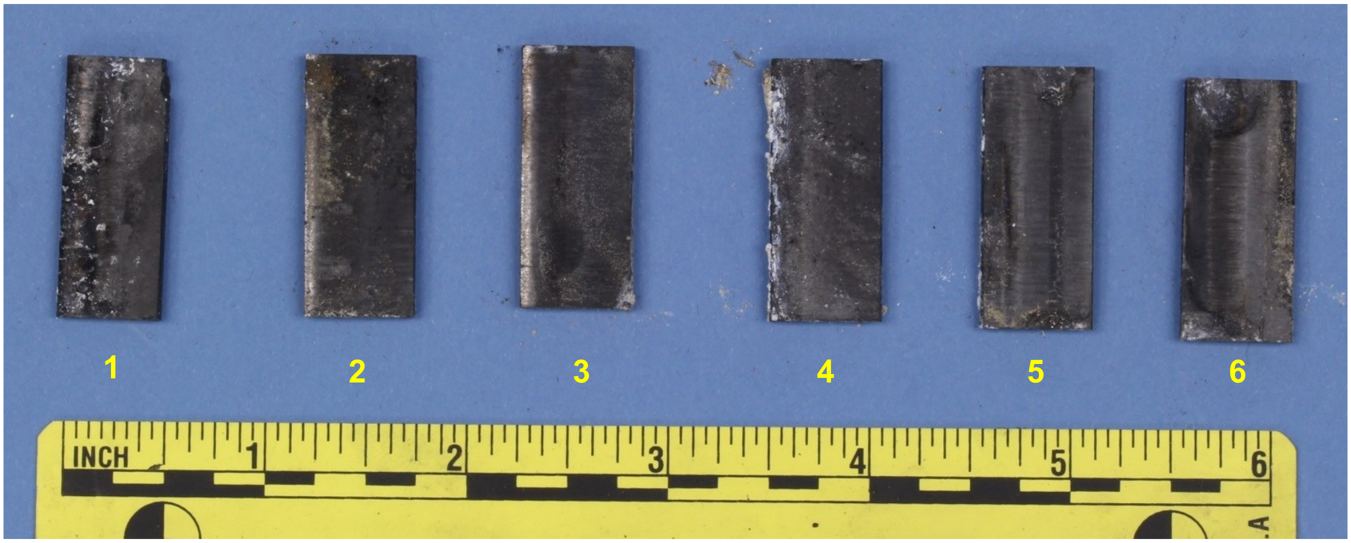

Figure 8 – The vanes from the left pump, after removal. The vanes were labeled 1 through 6 for the purposes of this report, and correspond to the slots clockwise of the rotor prongs labeled in Figure 4.

Figure 9 – The left pump vanes, after removal, showing the opposite faces from that shown in Figure 8.

Figure 10 – The inside face of the drive side housing cover, after removal of the interior rotor and vanes.

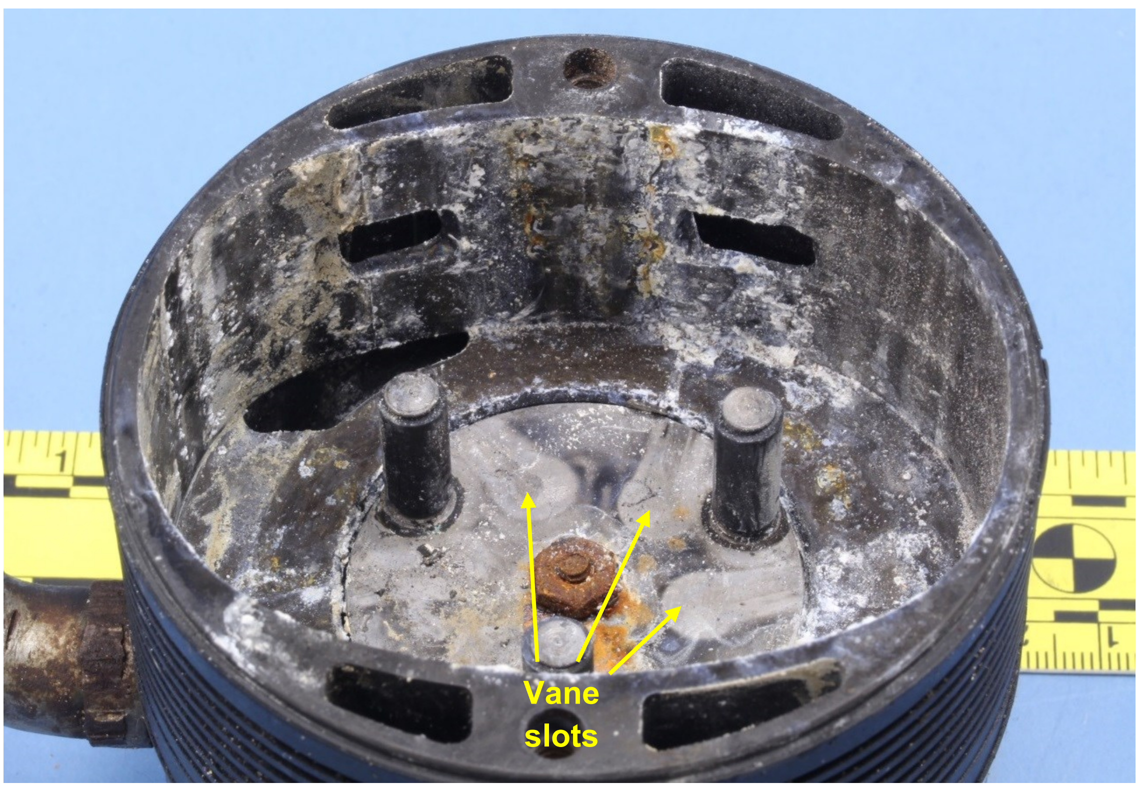

Figure 11 – The interior surface of the left pump housing, after removal of the rotor and vanes. The witness marks showing the locations of the vane slots are labeled on the figure.

Figure 12 – The interior surface of the left pump housing, after removal of the rotor and vanes, opposite Figure 11.

Figure 13 – The right vacuum pump, as received, showing the part and serial numbers.

Figure 14 – The right vacuum pump, as received, showing (a) the outlet side and (b) the drive side.

Figure 15 – The interior of the right vacuum pump after removing the outlet side housing cover.

Figure 16 – Closer view of the right vacuum pump rotor, after removal of the outlet housing cover. The rotor had fractured in multiple locations. The rotor prongs are labeled 1 through 6 for the purpose of this report.

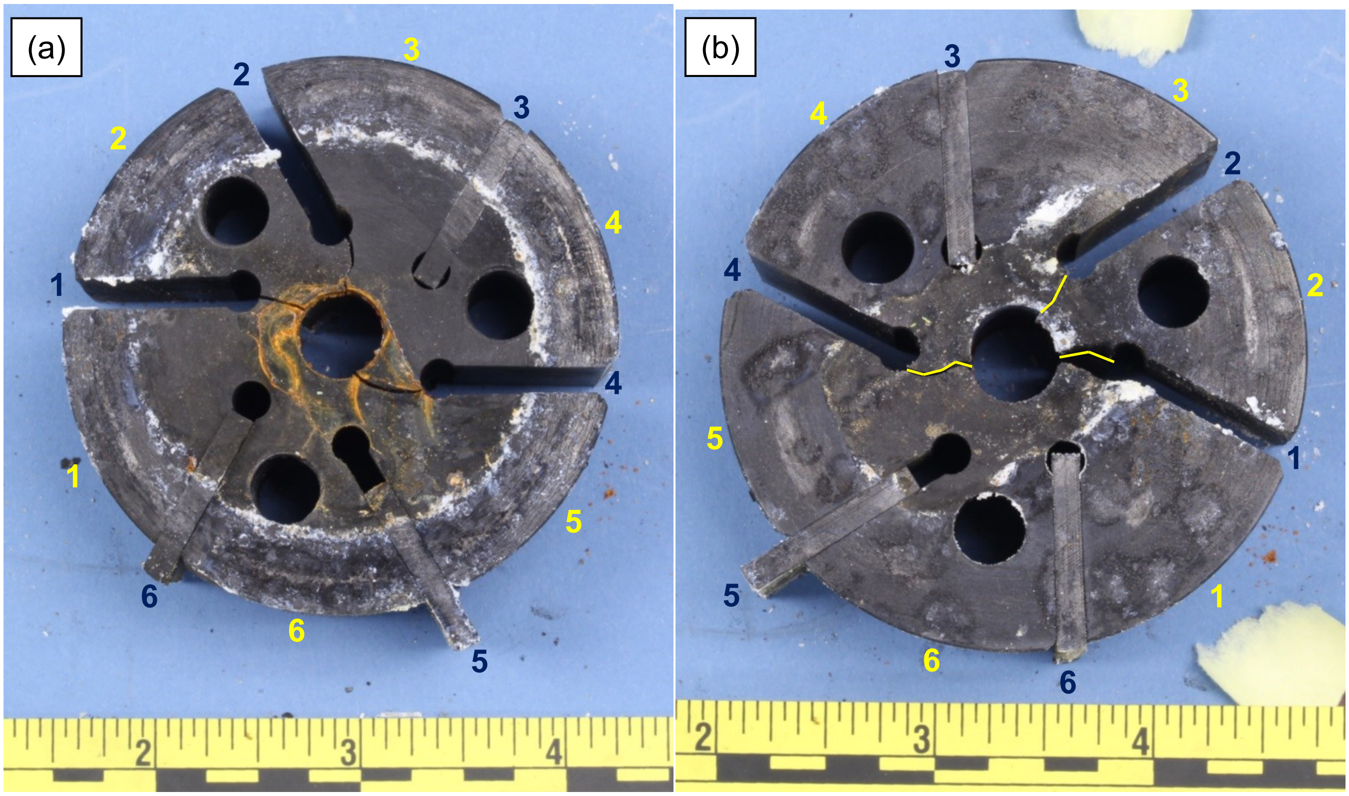

Figure 17 – The fractured rotor from the right vacuum pump, after removal from the housing from (a) the outlet side and (b) the opposite drive side. The fracture locations are highlighted with the primary cracks in yellow.

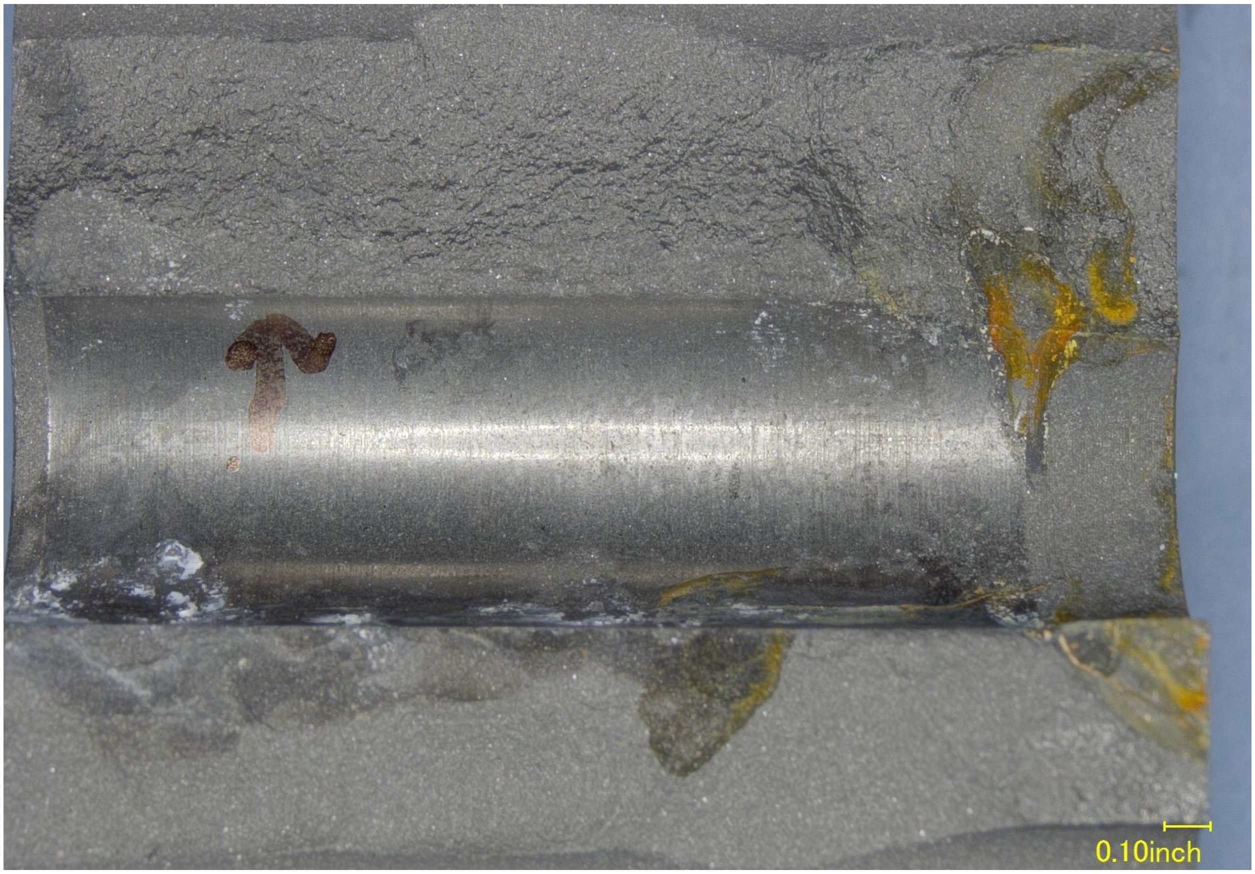

Figure 18 – The fracture surfaces of the rotor interior.

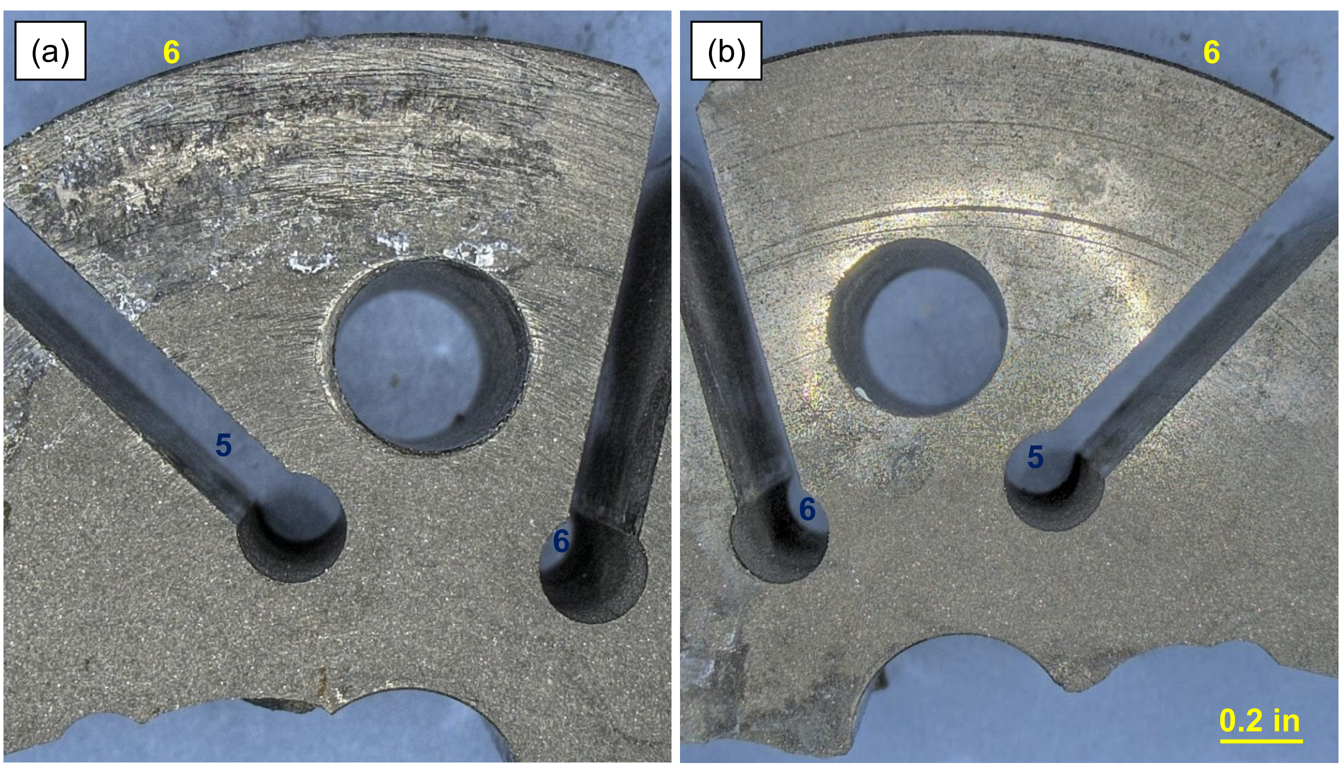

Figure 19 – The faces of the right pump rotor, showing rotational wear marks on (a) the outlet side and (b) the drive side.

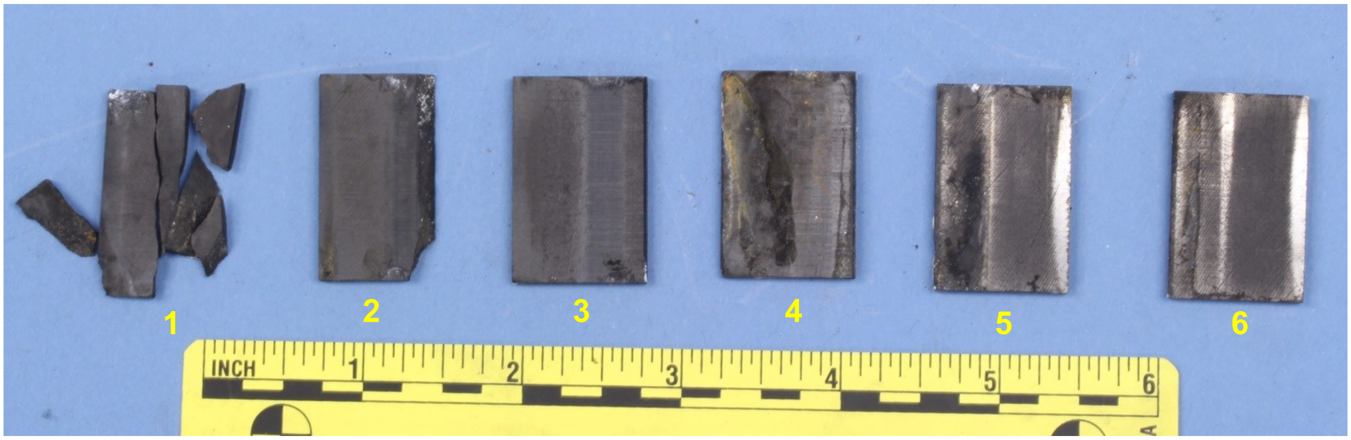

Figure 20 – The vanes from the right pump, after removal. The vanes were labeled 1 through 6 for the purposes of this report, and correspond to the slots clockwise of the rotor prongs labeled in Figure 16.

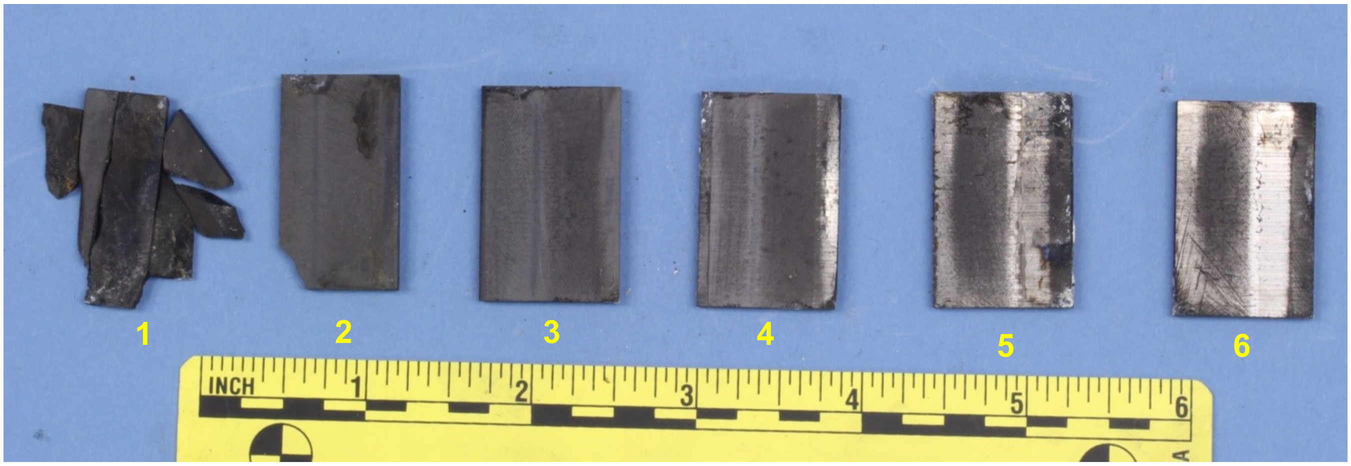

Figure 21 – The right pump vanes, after removal, shown opposite side that in Figure 20.

Figure 22 – The inside face of the drive side housing cover, after removal of the interior rotor and vanes from the right pump.

Figure 23 – The interior surface of the right pump housing, after removal of the rotor and vanes.

Figure 24 – The interior surface of the right pump housing, after removal of the rotor and vanes, opposite Figure 23.