NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C. 20594

August 4, 2020

POWERPLANTS GROUP CHAIRMAN'S FACTUAL REPORT

NTSB ID No.: ERA20MA001

A: ACCIDENT

Location:	Bradley International Airport, Windsor Locks, Connecticut
Date:	October 2, 2019
Time:	0953 eastern daylight time
Aircraft:	Boeing B-17G, N93012, Collings Foundation

B: POWERPLANTS GROUP

Group Chairman:	Gordon J. Hookey National Transportation Safety Board Washington, D.C.
Member:	Heidi Kemner National Transportation Safety Board Ashburn, Virginia
Member:	Michael Richards National Transportation Safety Board Washington, D.C.
Member:	Todd Gentry Federal Aviation Administration Washington, D.C.
Member:	Thomas J. Davis Federal Aviation Administration Kansas City, Missouri

C: SUMMARY

On October 2, 2019, at 0953 eastern daylight time, a Boeing B-17G, N93012, owned and operated by the Collings Foundation, was destroyed during a precautionary landing and subsequent runway excursion at Bradley International Airport (BDL), Windsor Locks, Connecticut. The commercial pilot, airline transport pilot, and five passengers were fatally injured. The flight mechanic/loadmaster and four passengers were seriously injured, while one passenger and one person on the ground incurred minor injuries. The local commercial sightseeing flight was conducted under the provisions of Title 14 *Code of Federal Regulations* Part 91, in accordance with a Living History Flight Experience exemption granted by the Federal Aviation Administration (FAA). Visual meteorological conditions prevailed in the area and no flight plan was filed for the flight, which departed BDL at 0947.

The engines installed on the airplane were Curtiss-Wright Cyclone R-1820 nine-cylinder radial engines.[1] The Nos. 3 and 4 engines were shipped to Vintage Radials in Tehachapi, California for disassembly and examination in the presence of members of the Powerplants Group on February 11 to 20, 2020.[2] The disassembly and examination of the two engines did not reveal any preexisting mechanical defects or failures. However, the examination of the No. 3 engine's pistons and spark plugs showed evidence of detonation that would have resulted in a significant loss of engine power.[3] The examination of the No. 4 engine showed the P-lead to the left and right magnetos was separated from the magnetos' housings. The leads to each of the magnetos were secured with a single strand of safety wire that was loose. The lead to the left magneto was completely out of the housing allowing the grounding tab to contact the housing shorting it out. When a piece of cardboard was placed between the grounding tab and the magneto case wall, all nine ignition leads sparked. The lead to the right magneto was partially engaged, so the grounding tab was not contacting the case. But the gap between the points was less than the required minimum and when the magneto was tested, the No. 8 cylinder's ignition leads did not spark at all and the sparks for the other eight cylinders' ignition leads were weak and intermittent.[4]

The No. 4 engine's two magnetos were shipped to S & T Aircraft Accessories, New Braunfels, Texas for testing and examination.[5] Because of the COVID-19 virus and the

[1] The engine is also referred to as a Wright R-1820. The R-1820 engine was originally made by the Wright Aeronautical Corporation that was a division of the Curtiss-Wright Corporation. The Curtiss-Wright Corporation was formed in 1929 with the merger of 12 aviation-related companies including the Curtiss Aeroplane and Motor Company of Buffalo, New York and the Wright Aeronautical Corporation of Dayton, Ohio. R-1820 engines were also made under license by Lycoming and Pratt & Whitney Canada and during World War II, by the Studebaker Corporation.

[2] Vintage Radials is an FAA-approved repair station, Certificate No. VDDR067R, that overhauls and repairs Curtiss-Wright and Pratt & Whitney radial engines.

[3] Detonation in a piston engine occurs when the fuel-air mixture in the cylinder detonates or explodes prematurely rather than being ignited by the spark plug and burning evenly and smoothly. Detonation can cause an engine to run rough and lose power.

[4] The cylinders are numbered in a clockwise pattern from the rear looking forward with the No. 1 cylinder being at the top of the engine, or the 12:00 o'clock position. All references to position or directions, as referenced to the clock, will be as viewed from the rear, looking forward, unless otherwise specified.

[5] S & T Aircraft Accessories is an FAA-approved Repair Station, Certificate No. CC2R737K, that repairs a wide range of aircraft reciprocating and turbine engine components including magnetos.

associated travel restrictions, it was necessary to accomplish the testing and examination of the magnetos via a teleconference link on July 15, 2020. On both the left and right magnetos, when the drive spline was rotated, the compensating cam rotated concurrently. Both the left and right magneto's compensating cams were marked for use on an R-1820 engine. The testing of the magnetos revealed the left magneto would produce sparks and the right magneto after initially producing sparks for a few seconds would not. The examination of the magnetos showed the points gap was 0.014 inches on the left magneto and 0.004 inches on the right magneto in comparison to the required 0.008 to 0.010 inch gap. The disassembly of the right magneto showed that the compensating cam and associated cam follower were worn.

The propellers on the airplane were Hamilton Standard three-bladed, variable-pitch constant speed propellers. The Nos. 4 and 3 propellers were shipped to Maxwell Aircraft Service, Minneapolis, Minnesota for disassembly and examination in the presence of members of the Powerplants Group on January 28, 2020 and July 15, 2020, respectively.[6] The examination of the No. 4 propeller showed that it was in the feathered position at the time of impact.[7] The examination of the No. 3 propeller showed that it was in the low pitch position at the time of impact.

D: DETAILS OF INVESTIGATION

1.0 No. 4 engine's magnetos

1.1 Magneto description

The R-1820-97 engine was equipped with two magnetos, identified as the left and right magnetos. The left magneto was a model No. SF 9 LU-3 and serial No. (SN) CC-44131 and the right magneto was model No. SF 9 LC-3and SN D7384. According to the repair instructions, the SF 9 LU-3 and SF 9 LC-3 are identical except for the manufacturer. The SF 9 signifies the magneto is a single type magneto, flange mounted for a nine-cylinder radial engine. The L signifies that it rotates counterclockwise. The U signifies the magneto was manufactured by American Bosch Corporation and the C signifies the magneto was manufactured by the Delco Remy Division of General Motors Corporation. The -3 signifies the modification number of the magneto.

A magneto is an electrical generator that uses a rotating magnet to produce high-voltage electricity and distributes the electricity to the spark plugs. The voltage generated is sufficient to jump the gaps on the spark plugs' tips to produce a spark to ignite the fuel-air

[6] Maxwell Aviation is an FAA-approved repair station, Certificate No. UF2R211L, that overhauls and repairs aircraft propellers.

[7] Feathering a propeller refers to rotating the propeller blades so the leading edge is into the wind to reduce the frontal area to an absolute minimum and to minimize or stop rotation of the propeller blades, to reduce the drag caused by the propeller.

mixture in the cylinders. The SF 9 LC-3/SF 9 LU-3 magnetos are four-pole magnet induction type magnetos for use on the nine-cylinder R-1820 radial engine. The left magneto provides the electrical current to the rear spark plugs and the right magneto provides the electrical current to the front spark plugs.

1.2 Magneto examination and testing

1.2.1 Vintage Radials

The left and right magnetos were still in place on the rear of the engine. (Photo No. 1) The left and right magnetos' serial numbers were D7384 and CC-44131, respectively. The left magneto's P-lead was pulled out of its fitting. The left and right magnetos' P-leads were both safety wired to their respective housings with a single strand of safety wire that was loose. The right magneto's P-lead was still in place, although it was partially pulled out of its fitting. (Photos Nos. 2 and 3) According to the maintenance instructions, the magnetos' P-leads should be secured with a clip rather than safety wire. The left magneto's lead had pulled out of the swaged fitting causing the magneto to internally ground when the grounding tab contacted the housing. (Photo No. 4) The right magneto's grounding tab had a gap between the tab and the magneto's housing. (Photo No. 5) It appeared that the safety wire was being used to hold the P-leads in position to the fittings.

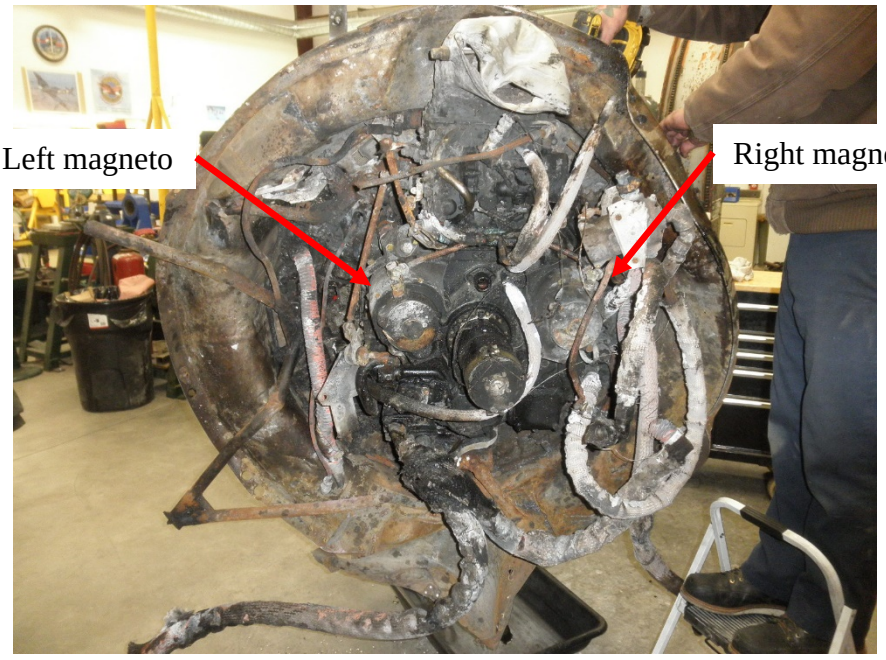

Photo No. 1: View of the rear of the No. 4 engine showing the left and right magnetos were still in place.

Photo No. 2: Close up of No. 4 engine's left magneto showing P-lead pulled out of the fitting and single strand of safety wire wrapped around the lead.

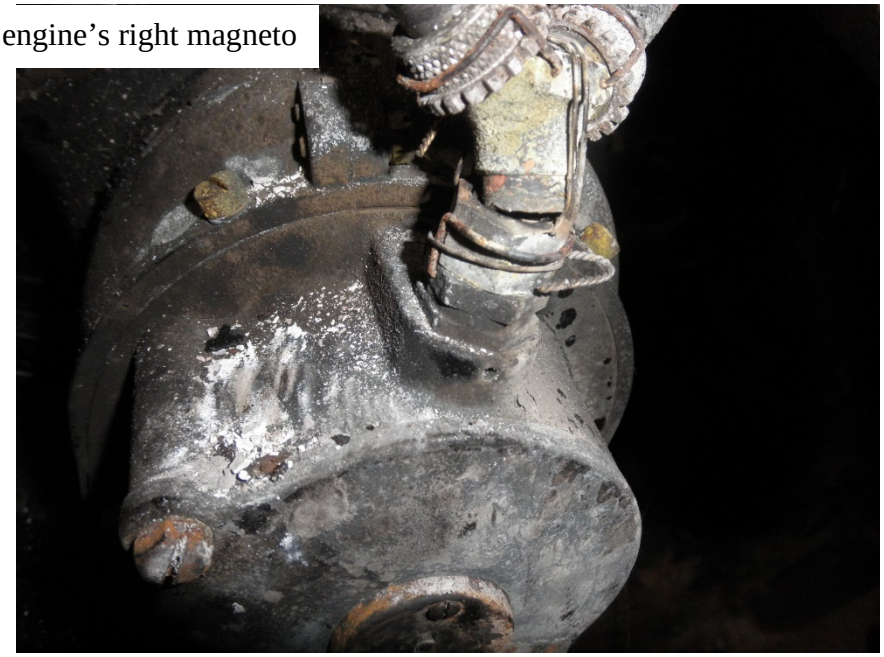

Photo No. 3: Close up of No. 4 engine's right magneto showing P-lead partially pulled out of the fitting and the single strand of safety wire wrapped around the lead.

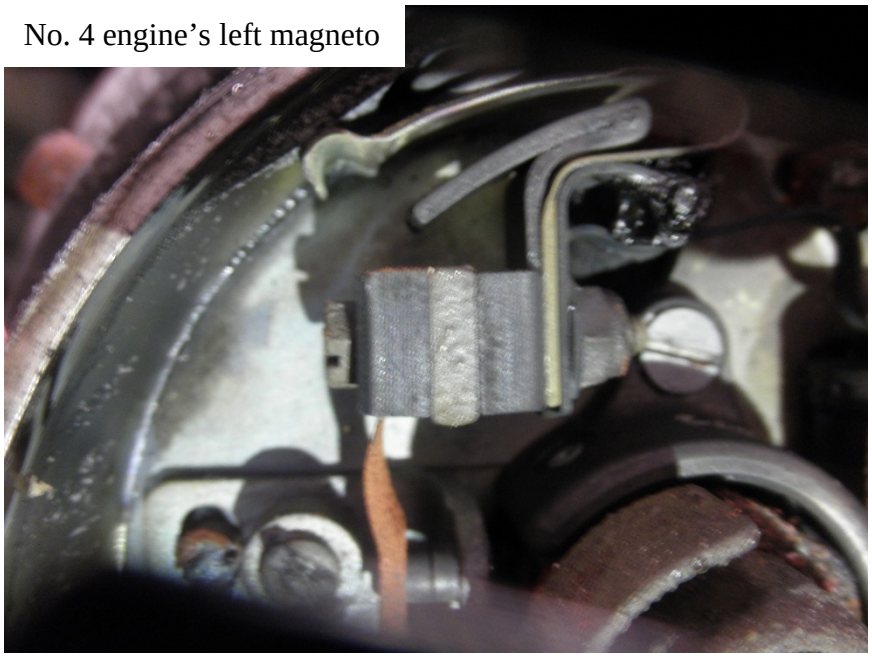

Photo No. 4: Close up view of No. 4 engine's left magneto showing grounding tab contacting the housing wall.

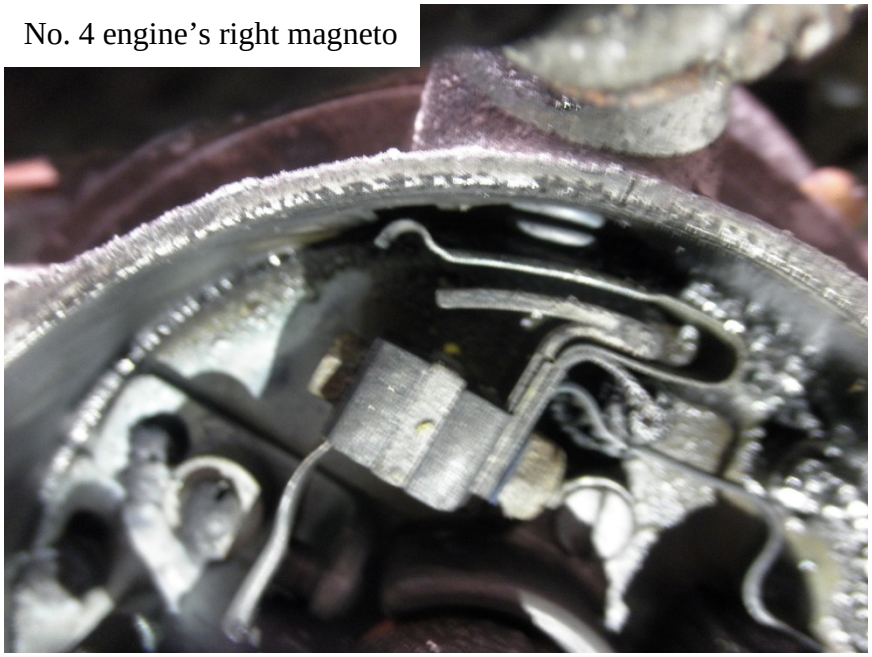

Photo No. 5: Close up view of No. 4 engine's right magneto showing grounding tab separated from the housing wall.

When the left magneto's drive shaft was rotated, the cam follower would open and close the points. The gap when the points were open was measured with a feeler gauge[8] and found to be 0.014 inches. (Photo No. 6) When the right magneto's drive shaft was rotated, the

[8] A feeler gauge is a tool consisting of strips of metal of different thicknesses used either individually or combined to measure the clearance between to parts.

gap when the points were open was measured and found to be 0.006 inches. (Photo No. 7) The gap should be 0.008 to 0.010 inches.

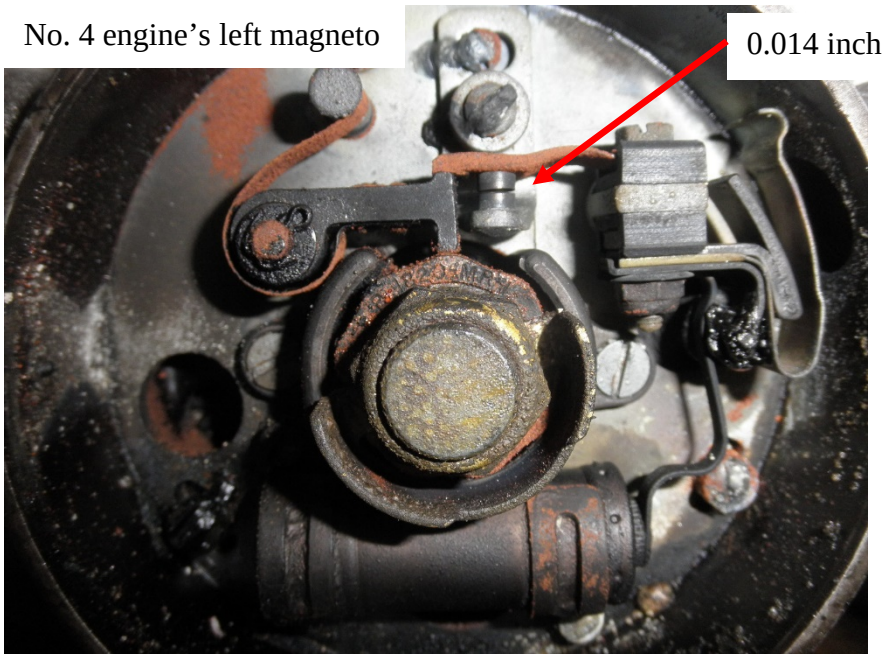

Photo No. 6: Close up of the No. 4 engine's left magneto points showing a gap of 0.014 inches.

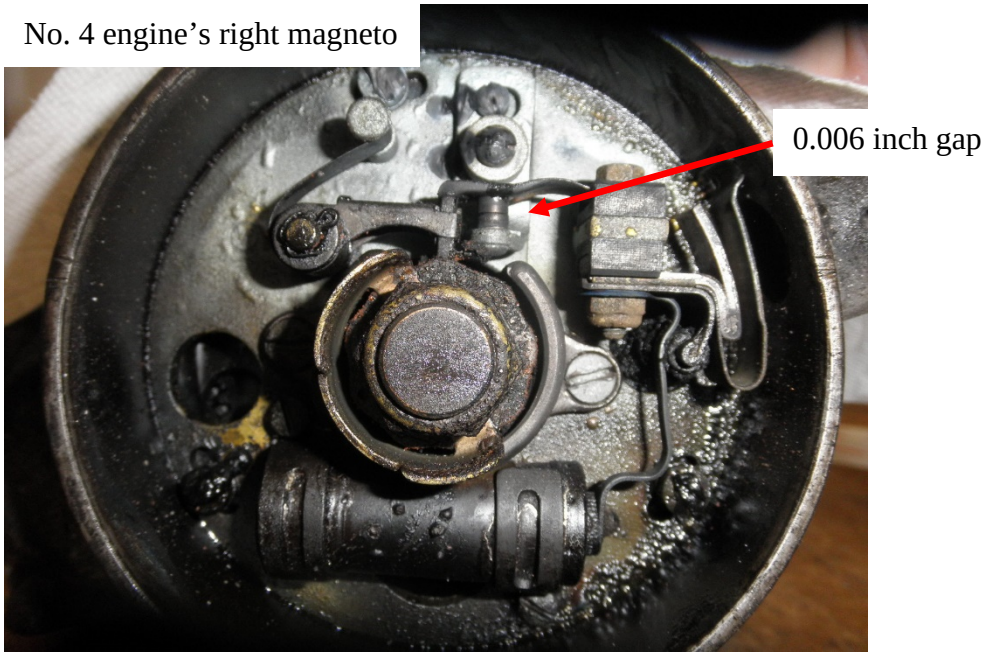

Photo No. 7: Close up of the No. 4 engine's right magneto points showing a gap of 0.006 inches.

The left and right magnetos were tested on a magneto test bench. (Photos Nos. 8 and 9) When the left magneto was initially tested, there were no sparks because the grounding tab was shorting out on the housing. When a piece of cardboard was inserted between the housing and the grounding tab and the magneto was tested again, there were sparks from all nine of the

ignition leads. When the right magneto was tested, ignition leads Nos. 1 through 7 and 9 would spark. The No. 8 ignition lead would not spark. The sparks observed from the ignition leads Nos. 1 through 7 and 9 were all very weak. In addition, the operation of the right magneto was intermittent.

Photo No. 8: Magneto test unit with a magneto installed.

Photo No. 9: Data plate on the magneto test unit.

1.2.2 S&T Aero

1.2.2.1 General

The left and right magnetos were received at S & T Aircraft Accessories in a cardboard box. (Photo No. 10) The examination of the box showed that it was intact and still sealed. When the box was opened, the two magnetos were removed. The magnetos had been marked at Vintage Radials with an L and R to identify them as the left and right magnetos, respectively. The examination of the data plate on the magneto marked L showed it to be Model No. SF 9 LU-3 and SN D7384. (Photos Nos. 11 and 12) The examination of the data plate on the magneto marked R showed it to be Model No. SF 9 LC-3 and SN CC-44131. (Photos No. 13 and 14) The model and serial numbers on the two magnetos corresponded to the model and serial numbers that were noted during the engine examination at Vintage Radials.

Photo No. 10: Box containing the magnetos as received at S & T Aircraft Accessories. (S&T)

Photo No. 11: Left magneto as removed from the box. (S&T)

Photo No. 12: Left magneto's data plate. (S&T)

Photo No. 13: Right magneto as removed from the box. (S&T)

Photo No. 14: Right magneto's data plate. (S&T)

1.2.2.2 Left magneto – Model No. SF 9 LU-3, SN CC-44131

When the spline drive was rotated, the compensating cam rotated concurrently. The points gap was measured with a feeler gage and found to be 0.014 inches. (Photo No. 15) The compensating cam was corroded. When the surface of the compensating cam was cleaned, it was noted that it was marked 'R 1820 MR-1.' (Photo No. 16) The R 1820 MR-1 indicates the cam is usable on a R-1820 radial engine and that the master rod is cylinder No. 1.

Photo No. 15: Close up view of left magneto's measured point gap of 0.014 inches. (S&T)

Photo No. 16: Close up view of left magneto's compensating cam showing it is marked R-1820 MR-1. (S&T)

The left magneto was mounted on to a magneto test bench. (Photo No. 17) When the left magneto was initially tested, it produced intermittent sparks. It was necessary to remove the

condenser to clean the grease from the inside of the magneto. The points gap was noted to be dirty and were cleaned with acetone. When the magneto was tested again, it produced sparks on all nine leads. The magneto would produce sparks at 51 rpm and higher. The strength of the magnet is checked by measuring the primary current output. The primary current was checked at 400 rpm and found to be vary between 1.8 to 1.9 amps. (Photo No. 18) The primary current output should be at least 1.65 amps.

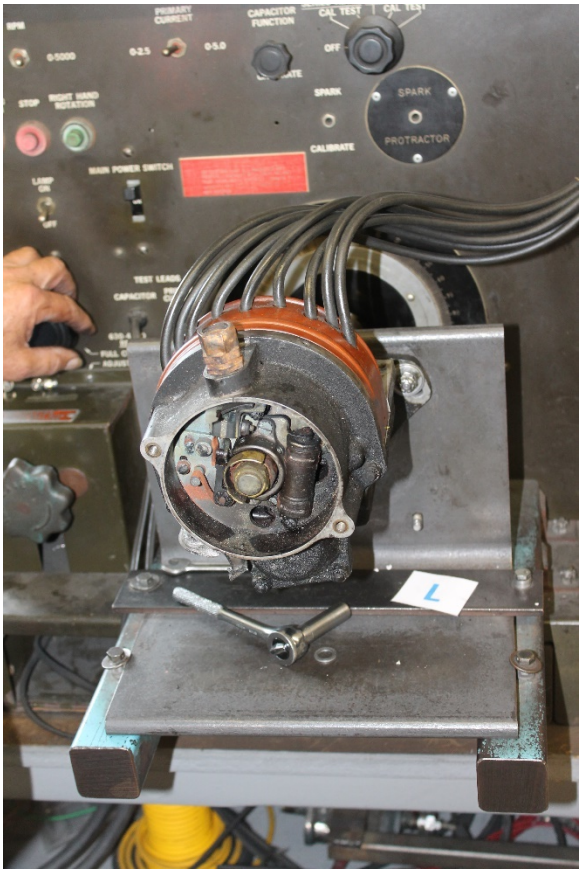

Photo No. 17: Left magneto installed on test bench. (S&T)

Photo No. 18: View of left magneto's multimeter reading of magnet's primary output of 1.888 amperes. (S&T)

After the left magneto was removed from the test bench, the coil assembly was removed from the magneto. The coil assembly primary coil resistance was 0.5 ohms and the secondary coil resistance was 3,919 ohms. (Photos No. 19 and 20, respectively) The coil assembly primary and secondary resistance requirements are 1.0 ohms minimum and 3,900 ohms minimum, respectively.

Photo No. 19: Left magneto coil assembly's primary coil resistance was 0.5 ohms. (S&T)

Photo No. 20: Left magneto coil assembly's secondary coil resistance was 3,919 ohms. (S&T)

The condenser was checked for resistance and leakage with a primary condenser tester. The test showed that the left coil was good for resistance and leakage. (Photos Nos. 21, 22, and 23)

Photo No. 21: View of primary condenser tester. (S&T)

Photo No. 22: View of left magneto's condenser test showing the resistance was good. (S&T)

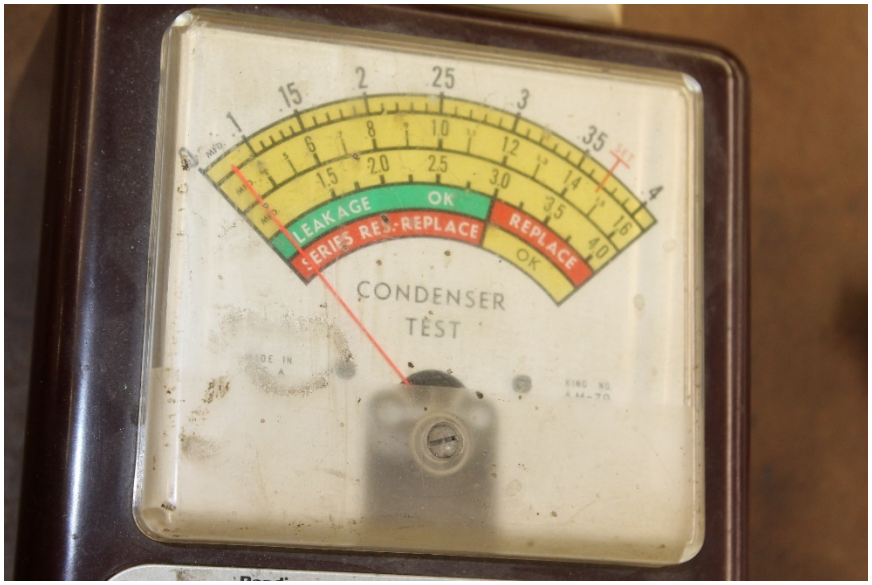

Photo No. 23: View of left magneto's condenser test showing the leakage was good. (S&T)

The cam follower was removed from the magneto and the contact surface thickness was measured with a micrometer. The thickness was 0.379 inches. (Photo No. 24) According to S & T, the left magneto's cam follower was the new configuration that has an integral spring. An exemplar cam follower was measured, and the thickness was 0.393 inches.

Photo No. 24: View showing the measurement of the left magneto's cam follower at 0.379 inches. (S&T)

The visual examination of the cam compensator showed that the wear surface was smooth. (Photo No. 25)

Photo No. 25: Close-up view of left magneto's cam compensator showing smooth wear surface. (S&T)

1.2.2.3 Right magneto – Model No. SF 9 LC-3, SN D7384

When the spline drive was rotated, the compensating cam rotated concurrently. The points gap was measured with a feeler gage and found to be 0.004 inches. (Photo No. 26) The

compensating cam was corroded. When the surface of the compensating cam was cleaned, it was noted that it was marked 'R 1820 MR-1.' (Photo No. 27)

Photo No. 26: Close up view of right magneto's measured point gap of 0.004 inches. (S&T)

Photo No. 27: Close up view of right magneto's compensating cam showing it is marked R-1820 MR-1. (S&T)

The right magneto was mounted on the magneto test bench. (Photo No. 28) When the right magneto was initially tested, it did not produce any sparks. It was necessary to clean the grease on the inside of the magneto. The points gap was noted to be dirty and were cleaned with acetone. When the magneto was tested again, it produced sparks for a few seconds and then after that intermittently on all nine leads. The magneto would produce sparks at 79 rpm and higher. The strength of the magnet is checked by measuring the primary current output. The primary current was checked at 400 rpm and found to be vary around 1.8 to 1.9 amps. (Photo

No. 29) According to S & T, visually, it appeared that the right magneto's magnet had gotten hotter than the magnet in the left magneto.

Photo No. 28: Right magneto installed on test bench. (S&T)

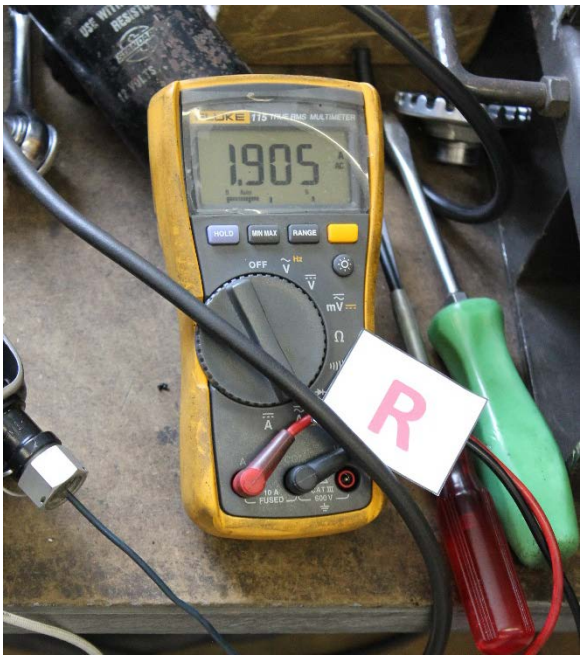

Photo No. 29: View of right magneto's multimeter reading of magnet's primary output of 1.905 amperes. (S&T)

After the right magneto was removed from the test bench, the coil assembly was removed from the magneto. The coil assembly primary coil resistance was 0.3 ohms and the secondary coils resistance was 3,879 ohms. (Photos No. 30 and 31, respectively)

Photo No. 30: Right magneto coil assembly's primary coil resistance was 0.3 ohms. (S&T)

Photo No. 31: Right magneto coil assembly's secondary coil resistance was 3,882 ohms. (S&T)

The condenser was checked for resistance and leakage with a primary condenser tester. The test showed that the right magneto condenser was good for resistance and not good for leakage. The needle was straddling the line between good and not good for leakage. According to S&T, they reject condensers when the needle is straddling the line. (Photos Nos. 32 and 33, respectively) The condenser had some leakage of solder from one end.

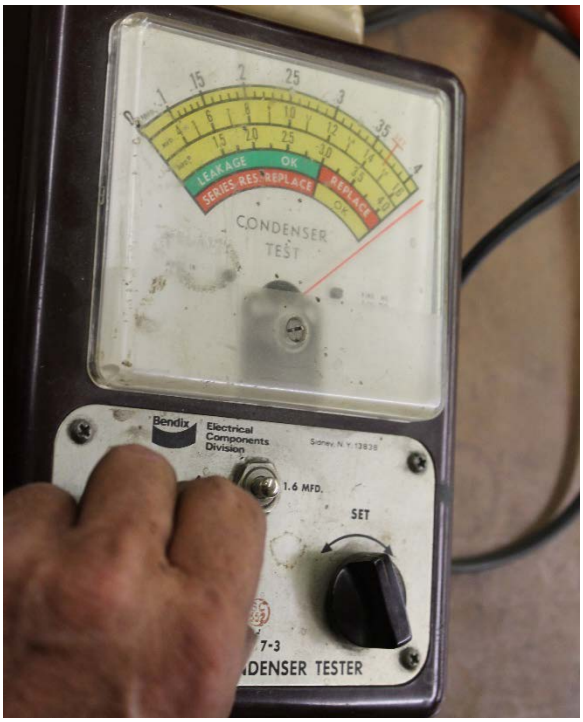

Photo No. 32: View of right magneto's condenser test showing the resistance was good. (S&T)

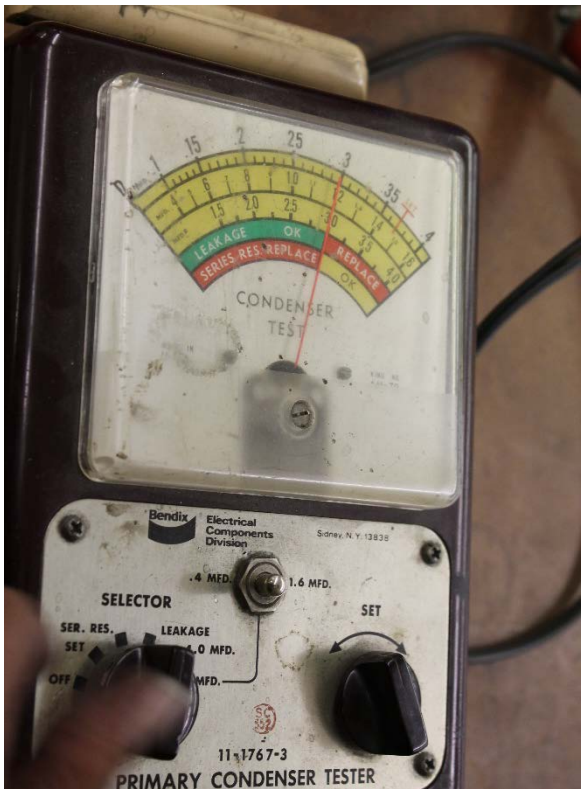

Photo No. 33: View of left magneto's condenser test showing the leakage was not acceptable. (S&T)

The cam follower was removed from the magneto and the contact surface thickness was measured with a micrometer. The thickness was 0.374 inches. (Photo No. 34)

Photo No. 34: View showing the measurement of the left magneto's cam follower at 0.374 inches. (S&T)

The visual examination of the cam compensator showed that it was corroded and the wear surface where it was contacted by the cam follower was worn and scored. (Photo No. 35)

Photo No. 35: Close up of right magneto's compensator cam showing wear and scoring on the cam lobes. (S&T)

2.0 Engines

2.1 Engine description

The engines installed on B-17 N93012 were Curtiss-Wright Cyclone R-1820-97 piston engines. The R-1820-97 engine is a nine-cylinder turbo supercharged radial engine that is rated at 1,200 horsepower.[9] The nine cylinders are in a single row and have a total displacement of 1,823 cubic inches. The R-1820 engine has a dry weight of 1,184 pounds.

2.2 Engine No. 3

2.2.1 Engine exterior

The engine was received at Vintage Radials sealed in a wood box that was opened in the presence of members of the Powerplants Group. The engine's data plate was checked and the model and serial number were confirmed to be an R-1820-97 and SN SW-041978, the No. 3 engine. (Photo No. 36)

Engine No. 3

Photo No. 36: Close up of the No. 3 engine's data plate confirming the engine model and serial number.

[9] The turbos were removed from the engines since they were not required because the airplane was not flown above 10,000 feet where supplemental oxygen would have been required for the crew and passengers. According to Vintage Radials, the supercharger would have been capable of producing the required levels of boost up to about 14,000 feet.

There were pieces of airframe structure such as the engine mount, cowling supports, and cowl flaps still attached to the engine. (Photo No. 37) The front and the rear of the engine were sooted. The engine had evidence of having been exposed to a fire with the heat resistant covering on the oil and fuel lines charred and partially burned away. The rear of the engine appeared to have been bent to the left. (Photos Nos. 38 and 39) The intake tubes to the Nos. 8, 9, and 1 cylinders were crushed and had a hole punched in the rear of the tube. The left and right exhaust manifolds were in place, but were bent and crushed. The air deflector in back of the cylinders was in place. The propeller shaft was in place, but was cut off flush to the front of the nose case. (Refer to Photos Nos. 37 and 38)

Engine No. 3

Photo No. 37: View of No. 3 engine after it was uncrated showing airframe structure still attached.

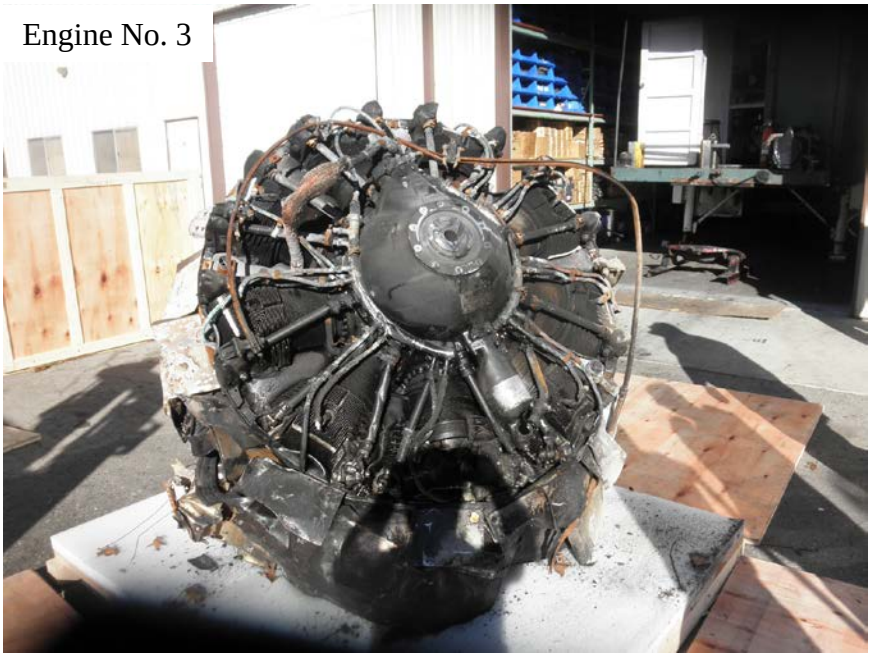

Photo No. 38: View of front of No. 3 engine showing sooting and propeller shaft cut off flush to nose case.

Photo No. 39: View of rear of No. 3 engine showing sooting, hose with charred and burned heat resistant covering, and accessories bent to the left.

2.2.2 Nose case

After the spark plugs were removed, an attempt was made to rotate the propeller shaft, but it was not possible to rotate the shaft. After the cylinders were removed, it was still not possible to rotate the propeller shaft.

The nose case was in place on the crankcase and was intact. (Refer to Photo 38) The bell gear was intact and there was no rotational damage to the gear teeth. (Photo No. 40) The planetary gear carrier was intact and all of the planetary gears were in place. There was no rotational damage to the planetary gears' gear teeth. (Photos Nos. 41and 42)

Photo No. 40: View of the bell gear showing that it was intact and had no rotational damage to the gear teeth.

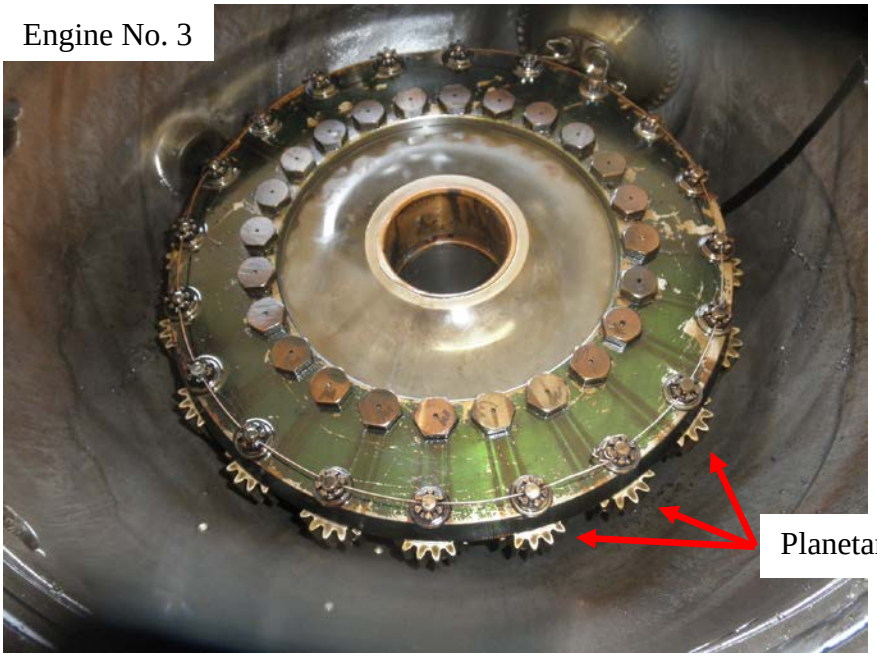

Photo No. 41: View of the planetary gear carrier showing it was intact and all of the planetary gears were in place.

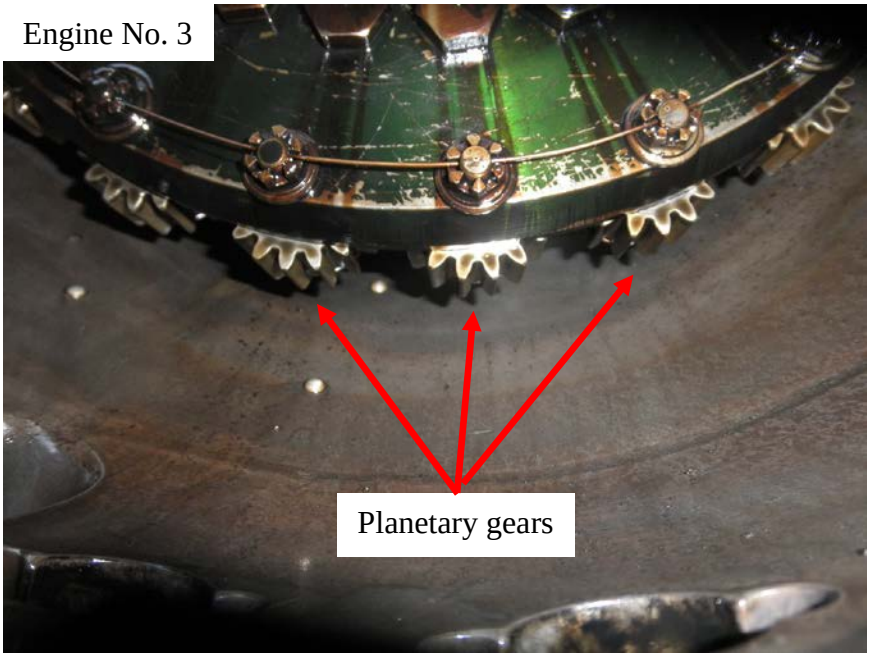

Photo No. 42: Close up of the planetary gears showing that they were intact and there was no damage to the gear teeth.

2.2.3 Crank case

The crankcase was intact. (Photo No. 43) All nine cylinders were in place on the crankcase. (Refer to Photo No. 38)

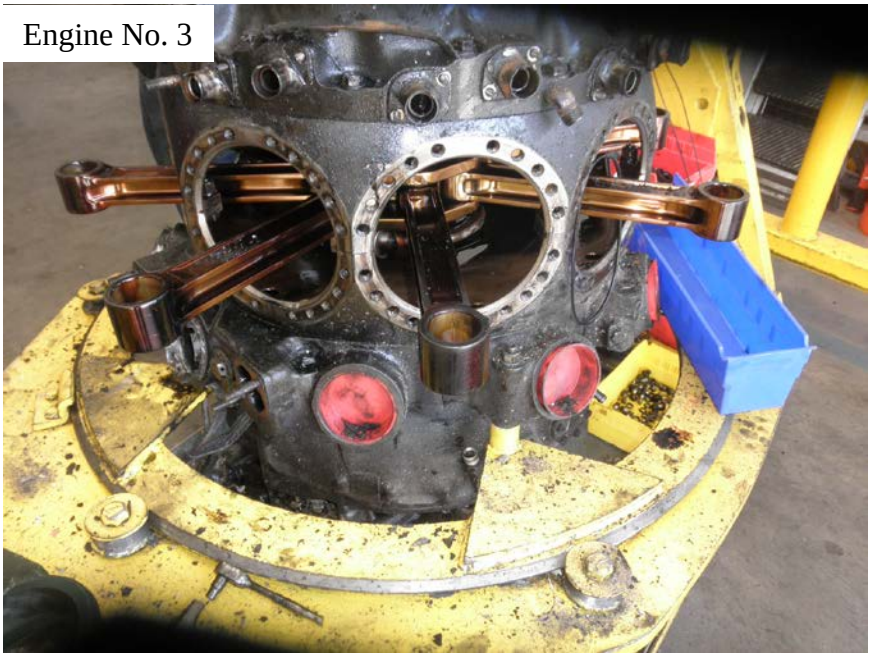

Photo No. 43: View of the crank case showing that it was intact.

The cam ring was intact and undamaged. (Photo No. 44) All of the valve lifter bodies were intact and undamaged. The rollers on all of the valve body lifters were in place, intact, and turned freely.

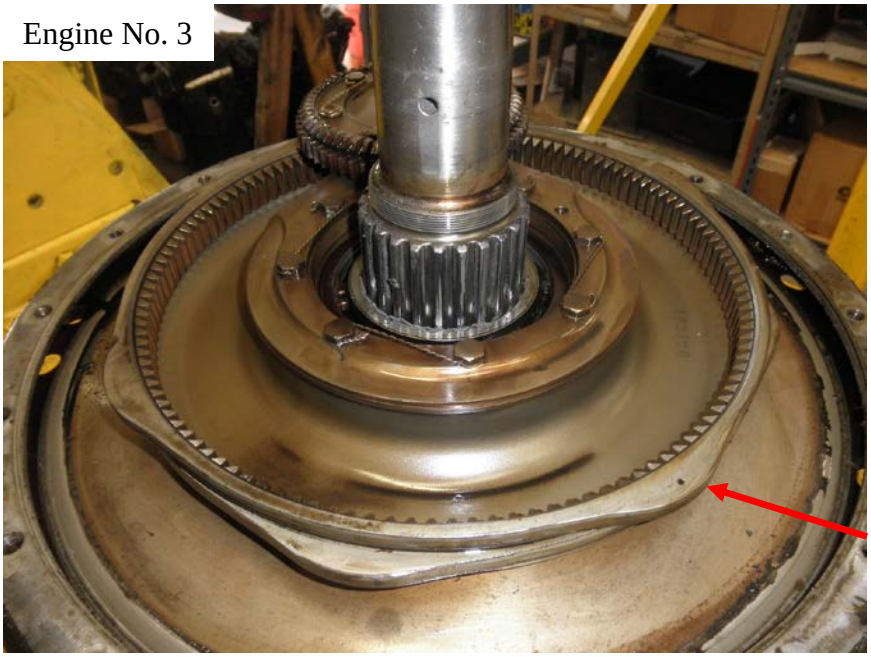

Photo No. 44: View of cam ring showing that it was intact and undamaged.

The crank shaft was intact and the two counterweights were in place. All of the articulating rods were in place on the master rod and were undamaged. (Photo No. 45) All of the articulating rods moved freely and smoothly. All of the wrist pins were in place and did not

have any damage. (Photo No. 46) The crank shaft front and rear bearings were intact and rotated freely and smoothly. (Photos Nos. 47 and 48) The piston pin bearing on the master rod and the piston pin and wrist pin bearings on all of the articulating rods did not have any damage. (Photos Nos 49 and 50)

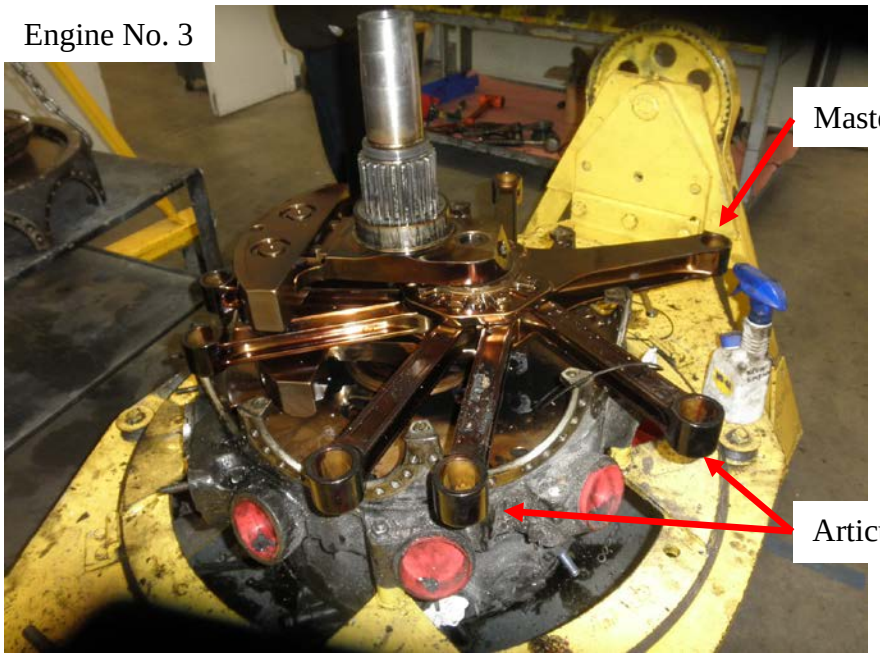

Photo No. 45: View of the crankshaft showing it and the master rod were intact with the counterweights and all of the articulating rods were in place and undamaged.

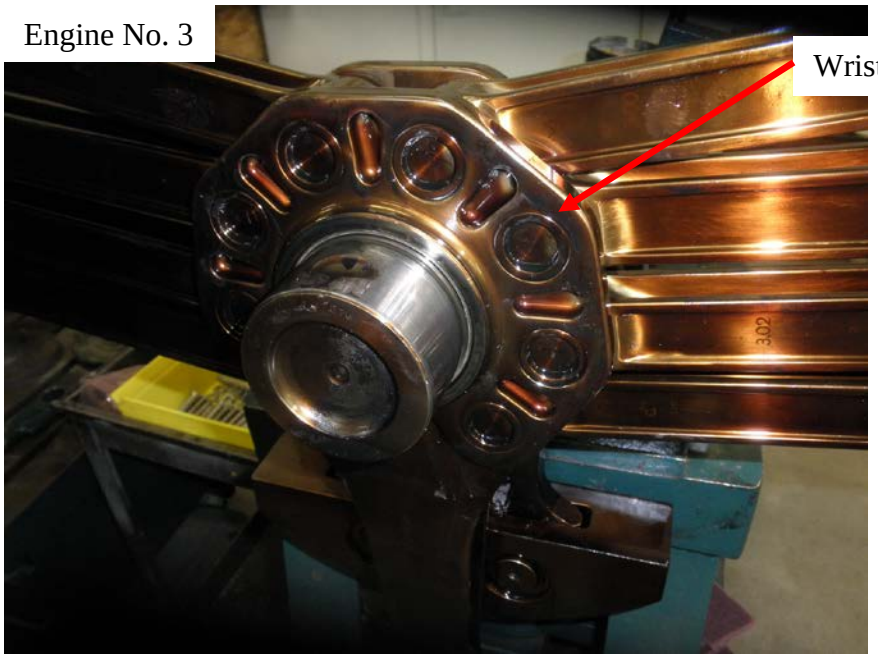

Photo No. 46: Close up crank shaft showing all of the wrist pins were in place with no damage.

Photo No. 47: View of front crank shaft bearing showing that it was intact and the rollers were in place.

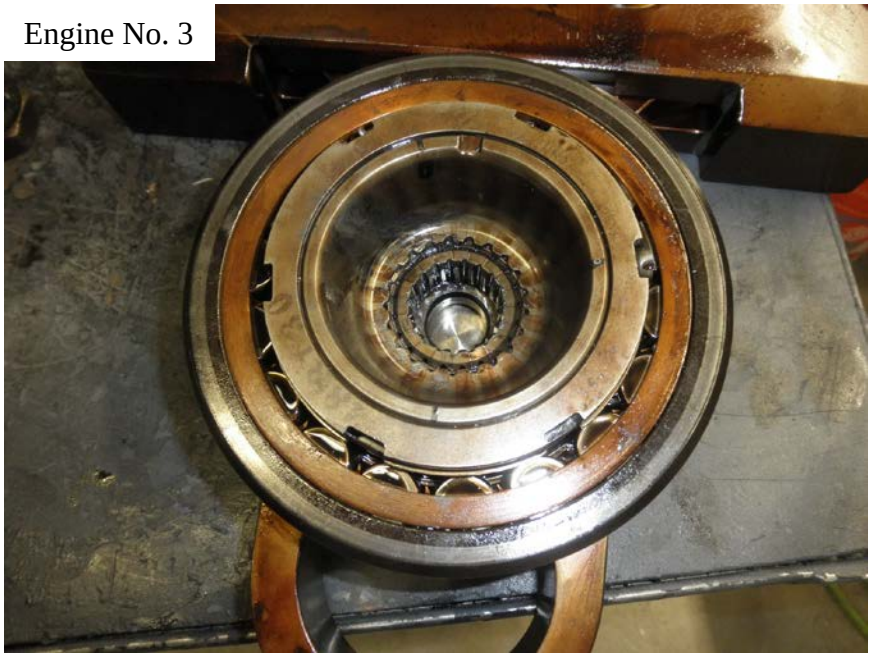

Photo No. 48: View of rear crank shaft bearing showing that it was intact and the rollers were in place.

Photo No. 49: Close up view of the master rod piston pin bearing surface showing that it was not damaged.

Photo No. 50: Close up of a typical articulating rod piston pin bearing surface showing that it was not damaged.

The supercharger fan did not have any damage.

2.2.4 Push rods

All of the intake and exhaust push rods and their respective shrouds were in place except for the No. 5 cylinder. The No. 5 cylinder's intake push rod shroud was still in place, but the exhaust push rod shroud was missing. The No. 2 cylinder's exhaust shroud was bent, although the respective push rod was straight. (Refer to Photo No. 61) The No. 4 cylinder's intake push rod shroud had a hole in the middle of the shroud and the outer end of the push rod was bent over. The push rod was stuck in the tube. The No. 4 cylinder's exhaust shroud was straight, but the push rod was bent in the middle. The No. 6 cylinder's exhaust push rod was bent at the outer end although the shroud was straight. Although the push rod shrouds remained in place, the shrouds inner and outer connectors were either partially or completely burned away. Most of the push rod shrouds had the paint burned off.

2.2.5 Cylinders

2.2.5.1 Cylinder No. 1

The No. 1 cylinder barrel was in place on the crank case (Refer to Photo No. 38) and the cylinder head was in place and intact. The intake and exhaust rocker arm covers were in place on the cylinder head and did not appear to have any damage. (Photos Nos. 51 and 52) The spark plugs were in place and the ignition leads were still attached.

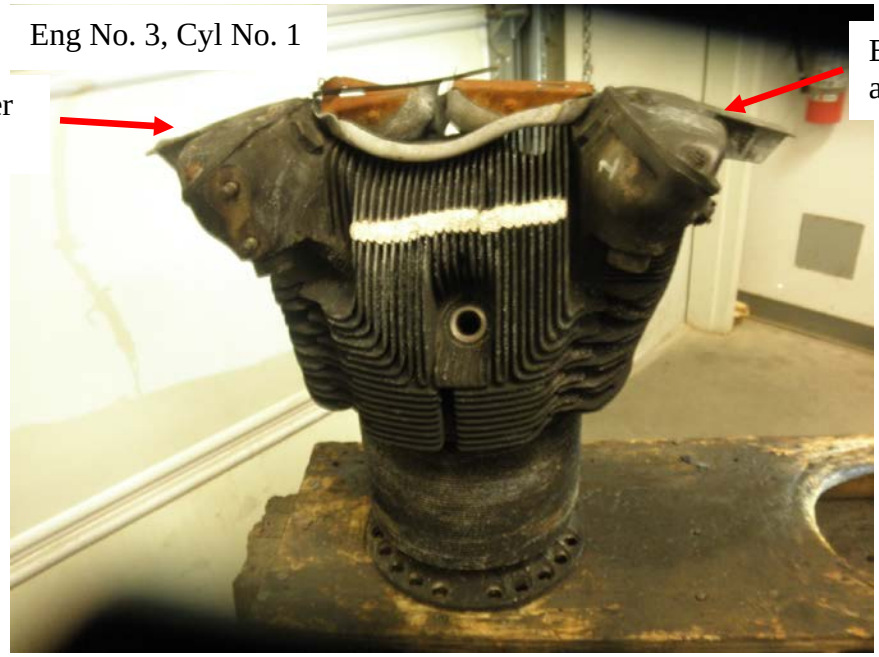

Photo No. 51: View of front of No. 1 cylinder showing it was intact with the head in place and intact, and the intake and exhaust rocker arm covers were in place.

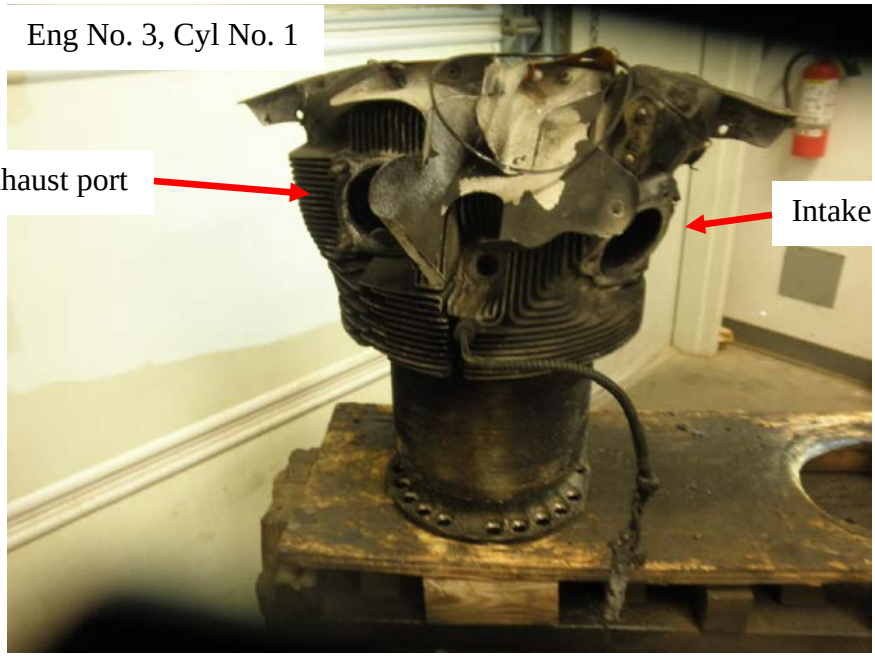

Photo No. 52: View of rear of No. 1 cylinder showing it was intact with the head in place and intact, and the intake and exhaust rocker arm covers were in place. The exhaust and intake ports are identified.

The No. 1 piston was connected to the master rod with the piston pin and the piston pin buttons were in place. The piston pin partially slipped off of the master rod when the cylinder was removed from the crank case. The piston pin did not have any damage. The piston was intact and all of the piston rings were in place and intact. The head of the piston was black in color. (Photos Nos. 53, 54, 55, and 56)

Photo No. 53: View of No. 1 cylinder's piston, piston pin, and push rod shrouds.

Photo No. 54: Close up view of No. 1 cylinder's piston head showing that it was intact and had a dark color.

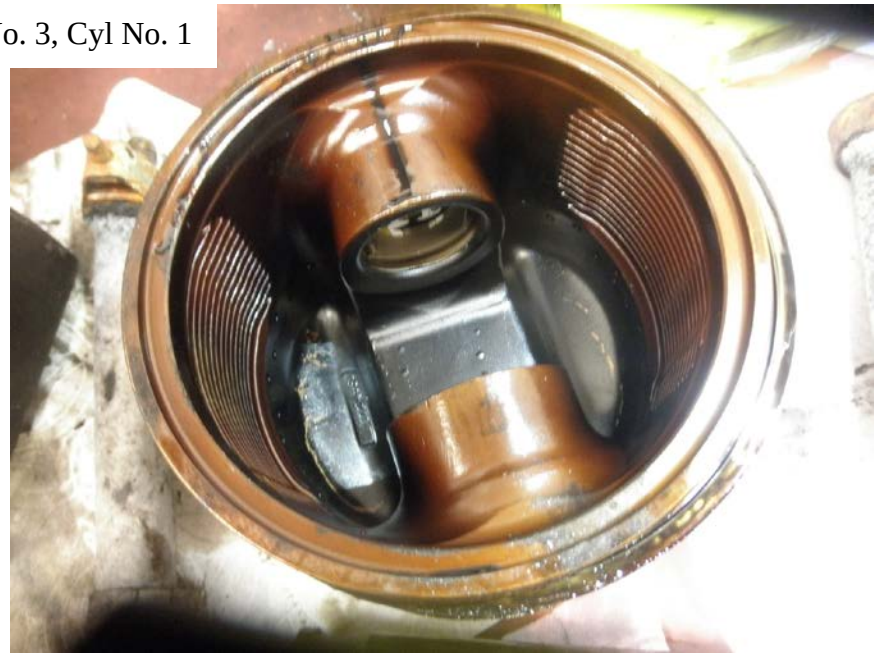

Photo No. 55: Close up view of underside of No. 1 cylinder's piston showing no damage.

Photo No. 56: Close up view of side of No. 1 cylinder's piston showing the rings were in place.

The cylinder barrel was intact and the inner surface did not have any damage. There were a few metal fragments on the wall of the cylinder barrel. The two valves were in place in the closed position centered on the valve seats. (Photo No. 57)

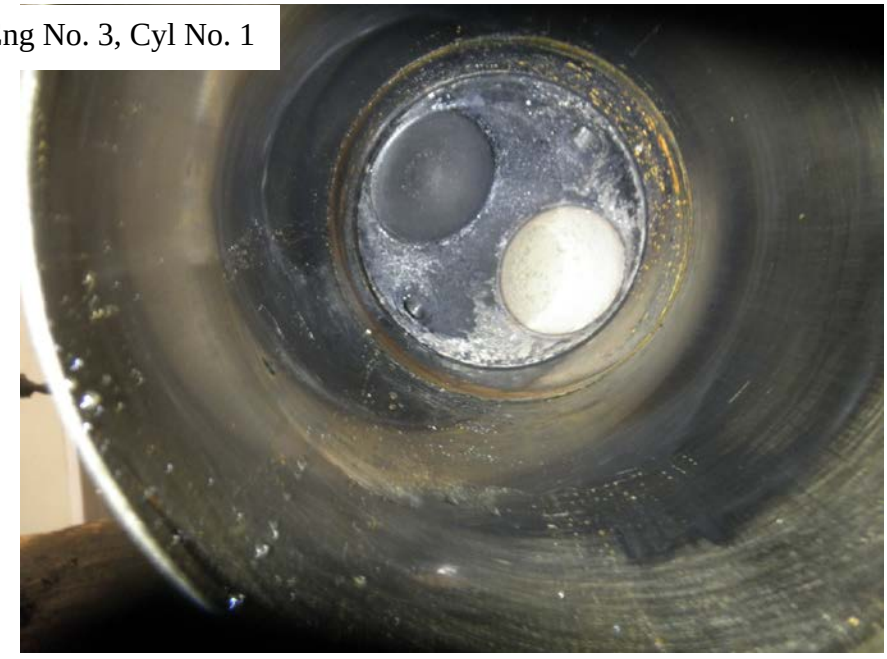

Photo No. 57: View of the inside of the No. 1 cylinder showing no damage to the barrel and the two valves centered in place in the close position.

2.2.5.2 Cylinder No. 2

The No. 2 cylinder barrel was in place on the crank case (Refer to Photo No. 38) and the cylinder head was in place and intact. The intake and exhaust rocker arm covers were in place on the cylinder head and did not appear to have any damage. (Photos Nos. 58 and 59) The spark plugs were in place and the ignition leads were still attached.

Eng No. 3, Cyl No. 2

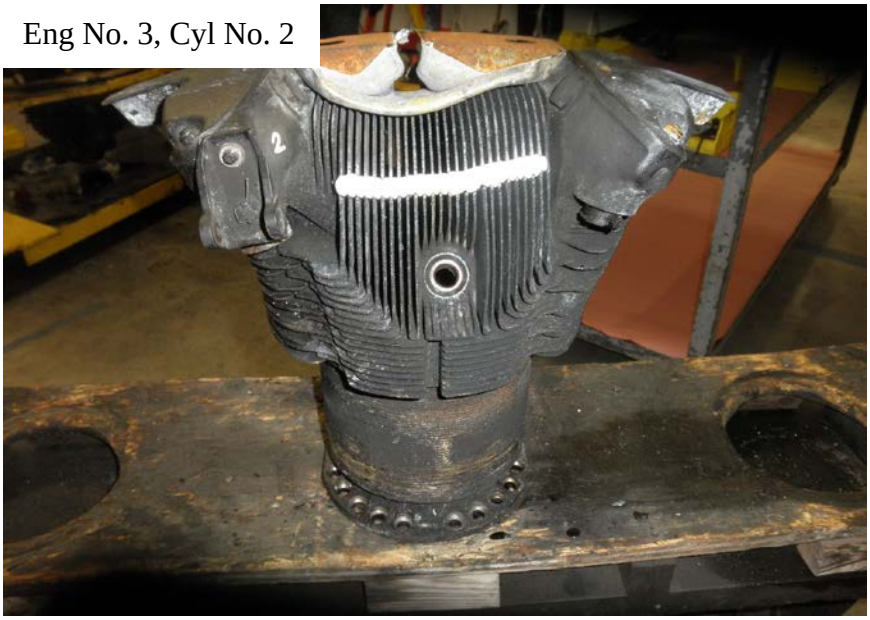

Photo No. 58: View of front of No. 2 cylinder showing it was intact with the head in place and intact, and the intake and exhaust rocker arm covers were in place.

Eng No. 3, Cyl No. 2

Photo No. 59: View of rear of No. 2 cylinder showing it was intact with the head in place and intact, and the intake and exhaust rocker arm covers were in place.

The No. 2 piston was connected to the articulating rod with the piston pin and the piston pin buttons in place. The piston was intact and all of the piston rings were in place and intact. The head of the piston was mostly black in color with small gray- and white-colored areas. (Photos Nos. 60, 61, 62, 63, and 64)

Photo No. 60: View of the No. 2 cylinder's piston and wrist pin showing that they were undamaged.

Photo No. 61: View of the two push rod shrouds and push rods showing the exhaust push rod shroud was bent slightly.

Photo No. 62: Close up of No. 2 cylinder's piston head showing that it was intact and had a dark color with small gray- and white-colored areas.

Photo No. 63: Close up of underside of No. 2 cylinder's piston showing no damage.

Photo No. 64: Close up view of side of No. 2 cylinder's piston showing the rings were in place.

The cylinder barrel was intact and the inner surface did not have any damage. The two valves were in place in the closed position centered on the valve seats. (Photo No. 65) The valves did not have any damage.

Photo No. 65: View of the inside of the No. 2 cylinder showing no damage to the barrel and the two valves centered in place in the closed position.

2.2.5.3 Cylinder No. 3

The No. 3 cylinder barrel was in place on the crank case (Refer to Photo No. 38) and the cylinder head was in place and intact. The intake and exhaust rocker arm covers were in place on the cylinder head and did not appear to have any damage. (Photos Nos. 66 and 67) The spark plugs were in place and the ignition leads were still attached.

Eng No. 3, Cyl No. 3

Photo No. 66: View of front of No. 3 cylinder showing it was intact with the head in place and intact, and the intake and exhaust rocker arm covers were in place.

Eng No. 3, Cyl No. 3

Photo No. 67: View of rear of No. 3 cylinder showing it was intact with the head in place and intact, and the intake and exhaust rocker arm covers were in place.

The No. 3 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston pin slipped out of the articulating rod when the cylinder was removed from the crank case. The piston was intact and all of the piston rings were in place and intact. The head of the piston was black in color. (Photos Nos. 68, 69, 70, and 71)

Photo No. 68: View of No. 3 cylinder's piston, wrist pin, push rods, and push rod shrouds.

Photo No. 69: Close up view of No. 3 cylinder's piston head showing that it was intact and had a dark color.

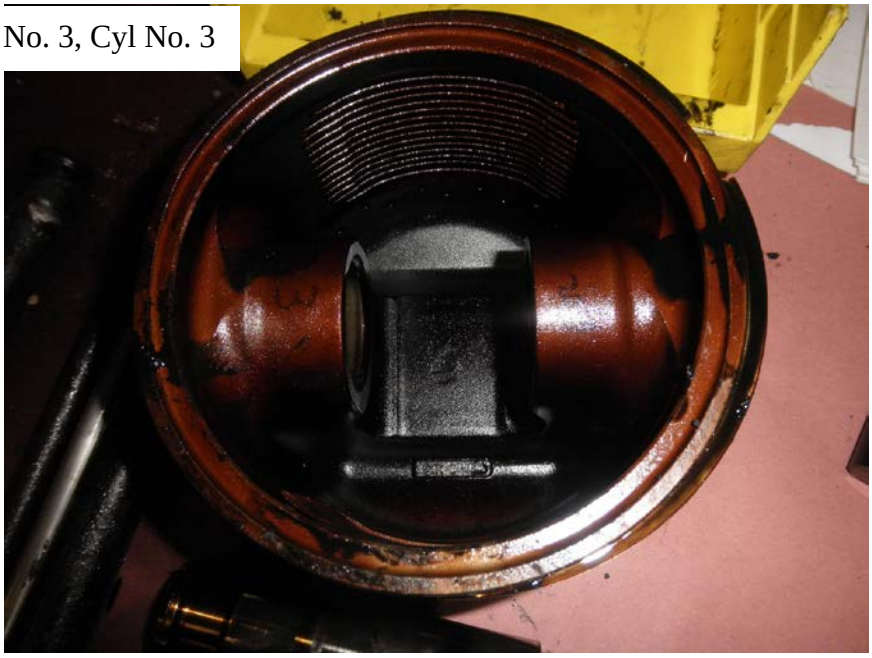

Photo No. 70: Close up of the underside of the No. 3 cylinder's piston showing that it was undamaged.

Photo No. 71: Close up view of the side of the No. 3 cylinder's piston showing the rings were in place.

The cylinder barrel was intact and the inner surface did not have any damage. The dome of the cylinder was black in color. The two valves were in place in the closed position centered on the valve seats. (Photo No. 72) The valves did not have any damage.

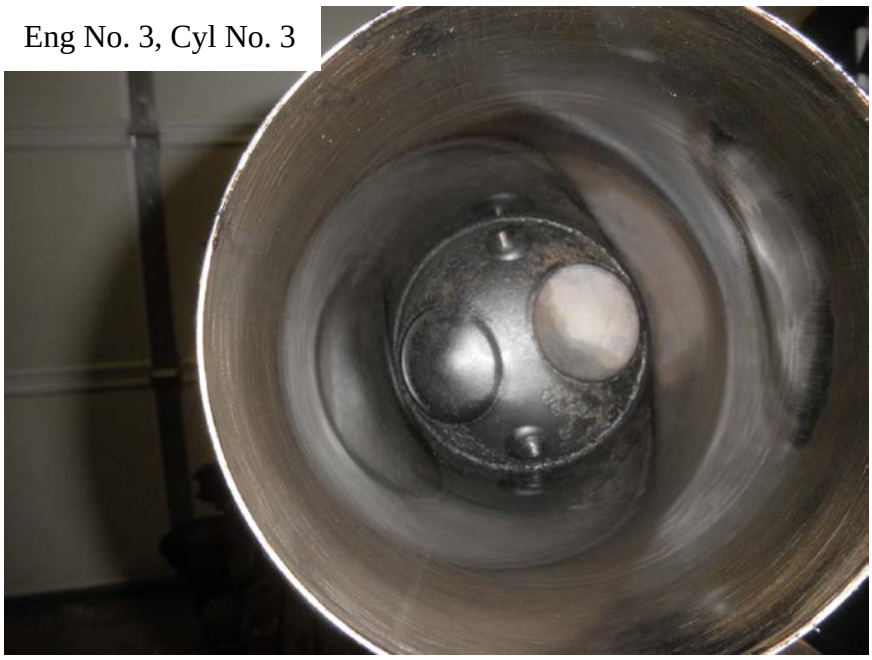

Photo No. 72: View of the inside of the No. 3 cylinder showing no damage to the barrel and the valves centered in the closed position.

2.2.5.4 Cylinder No. 4

The No. 4 cylinder barrel was in place on the crank case (Refer to Photo No. 38) and the cylinder head was in place and intact. (Photos Nos. 73 and 74) The cylinder head's intake and exhaust rocker arm assemblies were broken open on the front and the rocker arm covers were broken open and partially missing exposing the rocker arms. (Photos Nos. 75 and 76) The two rocker arms were in place and intact. The spark plugs were in place and the ignition leads were still attached.

Photo No. 73: View of front of No. 4 cylinder showing it was intact with the head in place and intact except for the rocker arm assemblies and covers that were broken.

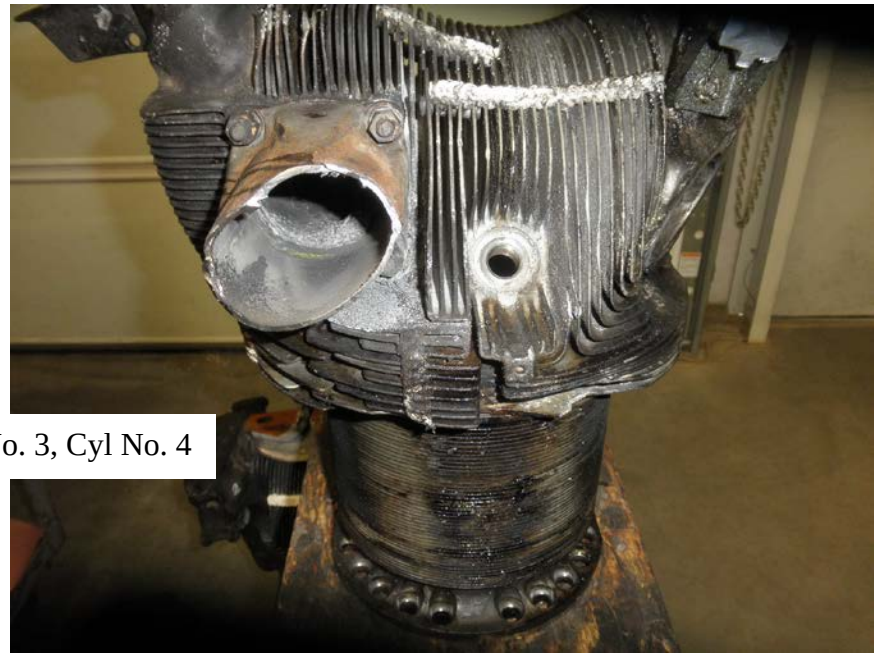

Photo No. 74: View of rear of No. 4 cylinder showing it was intact with the head in place and intact.

Photo No. 75: Close up view of broken intake rocker arm assembly and cover showing rocker arm intact.

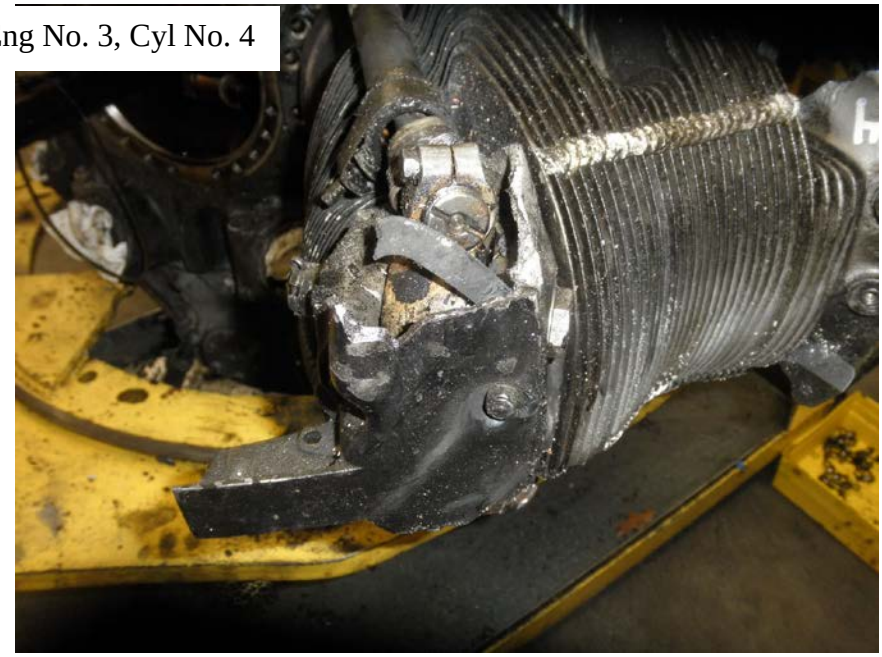

Photo No. 76: Close up view of broken exhaust rocker arm assembly and cover showing rocker arm intact.

The No. 4 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston was intact and the piston and piston pin remained attached to the articulating rod when the cylinder was removed from the crank case. (Photos Nos. E3zr and E3zs) All of the piston rings were in place and intact. (Photo No. E3zt) The head

of the piston was a dark gray color with areas of white. (Photo No. E3zu) According to Vintage Radial, the condition of the head of the piston was consistent with detonation.

Photo No. 77: View of No. 4 cylinder's piston, wrist pin, push rod shrouds, and push rods.

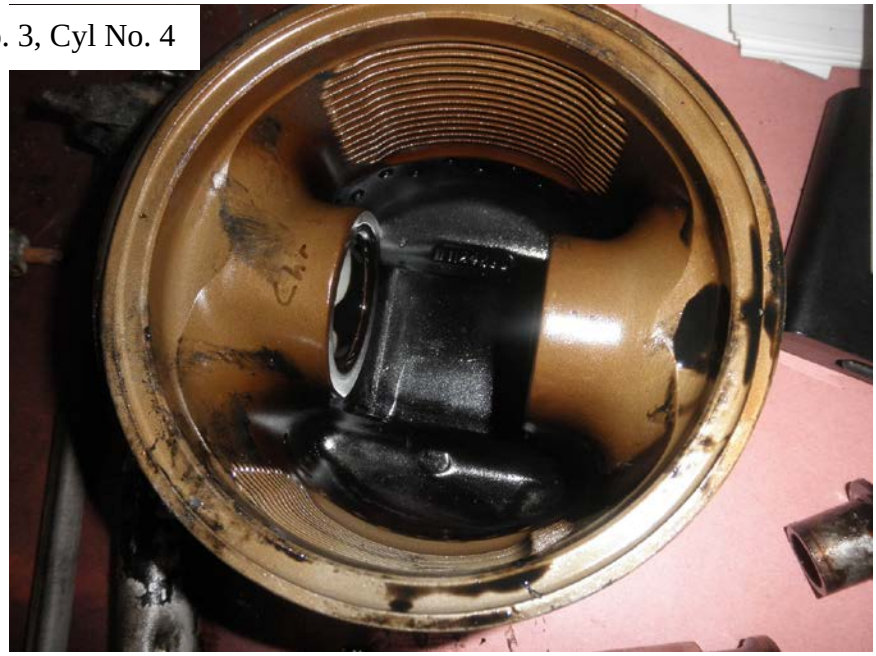

Photo No. 78: Close up view of the underside of the No. 4 cylinder's piston.

Photo No. 79: Close up view of the side of No. 4 cylinder's piston showing all of the rings were in place and intact.

Photo No. 80: Close up view of the top of the No. 4 cylinder's piston showing areas of dark gray and white coloration that is indicative of detonation.

The cylinder barrel was intact and the inner surface did not have any damage. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. (Photo No. 81)

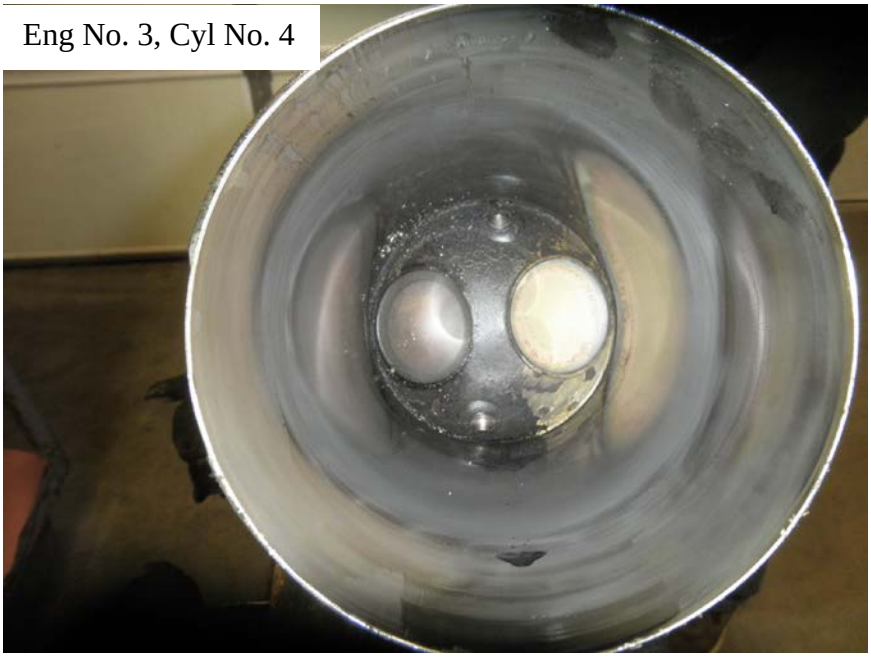

Photo No. 81: View of the inside of the No. 4 cylinder showing no damage to the barrel and the two valves centered in place in the closed position.

2.2.2.5 Cylinder No. 5

The No. 5 cylinder barrel was in place on the crank case. (Photo No. 82) The cylinder head was broken up into three pieces and partially separated from the barrel when the engine was uncrated and then came completely off of the barrel during the removal of the airframe components. (Photos Nos. 83, 84, and 85) The front of the cylinder head and the rocker arm covers were broken open and partially missing exposing the rocker arms. The two rocker arms were in place and intact. The spark plugs were in place in the threaded inserts and the ignition leads were still attached.

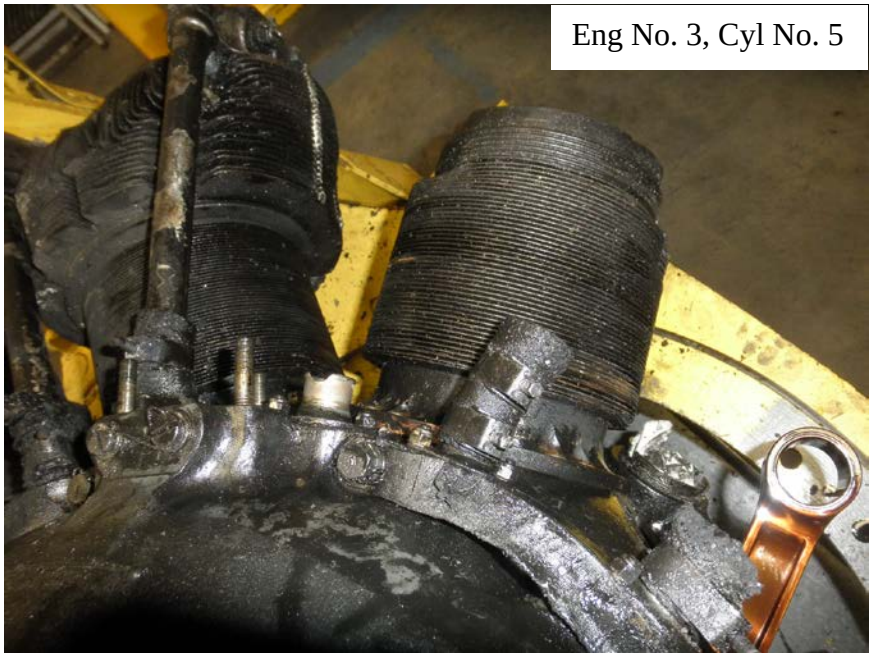

Photo No. 82: View of No.5 cylinder barrel in place on the crankcase.

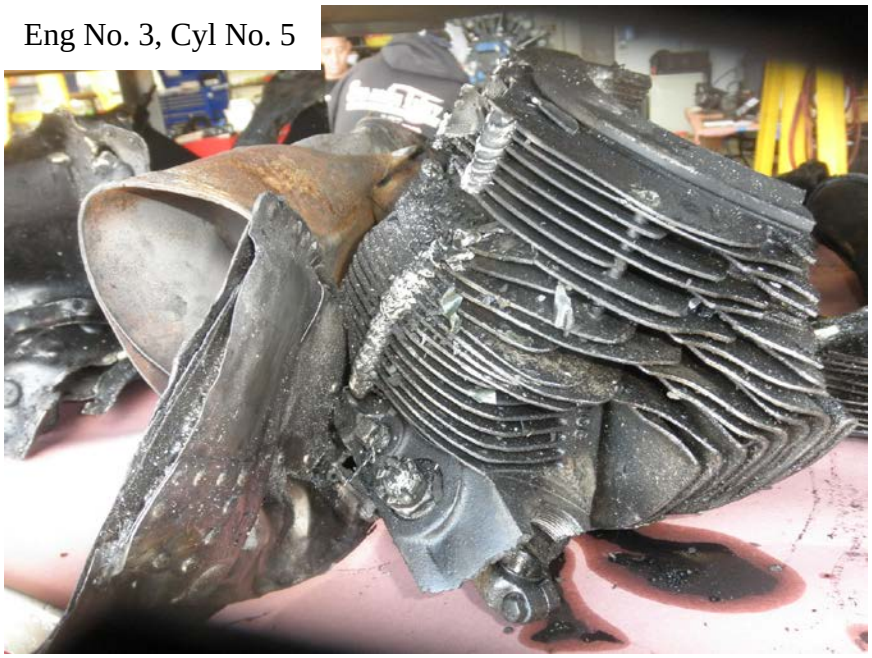

Photo No. 83: Broken piece of No. 5 cylinder head.

Photo No. 84: Broken piece of No. 5 cylinder head.

Photo No. 85: Broken piece of No. 5 cylinder head.

The No. 5 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston pin remained attached to the articulating rod when the cylinder was removed from the crank case, but the pin slipped out of the piston when the cylinder barrel was removed. The piston was intact. (Photos Nos. 86 and 87) All of the piston rings were in place and intact except the No. 1, top, ring that was broken. (Photos Nos. 88 and 89) The break in the ring was coincidental to some damage to the corner of the piston. The head of the piston was a dark gray color with areas of white. (Refer to Photo No. 86)

Eng No. 3, Cyl No. 5

Photo No. 86: View of No. 5 cylinder's piston head and wrist pin.

Eng No. 3, Cyl No. 5

Photo No. 87: View of underside of No. 5 cylinder's piston.

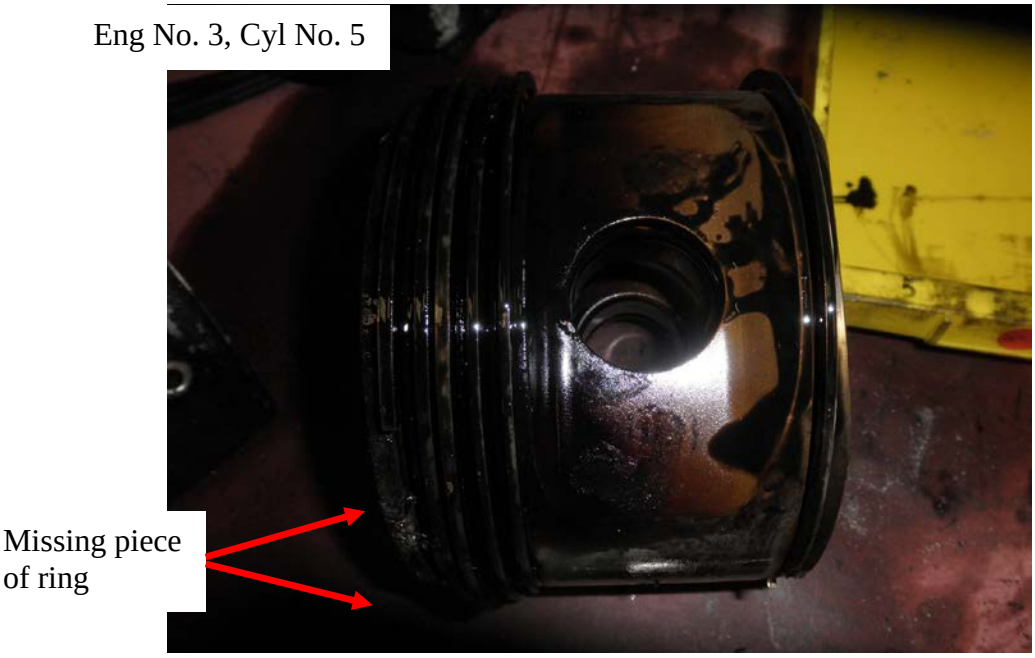

Photo No. 88: Close up of No. 5 cylinder's piston rings showing all were in place.

Photo No. 89: Broken piece of piston from No. 5 cylinder's piston.

The cylinder barrel was intact and the inner surface did not have any damage. There were metal fragments at the top of the barrel. (Photo No. 90 The intake valve was bent in the stem, but the head of the valve remained attached. The intake valve seat was loose around the valve stem and was bent up. The exhaust valve was still in place and was in the closed position centered on the valve seat. (Photos Nos. 91 and 92)

Photo No. 90: View of top of No. 5 cylinder barrel showing metal fragments.

Photo No. 91: View of piece of No. 5 cylinder head with bent intake valve.

Photo No. 92: View of piece of No. 5 cylinder head with exhaust valve in place.

2.2.2.6 Cylinder No. 6

The No. 6 cylinder barrel was in place on the crank case (Refer to Photo No. 38) and the cylinder head was in place and intact. (Photos Nos. 93, and 94) The cylinder head's intake and exhaust rocker arm assemblies were broken open on the front and the rocker arm covers were broken open and partially missing exposing the rocker arms. (Photo No. 95) The two rocker arms were in place and intact. The spark plugs were in place and the ignition leads were still attached.

Photo No. 93: View of the front of No. 6 cylinder showing that it was in place on the crankcase and that it was intact with the head in place.

Photo No. 94: View of the rear of No. 6 cylinder showing that it was intact with the head in place.

Photo No. 95: View of head of the No. 6 cylinder showing the intake and exhaust rocker arm assemblies were broken open exposing the rocker arms.

The No. 6 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston pin remained attached to the articulating rod when the cylinder was removed from the crank case. The piston and piston pin were intact and all of the piston rings were in place and intact. (Photos Nos. 96 and 97) The head of the piston was a dark gray color. (Photo No. 98)

Photo No. 96: View of No. 6 cylinder piston showing it is intact with all of the rings in place.

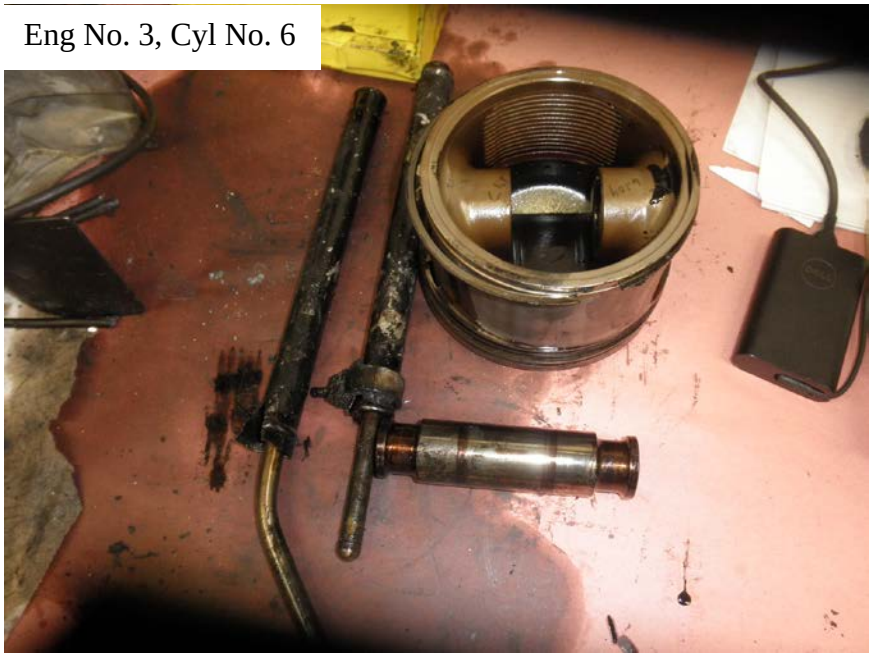

Photo No. 97: View of the underside of the No. 6 cylinder piston and the piston pin.

Photo No. 98: Close up view of the head of the No. 6 cylinder piston showing the dark gray color.

The cylinder barrel was intact and the inner surface did not have any damage. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. (Photo No. 99)

Eng No. 3, Cyl No. 6

Photo No. 99: View of the inside of the No. 6 cylinder showing no damage to the barrel and the two valves centered in place in the closed position.

2.2.5.7 Cylinder No. 7

The No. 7 cylinder barrel was in place on the crank case and the cylinder head was in place and intact. The intake and exhaust rocker arm covers were in place on the cylinder head and did not appear to have any damage. (Photos Nos. 100 and 101) The spark plugs were in place and the ignition leads were still attached.

Photo No. 100: View of the front of No. 7 cylinder showing that it was in place on the crankcase and that it was intact with the head in place.

Photo No. 101: View of the rear of No. 7 cylinder showing that it was intact with the head in place.

The No. 7 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston pin partially slid out of the piston when the cylinder was removed. The piston was intact and all of the piston rings were in place and intact. The head of the piston was black in color. (Photos Nos. 102, 103, and 104)

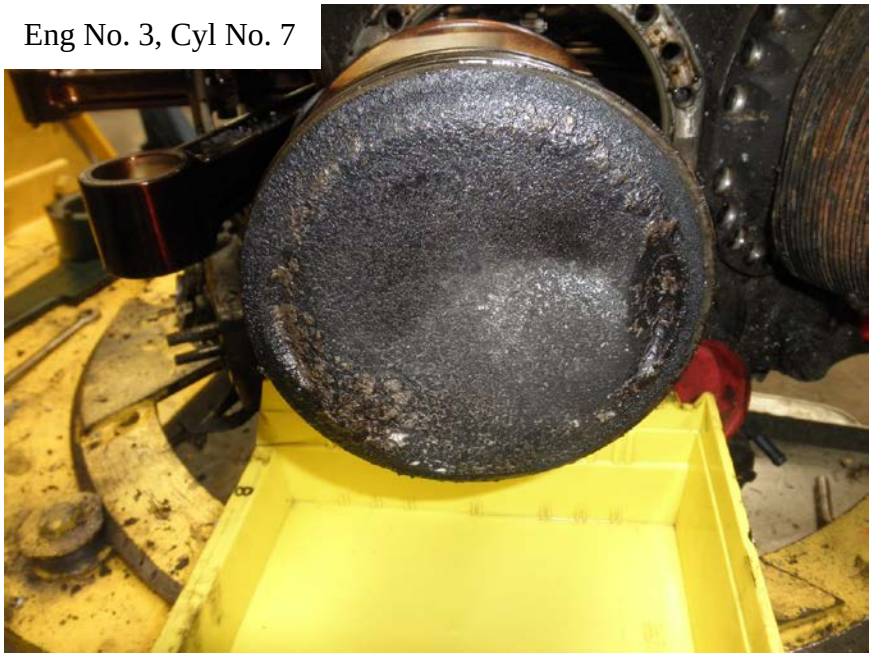

Photo No. 102: View of the head of the No. 7 cylinder's piston showing that it was intact.

Photo No. 103: View of the underside of the No. 7 cylinder's piston, the piston ring, and push rod shrouds with push rods.

Photo No. 104: Close up view of side of No. 7 cylinder's piston showing all of the rings were in place.

The cylinder barrel was intact and the inner surface did not have any damage. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. The inside of the barrel and the cylinder head were black. (Photo No. 105)

Photo No. 105: View inside of the No. 7 cylinder's barrel showing the dark color of the barrel and head and that the two valves were in place in the closed position.

2.2.5.8 Cylinder No. 8

The No. 8 cylinder barrel was in place on the crank case and the cylinder head was in place and intact. (Refer to Photo No. 38) The intake and exhaust rocker arm covers were in place on the cylinder head and did not appear to have any damage. There was metal slag on the cylinder head between the two rocker arm assemblies. (Photos Nos. 106, 107, and 108) The spark plugs were in place and the ignition leads were still attached.

Photo No. 106: View of the front of No. 8 cylinder showing that it was intact with the head in place.

Photo No. 107: View of the rear of No. 8 cylinder showing that it was intact with the head in place.

Photo No. 108: View of the No. 8 cylinder head showing the metal slag.

The No. 8 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston pin partially slid out of the piston when the cylinder was removed. The piston was intact and all of the piston rings were in place and intact. The head of the piston was mostly black in color with an area of a light color. (Photos Nos. 109, 110, 111, and 112)

Photo No. 109: View of No. 8 cylinder's piston showing that it was intact.

Photo No. 110: View of the underside of the No. 8 cylinder's piston, the piston pin, push rod shrouds, and the push rods.

Photo No. 111: Close up view of the side of the No. 8 cylinder's piston showing the rings were in place.

Eng No. 3, Cyl No. 8

Photo No. 112: Close up view of the head of the No. 8 cylinder's piston showing it to be mostly a dark color with a light colored area.

The cylinder barrel was intact and the inner surface did not have any damage. There were metal fragments on the inside of the cylinder barrel. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. The inside of the barrel and the cylinder head were black. (Photo No. 113)

Eng No. 3, Cyl No. 8

Photo No. 113: View inside of the No. 8 cylinder's barrel showing the metal fragments, but no damage to the barrel and that the two valves were in place in the closed position.

2.2.5.9 Cylinder No. 9

The No. 9 cylinder barrel was in place on the crank case and the cylinder head was in place and intact. (Refer to Photo No. 38) The intake and exhaust rocker arm covers were in place on the cylinder head. The intake rocker arm cover was missing and the exhaust rocker arm cover was broken exposing the rocker arms that were intact. . (Photos Nos. 114 and 115) The spark plugs were in place and the ignition leads were still attached.

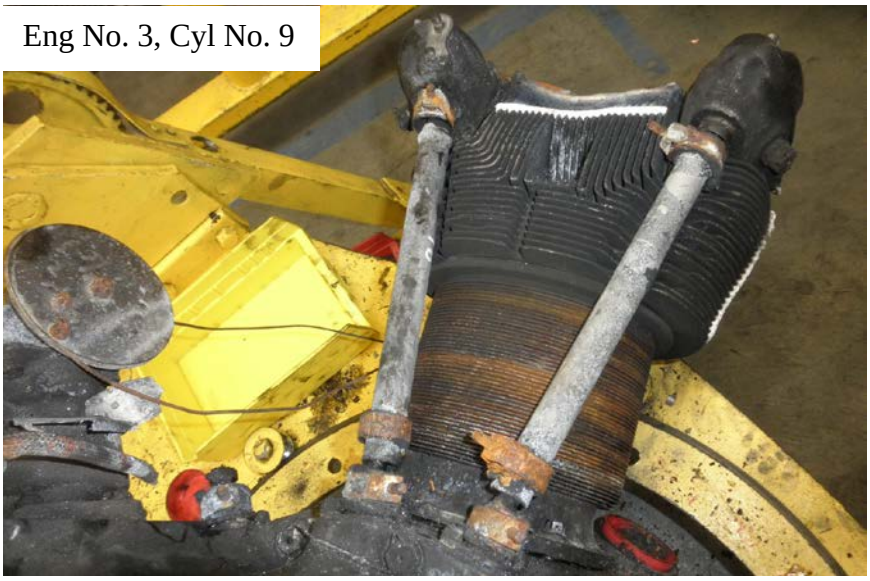

Photo No. 114: View of the front of No. 9 cylinder showing that it was intact with the head in place.

Photo No. 115: View of the rear of No. 9 cylinder showing that it was intact with the head in place. Also showing the broken exhaust rocker arm cover and the missing intake rocker arm cover.

The No. 9 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. (Photo No. 116) The piston pin partially slid out of the piston when the cylinder was removed. The piston was intact and all of the piston rings were in place and intact. (Photos No. 117 and 118) The head of the piston was a brown color, although there were white colored crystals that according to Vintage Radials were typical of corrosion. (Photo No. 119)

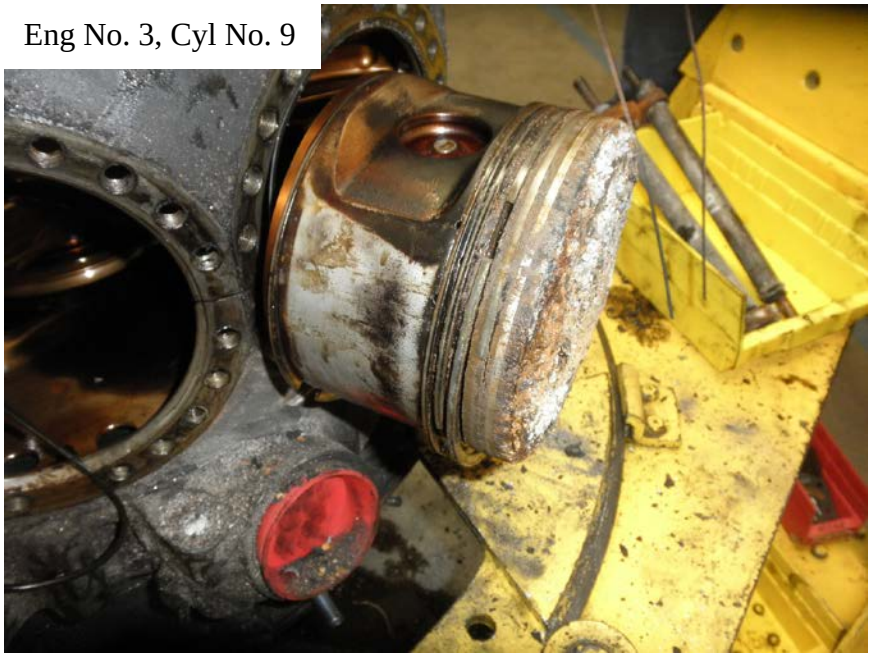

Photo No. 116: View of No. 9 cylinder's piston showing that it was intact.

Photo No. 117: View of the underside of the No. 9 cylinder's piston, the piston pin, push rod shrouds, and the push rods.

Eng No. 3, Cyl No. 9

Photo No. 118: Close up view of the side of the No. 9 cylinder's piston showing the rings were in place.

Eng No. 3, Cyl No. 9

Photo No. 119: Close up view of the head of the No. 9 cylinder's piston showing the brown color with the white crystals consistent with corrosion.

The cylinder barrel was intact. The inner surface of the cylinder barrel was corroded. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. (Photo No. 120)

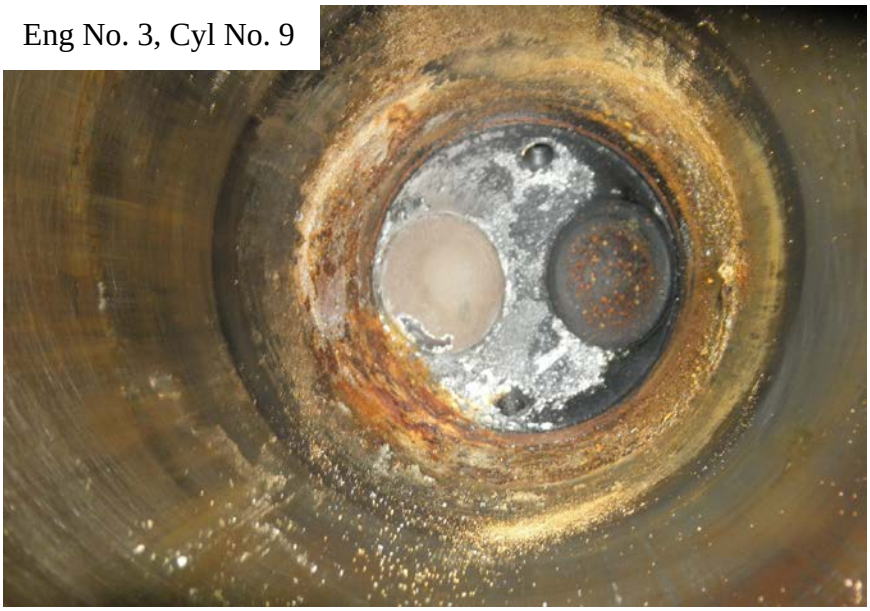

Photo No. 120: View inside of the No. 9 cylinder's barrel showing the corrosion and that the two valves were in place in the closed position.

2.2.6 Spark plugs

The electro gap on all of the plugs were checked. All of the plugs had a gap that was in excess of 0.022 inches except the No. 1 cylinder's front plug and No. 7 cylinder's rear plug that were within the manufacturer's recommended gap of 0.016 to 0.022 inches. Table 1 lists the visual condition and gap measurements for each of the No. 3 engine's spark plugs. (Photos Nos. 121, 122, and 123)

Table 1: No. 3 engine's spark plug visual examination.

	Front		Rear	
Cylinder	Condition	Gap (inches)	Condition	Gap (inches)
1	The insulator was a white color. The tip was not fouled with lead. There were specks of lead consistent with detonation.	0.022 Front 0.018 Rear	The insulator was a light color. The tip had small specks of lead that were that were consistent with detonation.	0.022
2	The tip of the plug was not fouled with lead. The insulator was a light color. There were several specks of lead on the tip.	>0.022	The insulator was a light color. There was no lead fouling of the tip.	>0.022 Front 0.022 Rear
3	The tip of the plug was fouled with oil. The insulator was a dark color.	>0.022	The tip of the plug was fouled with oil. The insulator was a dark color.	>0.022

4	The tip was fouled with lead and oil. The insulator was a light color. The center of the electrode was eroded.	>0.022	The tip of the plug did not have any lead or oil fouling. The insulator was a light color. The center electrode appeared to be consistent with new plug. The top of the spark plug was broken off. The associated washer was heat discolored. According to Vintage Radial, the condition of this plug and the associated washer was consistent with detonation.	>0.022 Front 0.022 Rear
5	The center electrode was bent over against the side of the tip. One of the side electrodes was bent over. The tip was wet. The insulator was cracked.	---	The insulator was a dark gray color. There was heavy carbon build up on the tip. There was no lead or oil fouling on the tip.	>0.022 Front 0.018 Rear
6	The tip was fouled with oil and lead. The insulator was a dark color.	>0.022	The tip was fouled with oil. The insulator was a dark color.	0.022
7	The insulator was a light color. The tip was fouled with oil.	>0.022	The tip was fouled with oil. The insulator was a light color. There were white specks on the tip that was consistent with detonation.	>0.022 Front 0.022 Rear
8	The insulator was a light color. There was no oil or lead fouling of the tip.	>0.022	There were lead deposits on the tip. But the tip was not fouled with oil. The insulator was a light color.	0.022
9	The tip was fouled with lead. There were white colored specks on the tip consistent with detonation. The insulator was a dark color.	>0.022	There were small white specks on the insulator that was consistent with detonation. There were no lead or oil deposits on the tip. The insulator was a dark color.	0.022

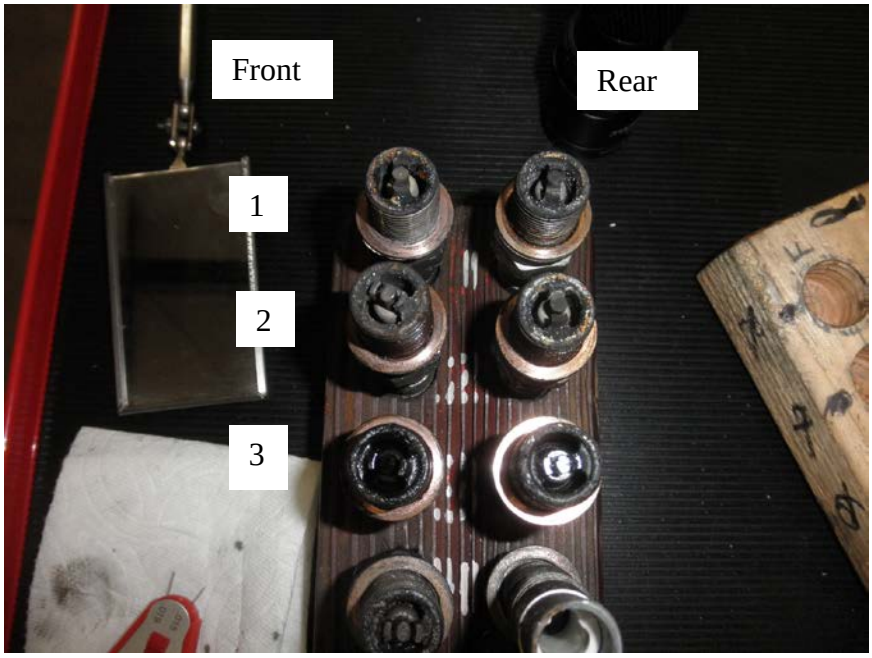

Photo No. 121: No. 3 engine's spark plugs for cylinders Nos. 1, 2, and 3.

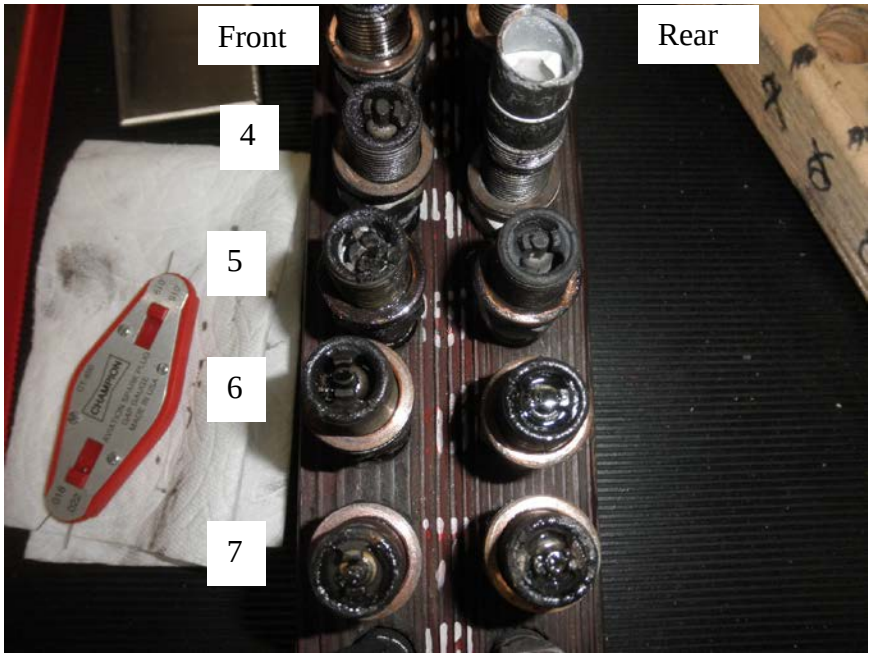

Photo No. 122: No. 3 engine's spark plugs for cylinders Nos. 4, 5, 6, and 7.

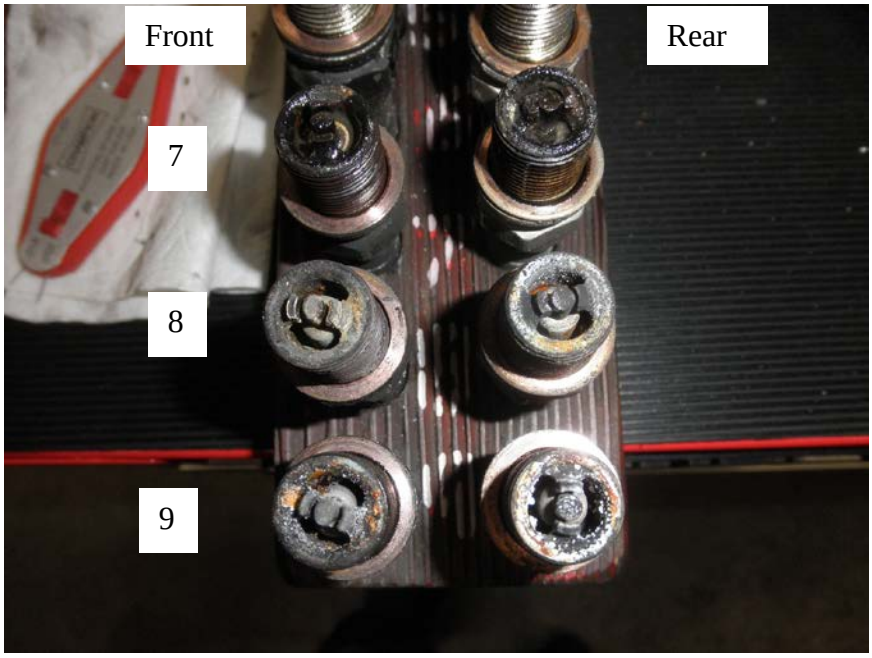

Photo No. 123: No. 3 engine's spark plugs for cylinders Nos. 7, 8, and 9.

2.2.7 Valves

The No. 3 engine's cylinder heads were partially disassembled to remove and examine the intake valves. All of the intake valves were intact. The valve stems were shiny and smooth. The valve stems fit into their respective valve guides and could be moved freely. The valve heads and the underside of the valve heads were typically a dark gray to black color. The edges of the valve heads had a uniform contact pattern with the valve seat and there were no indications of any burning on the edge of the valve heads.

During the disassembly of the cylinder heads to remove the intake valves, it was noted that there were two rather than three valve springs. The force to compress the two and three spring configuration was measured. The force to compress the inner and outer springs of the two spring configuration was 115 and 88 pounds, respectively, for a total of 203 pounds. The force to compress the inner, middle, and outer springs was 95, 71, and 53 pounds respectively, for a total of 219 pounds. (Photos Nos. 124 and 125)

Photo No. 124: View of two valve springs that were found in the No. 3 engine's cylinders.

Photo No. 125: View of the three valve springs that should normally be installed in a R-1820 engine.

2.2.8 Accessories

The carburetor, left and right magnetos, generator, and starter were still on the rear of the engine.

The accessory drive gear shaft was broken in the splines.[10] The splines were twisted slightly in the clockwise direction adjacent to the break. (Photos Nos. 126, 127, and 128) An examination of the fracture surface by NTSB metallurgists confirmed that it was a torsional fracture.[11]

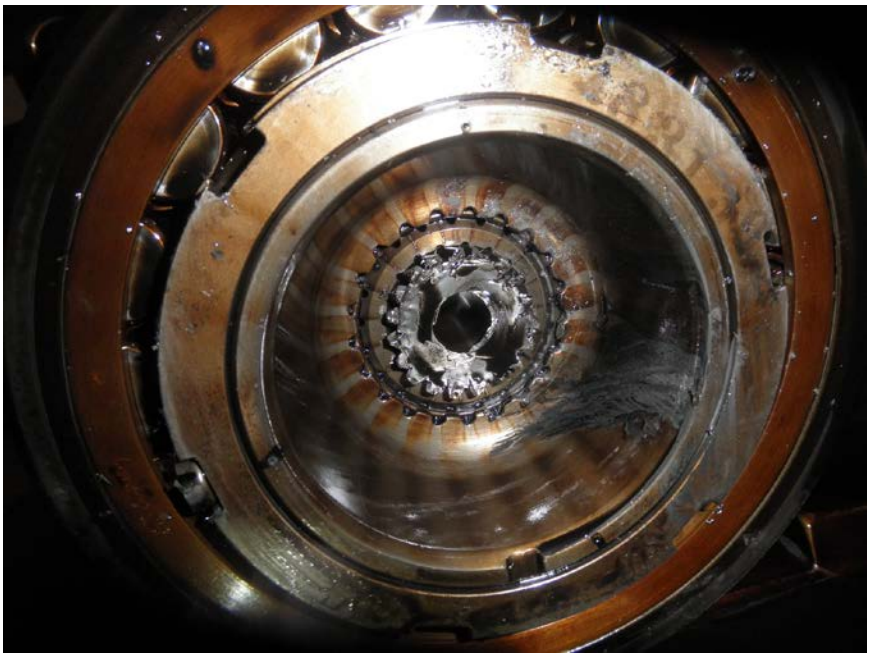

Photo No. 126: View of fractured forward end of accessory drive gear shaft in end of crankshaft.

Photo No. 127: View of side of aft end of accessory drive gear shaft showing splines at fractured end twisted slightly.

[10] The accessory drive spline transmits rotational power from the crankshaft to drive the magnetos, generator, and the supercharger that turns at 17,500 rpm.

[11] A photograph of the fracture surface was provided to NTSB metallurgists in Washington, D.C. for their review.

Photo No. 128: Close up view of fracture surface on aft end of accessory drive gear shaft.

The Cuno oil filter was removed from the rear of the crankcase.[12] The filter was disassembled. (Photos Nos. 129, 130, and 131) The filter elements were flushed out and they had a small amount of small black and silver colored particles as well as a piece of tan colored plastic. (Photo No. 132) When touched with a magnet, all of the silver colored particles stuck to the magnet.[13]

Photo No. 129: The No. 3 engine's Cuno oil filter after removal from the engine.

[12] CUNO is the name of the manufacturer. The company developed a compact, high flow filter in the mid-1920s..
[13] According to Vintage Radial, the amount of metal found in the filter was typical.

Photo No. 130: The No. 3 engine's Cuno oil filter after the filter housing was removed.

Photo No. 131: The No. 3 engine's Cuno oil filter elements after they were unstacked.

Photo No. 132: Debris that was flushed from the No. 3 engine's Cuno oil filter.

The left and right magnetos were in place on the rear of the engine. (Photo No. 133) The P-lead was separated from the left and right magnetos at the housing fitting. The left magneto's housing paint was intact, but the paint on the right magneto's housing was blistered and partially missing. (Photos Nos. 134 and 135) The left magneto's distributer block had the varnish missing. (Photo No. 136) On the right magneto distributor block, the varnish was still in place. (Photo No. 137) The drives for the left and right magnetos had a red colored substance with the right drive having more than around the left drive. (Photo No. 138) The left and right magnetos were tested on a magneto test unit. Both the left and right magnetos produced sparks for all nine leads throughout the speed range.

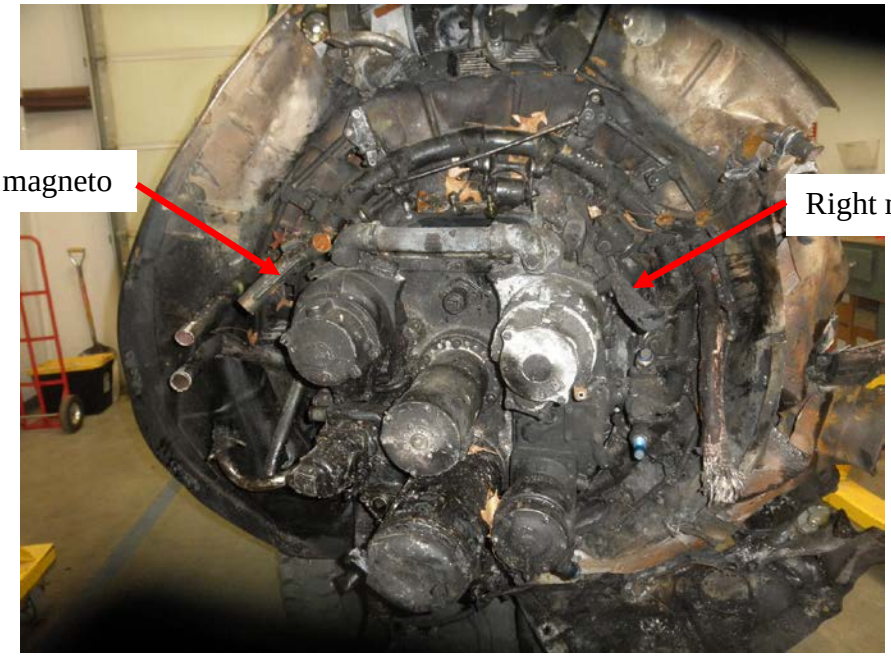

Photo No. 133: View of the rear of the engine showing the left and right magnetos were in place although the P-lead was separated from both.

Photo No. 134: Close up view of left magneto housing showing it was intact.

Photo No. 135: Close up view of right magneto housing showing it was intact, but the paint was blistered and partially burned away.

Photo No. 136: View of left magneto's distributer block showing the varnish was missing.

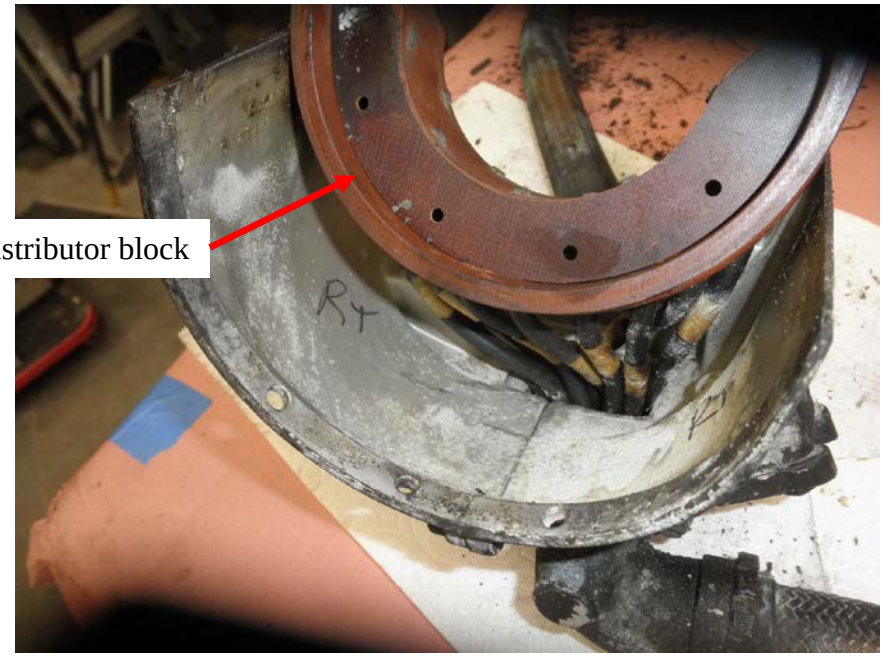

Photo No. 137: View of right magneto's distributer block showing the varnish was in place.

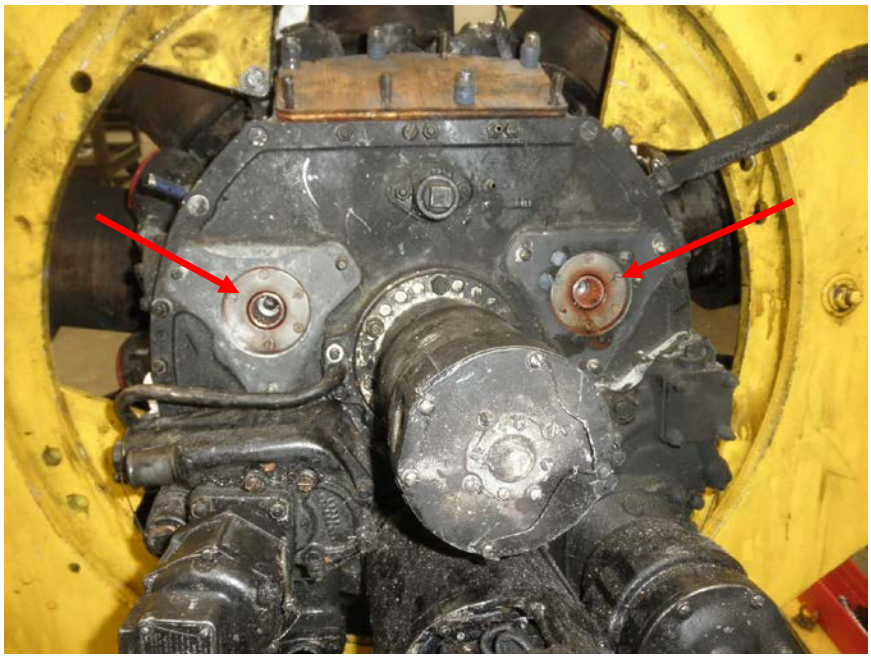

Photo No. 138: View of the left and right magneto drives showing a red material on the drives with more being on the right than on the left.

The feathering pump was tested and it worked normally.

The blower drain was checked and found to be clear.

The firewall fuel strainer was clear.

2.2.9 Carburetor

The carburetor was a Stromberg Injection Carburetor Model PD-12-H2, SN 561943 A. (Photo No. 139) The carburetor was securely in place on the back of the engine. When it was attempted to shake the carburetor to see if it was loose on the engine, it would not move. The carburetor was removed from the engine and taken to Vintage Carburetors, Tehachapi, California, where it was tested in the presence of members of the Powerplants Group. (Photo No. 140) The as-received examination of the carburetor revealed the vent adapter nut was not safety wired. (Photo No. 141) In addition, the jet and idle valve chambers both had evidence of corrosion that according to Vintage Carburetor was consistent with water in the fuel. (Photo No. 142)

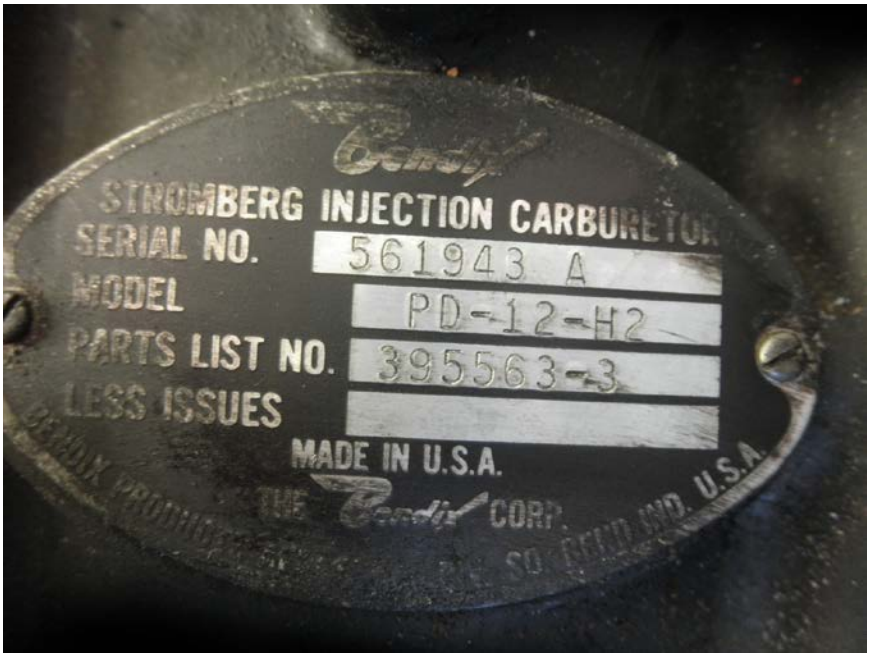

Photo No. 139: No. 3 engine's carburetor data plate.

Photo No. 140: No. 3 engine's carburetor.

Photo No. 141: Close up of the No. 3 engine's carburetor vent adapter nut showing that it was not safety wired.

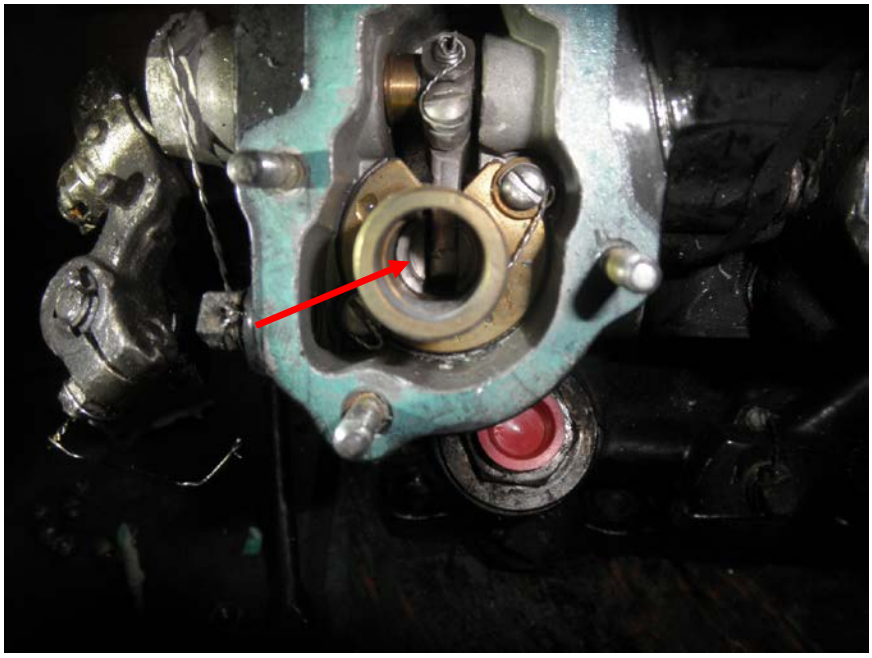

Photo No. 142: Close up view of No. 3 engine's carburetor idle jet chamber showing corrosion.

The carburetor was tested on a Stromberg Flow Bench. All of the gages that were used on the flow bench were tagged with a calibration sticker that indicated the calibration was valid at the time of the test. The test fluid utilized for the tests was naphtha. When the fluid pressure was applied to the carburetor, the nozzle opened at 5 pounds per square inch (psi), with the limit for opening being 4 to 6 psi. The nozzle closed at 4 psi and held the pressure. The carburetor was tested and the test was repeated twice to see if the results were repeatable. Table 2 provides the results of the carburetor's flow tests with the associated limits.

Table 2: No. 3 engine's carburetor test results

		Test		
Test point	Limits (pph[14])	1 (pph)	2 (pph)	3 (pph)
4	98 - 105	75	86	78
5	134 – 140	128	134	130
6	209 – 218	216	220	218
7	182 – 189	195	205	195
8	257 – 268	294	310	300
9	298 – 310	325	332	330
10	435 – 453	455	470	470
11	395 – 411	430	450	445
12	640 – 666	640	655	670
13	895 – 931	900	935	930
14	1065 – 1108	1065	1100	1095
15	1045 minimum	1055	1080	1075

[14] pph is pounds per hour.

Following the bench test, the carburetor was disassembled. During the disassembly, it was noted that the diameter of the safety wire on the enrichment valve was smaller than the safety wire used on the rest of the carburetor. The float plate was dimpled that according to Vintage Carburetor was indicative of an over pressurization of some kind. The nozzle strainer had a small amount of debris in the filter mesh. (Photo No. 143) All of the diaphragms were intact. (Photo No. 144) The poppet valve moved freely. The beam over the idle spring moved freely.

Photo No. 143: Close up view of strainer showing debris.

Photo No. 144: View of typical diaphragm showing it was intact.

2.3 Engine No. 4

2.3.1 Engine exterior

The engine was received at Vintage Radials sealed in a wood box that was opened in the presence of members of the Powerplants Group. The engine's data plate was checked and the serial number was confirmed to be SN 156819, the No. 4 engine. (Photo No. 145)

Photo No. 145: Close up of the No. 4 engine's data plate confirming the serial number.

There were pieces of airframe structure such as cowling supports and cowl flaps still attached to the engine. The engine had evidence of having been exposed to a fire with the heat resistant covering on the oil and fuel lines partially burned away as well as the paint on the left magneto. The air deflector in back of the cylinders was bent and buckled all the way around. The propeller shaft was in place, but was cut off flush to the front of the nose case. The left and right exhaust manifolds were still in place The left exhaust manifold was bent forward and buckled between about 6 and 9 o'clock. The right hand manifold intact, but was dented at about 2:30 o'clock. (Photos Nos. 146 and 147)

Photo No. 146: View of front of engine showing some airframe structure still attached.

Photo No. 147: View of rear of No. 4 engine showing fire damage and some airframe structure still attached.

2.3.2 Nose case

The propeller shaft could not be rotated until after the spark plugs were removed. After the cylinders had been removed from the crank case and the propeller shaft was rotated, all of the pistons moved concurrently.

The nose case was in place on the crankcase and was intact. (Photo No. 148) The bell gear was intact and there was no rotational damage to the gear teeth. The planetary gear carrier was intact and all of the planetary gears were in place. There was no rotational damage to the planetary gear teeth. (Photos Nos. 149 and 150)

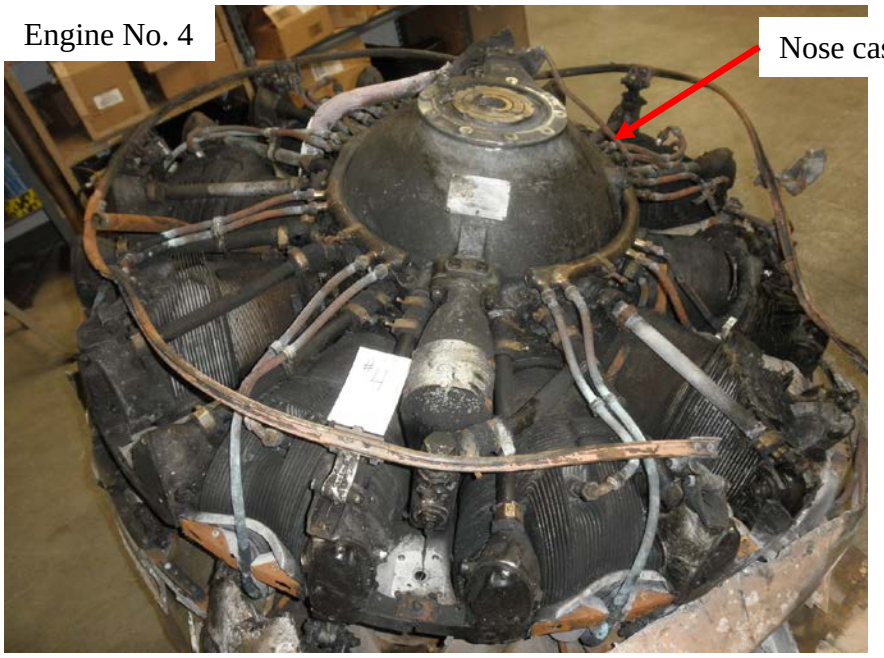

Photo No. 148: View of front of engine showing nose case in place and intact.

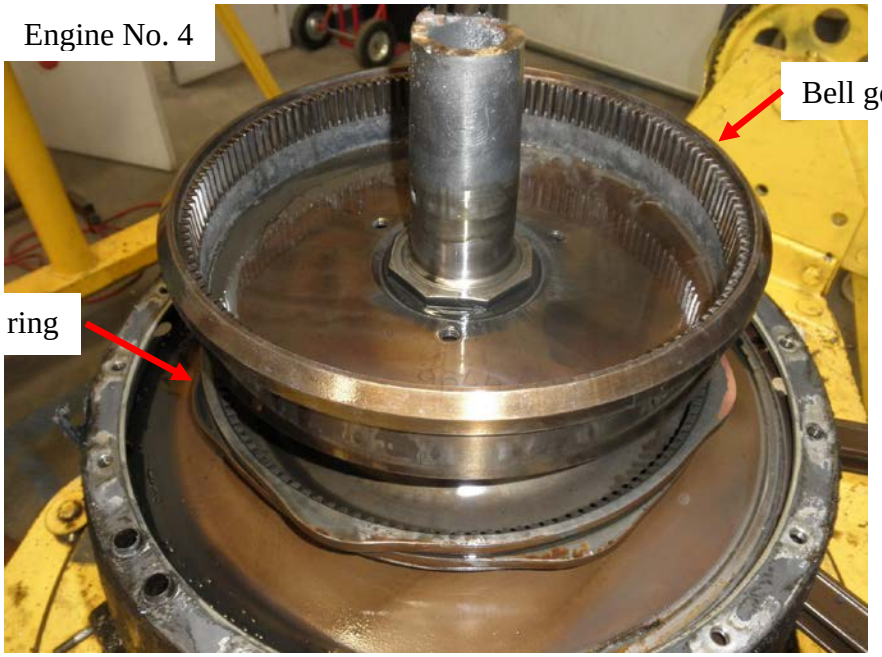

Photo No. 149: View of the bell gear showing that it was intact and had no rotational damage to the gear teeth. Also shown is the cam ring showing that it was intact.

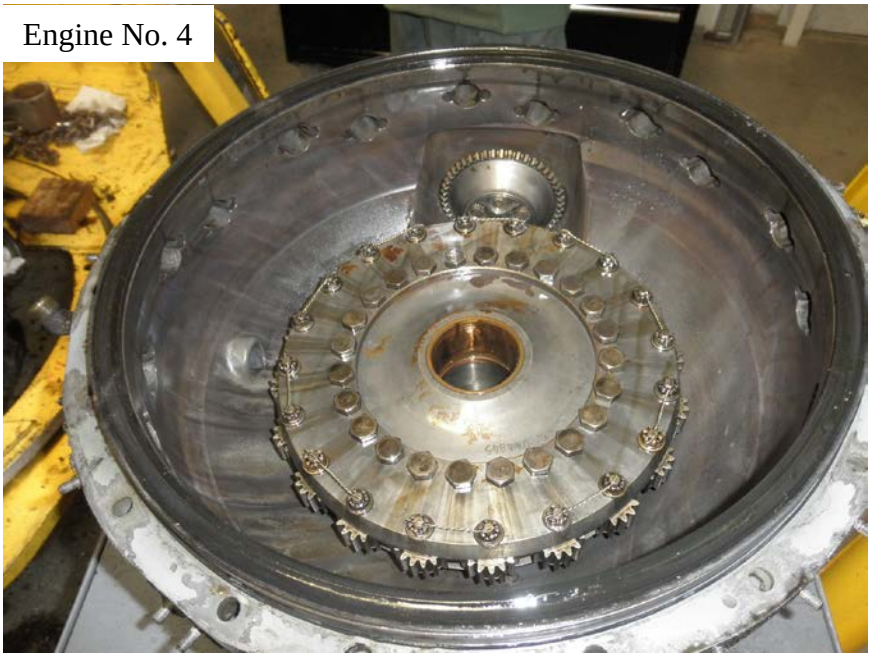

Photo No. 150: View of the planetary gear carrier showing it was intact and all of the planetary gears were in place.

2.3.3 Crankcase

The crankcase was intact. All nine cylinders were in place on the crankcase. (Photo No. 151)

Photo No. 151: View of the front of the No. 4 engine showing all nine cylinders in place on the crank case.

The cam ring was intact and undamaged. (Refer to Photo No. 149) All of the valve lifter bodies were intact and undamaged. The rollers on all of the valve body lifters were in place, intact, and turned freely.

The crank shaft was intact and the two counterweights were in place. (Photo No. 152) The crank shaft front and rear bearings were intact and rotated freely and smoothly. (Photo No. 153 All of the articulating rods were in place on the master rod and were undamaged. (Photo No. 154) The piston pin bearing on the master rod and the piston pin and wrist pin bearings on all of the articulating rods did not have any damage. (Photo No. 155 and refer to Photo No. 154) All of the wrist pins were in place and did not have any damage.

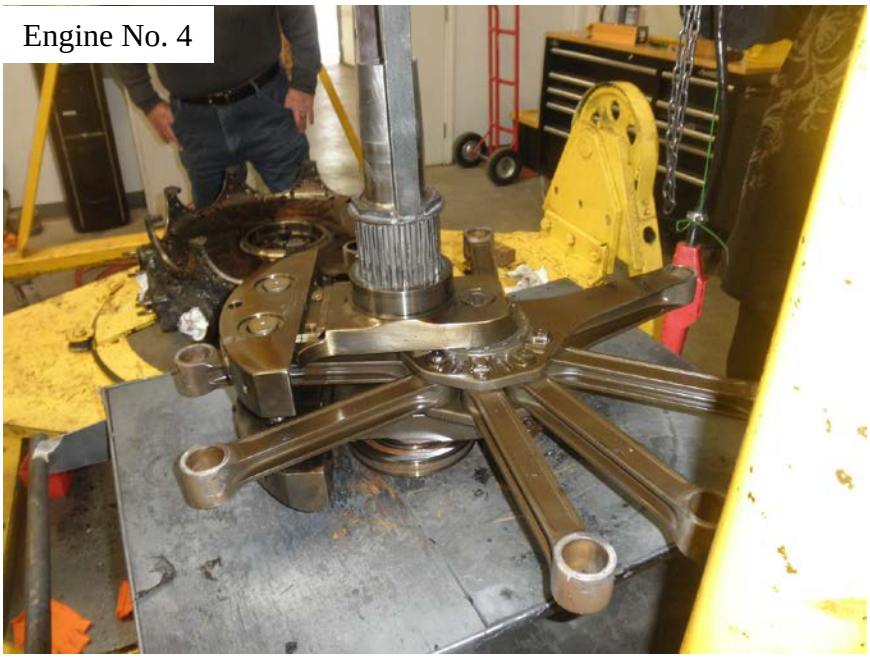

Photo No. 152: View of crank shaft showing it is intact with the two counterweights in place.

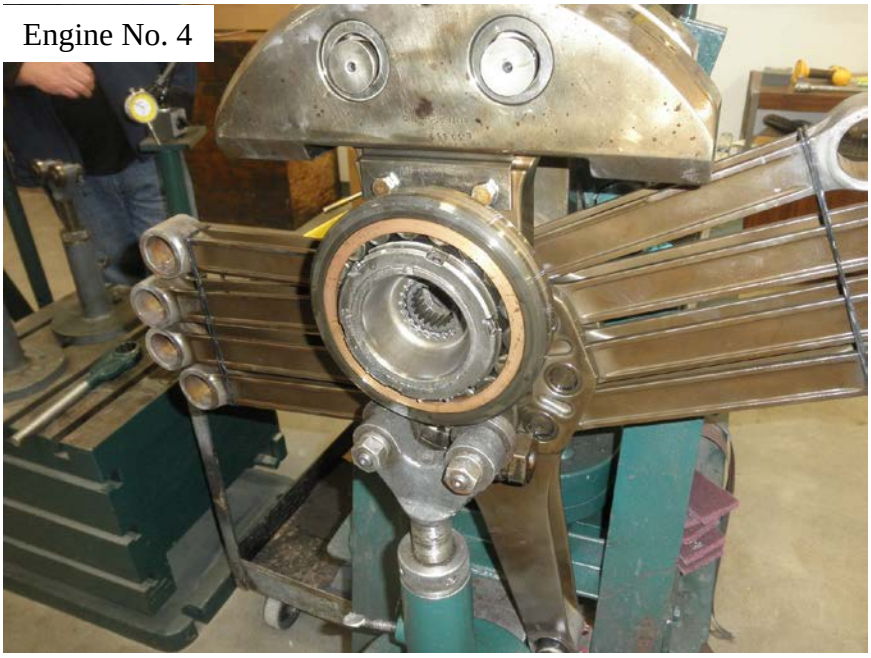

Photo No. 153: View of crank shaft rear bearing showing it was intact.

Photo No. 154: View of the master rod and all of the articulating rods showing all were intact and undamaged.

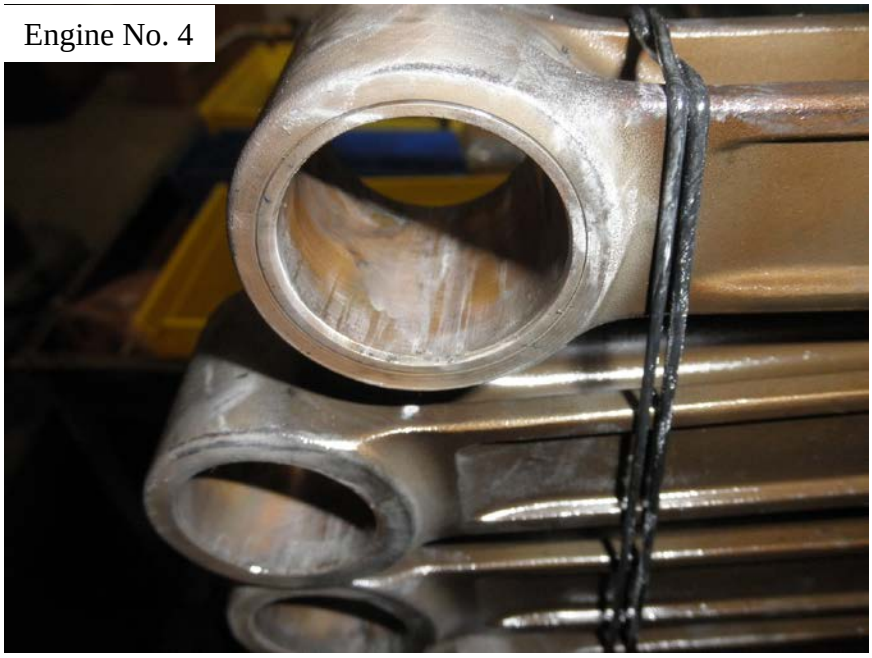

Photo No. 155: Close up view of a typical articulating rod piston pin bearing showing no damage to the bearing surface.

The supercharger fan did not have any damage. When the supercharger fan was rotated, the magneto drives rotated concurrently.

2.3.4 Push rods

The push rods and their shrouds were all in place except the push rods and shrouds for the No. 7 intake valve and the No. 8 intake and exhaust valves that were missing. All of the push rods were straight except for the push rod for No. 4 cylinder intake valve that was bent slightly coincidental to a bend in the respective push rod shroud.

2.3.5 Cylinders

2.3.5.1 Cylinder No. 1

The No. 1 cylinder barrel was in place on the crank case and the cylinder head was in place and intact. (Refer to Photo No. 151) The intake and exhaust rocker arm covers were in place on the cylinder head and did not appear to have any damage. The spark plugs were in place and the ignition leads were still attached.

The No. 1 piston was connected to the master rod with the piston pin and the piston pin buttons were in place. The piston was intact and all of the piston rings were in place and intact. There were small metal particles trapped on the side of the piston between the rings. The

head of the piston had a white-colored deposit that appeared to be flaking off. (Photos Nos. 156, 157, and 158)

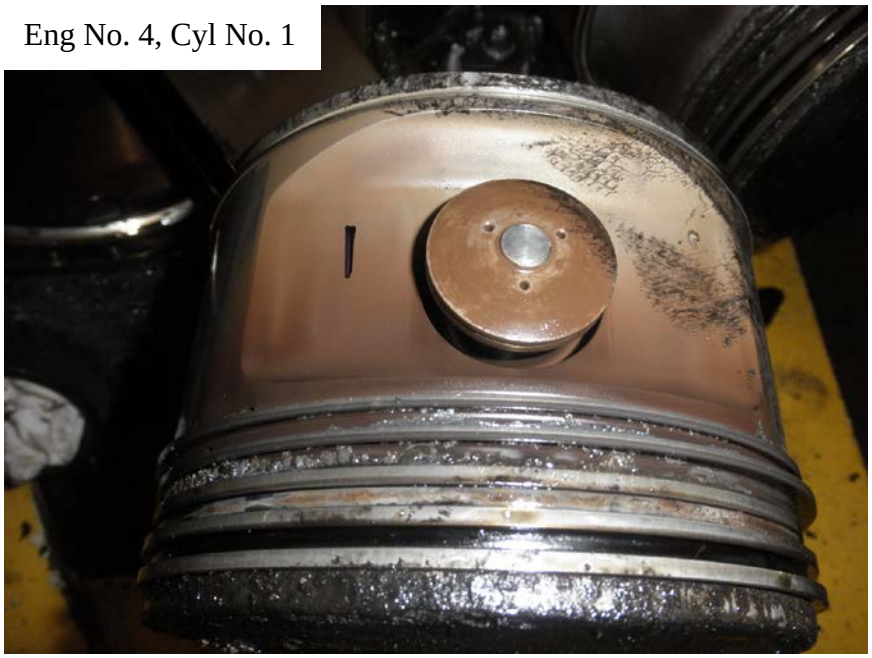

Photo No. 156: View of No. 1 cylinder's piston in place on the master rod showing that the piston was intact and that all of the piston rings were in place.

Photo No. 157: Close up view of the No. 1 cylinder's piston head showing the white-colored deposit.

Eng No. 4, Cyl No. 1

Photo No. 158: View of underside of No. 1 cylinder's piston along with the piston pin, piston pin buttons, and the cam followers showing all were intact and undamaged.

The cylinder barrel was intact and the inner surface did not have any damage. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. (Photo No. 159)

Eng No. 4, Cyl No. 1

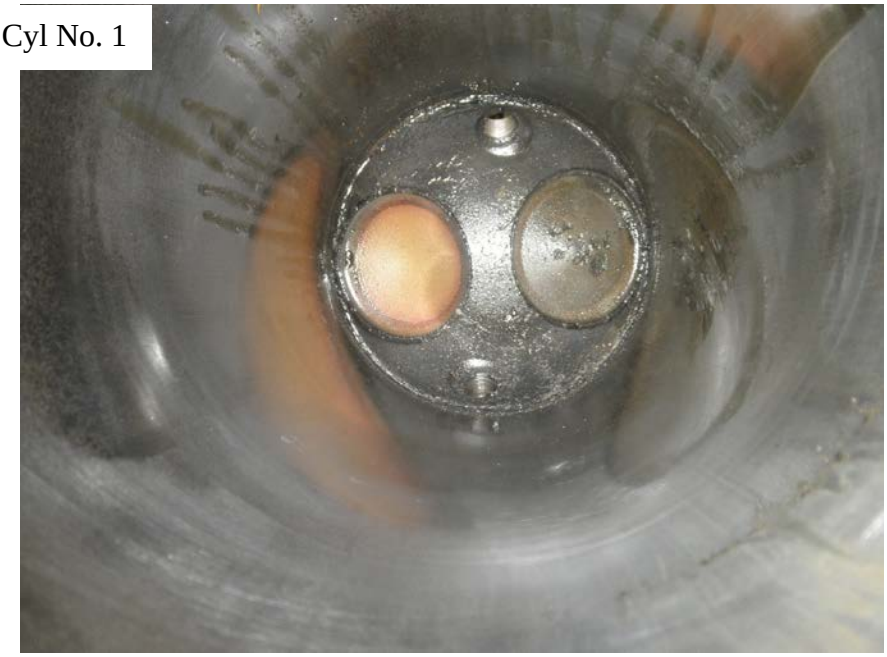

Photo No. 159: View of the inside of the No. 1 cylinder showing no damage to the barrel and the two valves were centered in place in the closed position.

2.3.5.2 Cylinder No. 2

The No. 2 cylinder barrel was in place on the crank case and the cylinder head was in place and intact. (Refer to Photo No. 151) The intake and exhaust rocker arm covers were in place on the cylinder head and did not appear to have any damage. The spark plugs were in place and the ignition leads were still attached.

The No. 2 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston was intact and all of the piston rings were in place and intact. There were small metal particles trapped on the sides of the piston between the rings. The head of the piston was a bronze-color for about half of the surface and a dark gray-color for the other half with the perimeter of the head being a black color. (Photos Nos. 160, 161, and 162)

Photo No. 160: View of No. 2 cylinder's piston in place on the articulating rod showing that the piston was intact and that all of the piston rings were in place.

Photo No. 161: Close up view of the No. 2 piston's head showing the dark- and bronze-colored areas.

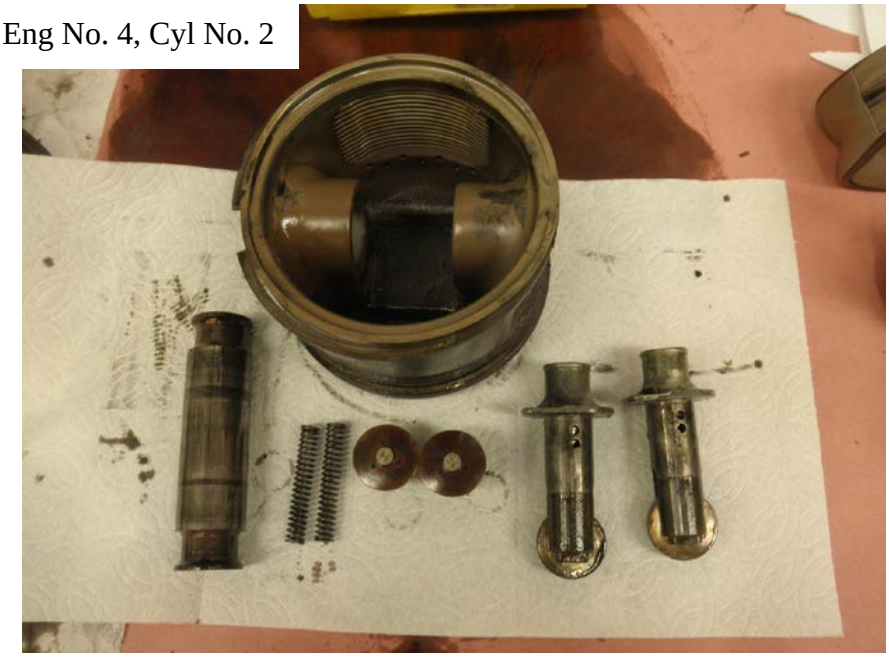

Photo No. 162: View of underside of No. 2 cylinder's piston along with the piston pin, piston pin buttons, and the cam followers showing all were intact and undamaged.

The cylinder barrel was intact and the inner surface did not have any damage. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. (Photo No. 163)

Photo No. 163: View of the inside of the No. 2 cylinder showing no damage to the barrel and the two valves were centered in place in the closed position.

2.3.5.3 Cylinder No. 3

The No. 3 cylinder barrel was in place on the crank case and the cylinder head was in place on the cylinder barrel. (Refer Photo No. 151) The intake valve rocker arm cover was in place and intact. The exhaust valve rocker arm cover was in place, but the aft end of the cover was broken open exposing the rocker arm that was intact. (Photo No. 164) The spark plugs were in place and the ignition leads were still attached.

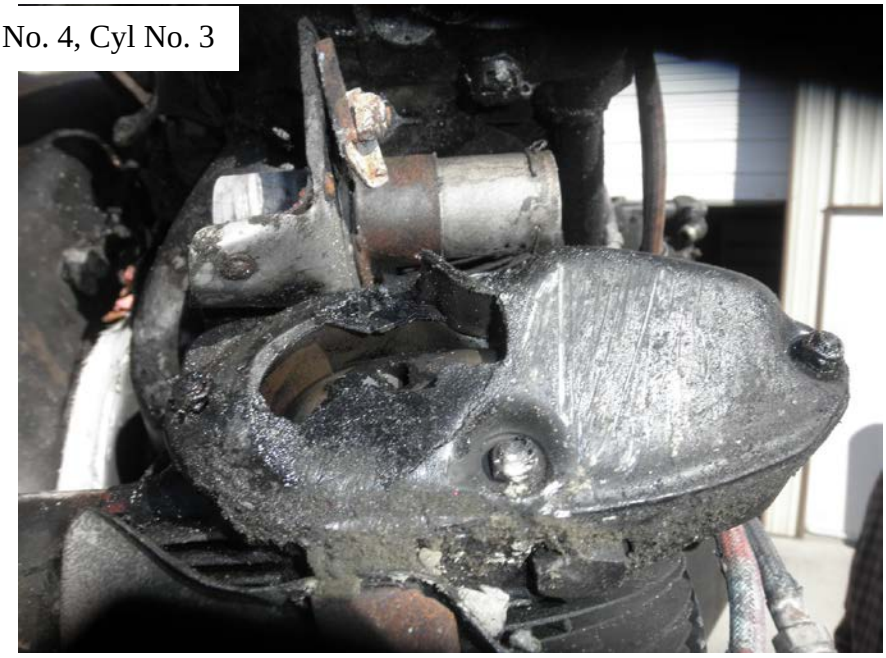

Photo No. 164: Close up view of the No. 3 cylinder's exhaust rocker arm cover showing the hole in the cover.

The No. 3 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston was intact and all of the piston rings were in place and intact. There were small metal particles trapped on the sides of the piston between the rings. The head of the piston was a dark gray color. (Photos Nos. 165, 166, and 167)

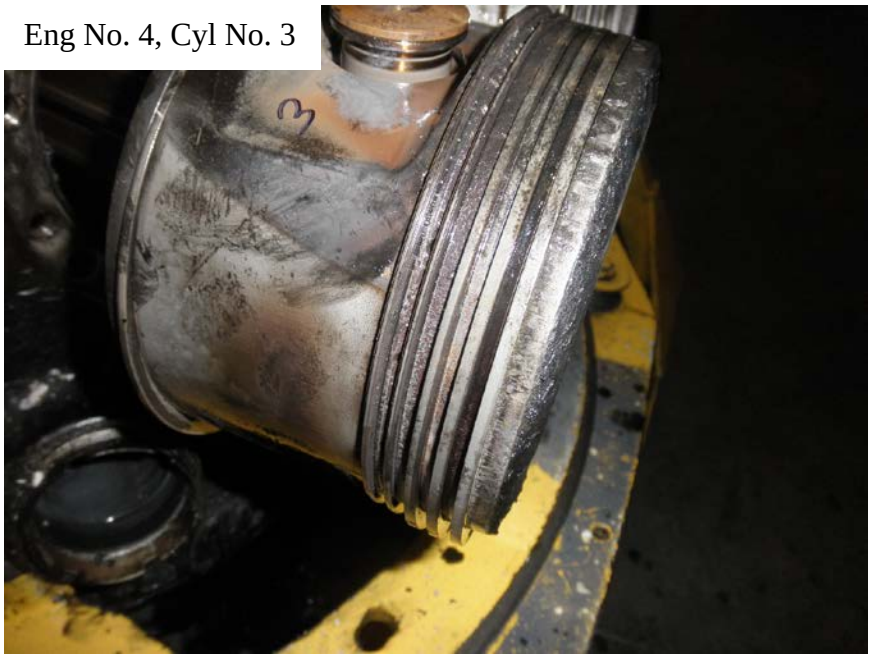

Photo No. 165: View of No. 3 cylinder's piston in place on the articulating rod showing that the piston was intact and that all of the piston rings were in place.

Photo No. 166: Close up view of the No. 3 piston's head showing the dark gray color.

Photo No. 167: View of underside of No. 3 cylinder's piston along with the piston pin, piston pin buttons, and the cam followers showing all were intact and undamaged.

The cylinder barrel was intact and the inner surface did not have any damage. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. (Photo No. 168)

Eng No. 4, Cyl No. 3

Photo No. 168: View of the inside of the No. 3 cylinder showing no damage to the barrel and the two valves were centered in place in the closed position.

2.3.5.4 Cylinder No. 4

The No. 4 cylinder barrel was in place on the crank case and the cylinder head was in place and intact. (Refer to Photo No. 151) The intake and exhaust rocker arm covers were in place on the cylinder head and did not appear to have any damage. The spark plugs were in place and the ignition leads were still attached.

The No. 4 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston was intact and all of the piston rings were in place and intact. There were small metal particles trapped on the sides of the piston between the rings. The head of the piston was a dark gray-color. (Photos Nos. 169, 170, and 171)

Eng No. 4, Cyl No. 4

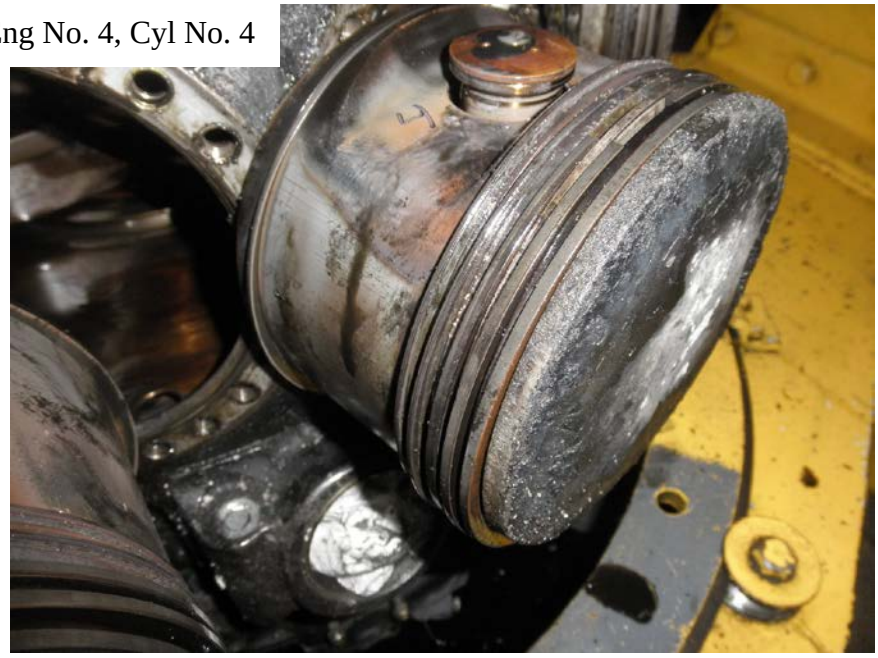

Photo No. 169: View of No. 4 cylinder's piston in place on the articulating rod showing that the piston was intact and that all of the piston rings were in place.

Eng No. 4, Cyl No. 4

Photo No. 170: Close up view of the No. 4 piston's head showing the dark gray color.

Photo No. 171: View of underside of No. 4 cylinder's piston along with the piston pin, piston pin buttons, and the cam followers showing all were intact and undamaged.

The cylinder barrel was intact and the inner surface did not have any damage. There were metal fragments on the cylinder barrel walls. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. The exhaust valve had what appeared to be areas of yellow paint on the face of the valve. (Photo No. 172)

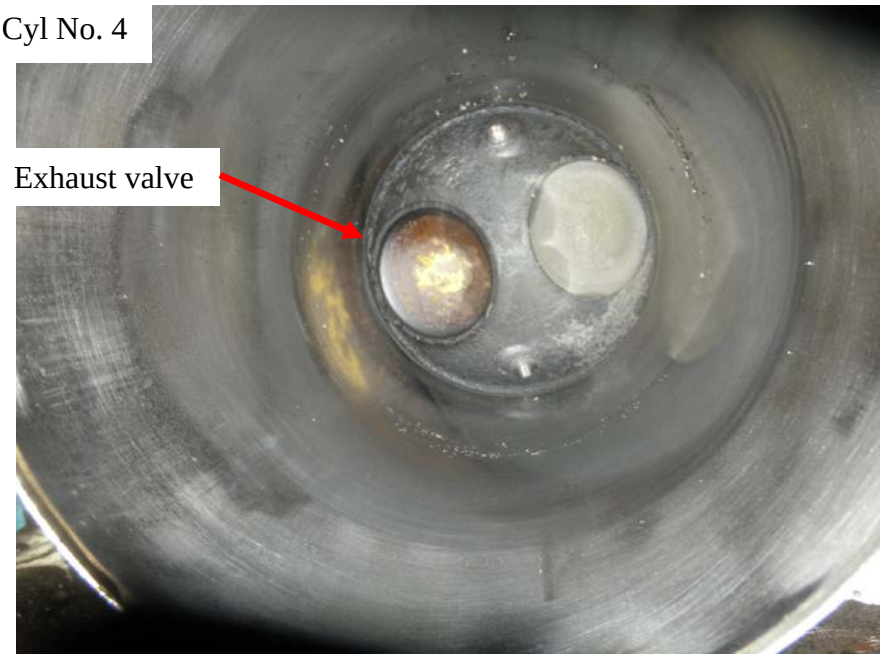

Photo No. 172: View of the inside of the No. 4 cylinder showing no damage to the barrel and the two valves were centered in place in the closed position. Also shown is what appeared to be yellow paint on the exhaust valve.

2.3.5.5 Cylinder No. 5

The No. 5 cylinder barrel was in place on the crank case and the cylinder head was in place and intact. (Refer to Photo No. 151) The intake and exhaust rocker arm covers were in place on the cylinder head and did not appear to have any damage. The spark plugs were in place and the ignition leads were still attached.

The No. 5 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston was intact and all of the piston rings were in place and intact. There were small metal particles trapped on the sides of the piston between the rings. The head of the piston was a dark gray color. (Photos Nos. 173, 174, and 175)

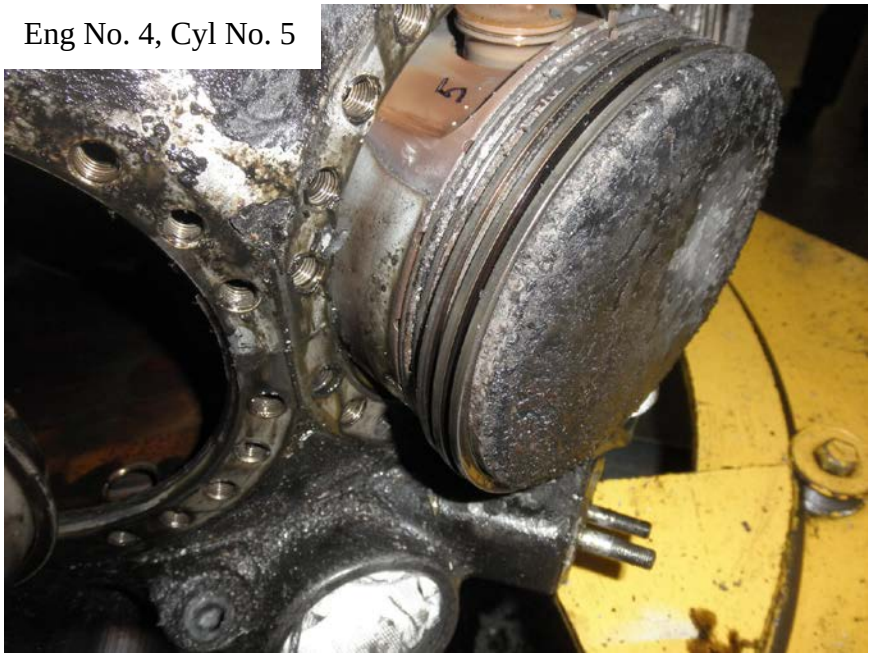

Photo No. 173: View of No. 5 cylinder's piston in place on the articulating rod showing that the piston was intact and that all of the piston rings were in place.

Photo No.174: Close up view of the No. 5 piston's head showing the dark gray color.

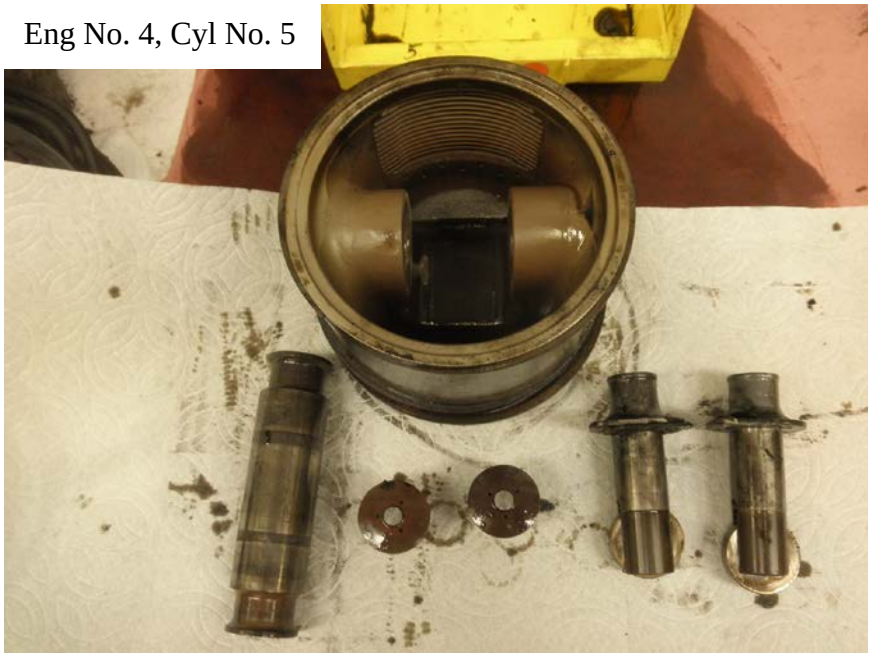

Photo No. 175: View of underside of No. 5 cylinder's piston along with the piston pin, piston pin buttons, and the cam followers showing all were intact and undamaged.

The cylinder barrel was intact and the inner surface did not have any damage. There were metal fragments on the cylinder barrel walls. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. (Photo No. 176)

Eng No. 4, Cyl No. 5

Photo No. 176: View of the inside of the No. 5 cylinder showing no damage to the barrel and the two valves were centered in place in the closed position.

2.3.5.6 Cylinder No. 6

The No. 6 cylinder barrel was in place on the crank case and the cylinder head was in place and intact. (Refer to Photo No. 151) The intake and exhaust rocker arm covers were in place on the cylinder head and did not appear to have any damage. The spark plugs were in place and the ignition leads were still attached.

The No. 6 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston was intact and all of the piston rings were in place and intact. There were small metal particles trapped on the sides of the piston between the rings. The head of the piston was a gray color that appeared to flaking off in the center exposing patches of white. (Photos Nos. 177, 178, and 179)

Photo No. 177 View of No. 6 cylinder's piston in place on the articulating rod showing that the piston was intact and that all of the piston rings were in place.

Photo No. 178: Close up view of the No. 6 piston's head showing the gray color.

Photo No. 179: View of underside of No. 6 cylinder's piston along with the piston pin, piston pin buttons, and the cam followers showing all were intact and undamaged.

The cylinder barrel was intact and the inner surface did not have any damage. There were metal fragments on the cylinder barrel walls. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. (Photo No. 180)

Photo No. 180: View of the inside of the No. 6 cylinder showing no damage to the barrel and the two valves were centered in place in the closed position.

2.3.5.7 Cylinder No. 7

The No. 7 cylinder barrel was in place on the crank case. (Refer to Photo No. 151) The center of the cylinder head was crushed inward and rearward and the cooling fins were broken off almost flush to the surface. The front of the cylinder head under the intake valve cover was broken open. The front of the intake and exhaust valve rocker arm housings were broken open exposing the ends of the rocker arms that were intact. The intake push rod shroud and push rod were missing. The exhaust push rod shroud was in place, but it was dislodged at the inner and outer ends. The forward spark plug was broken off flush to the cylinder head surface. The aft spark plug was in place. The two ignition leads were both broken.

The No. 7 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston was intact and all of the piston rings were in place and intact. There were small metal particles trapped on the sides of the piston between the rings. The head of the piston was a dark gray color. (Photos Nos. 181, 182, and 183)

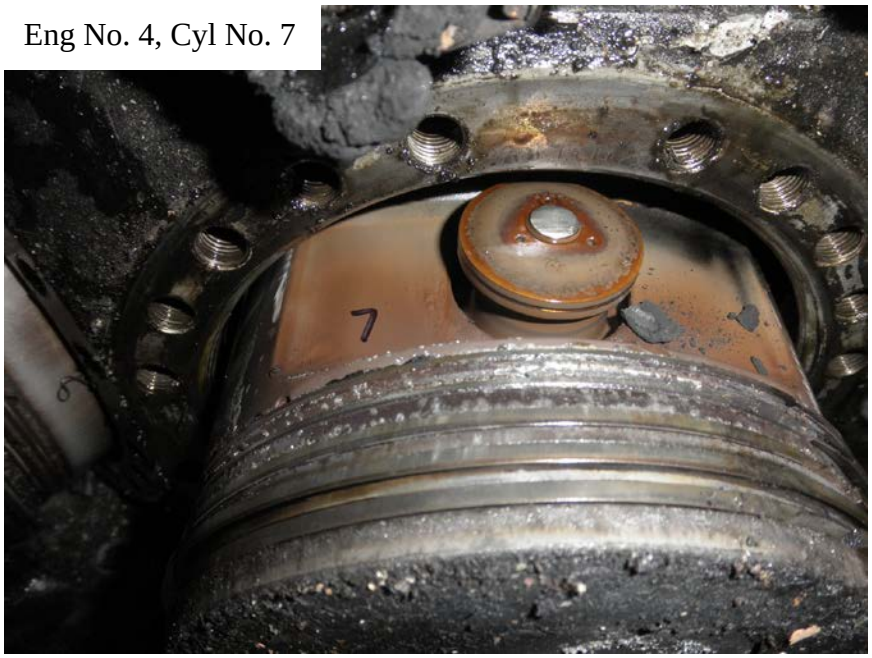

Photo No. 181: View of No. 7 cylinder's piston in place on the articulating rod showing that the piston was intact and that all of the piston rings were in place. Also shown are small metal particles in the piston rings.

Photo No. 182: Close up view of the No. 7 piston's head showing the dark gray color.

Photo No. 183: View of underside of No. 7 cylinder's piston along with the piston pin, piston pin buttons, and the cam followers showing all were intact and undamaged.

The cylinder barrel was intact. The interior surface of the cylinder did not have any damage. There were metal fragments on the sides of the cylinder barrel. Both of the valves were in the open position. The intake valve was slightly off center, although the witness marks on the valve seat in the cylinder head were concentric with the opening. The exhaust valve was centered to the valve seat. (Photo No. 184)

4.5

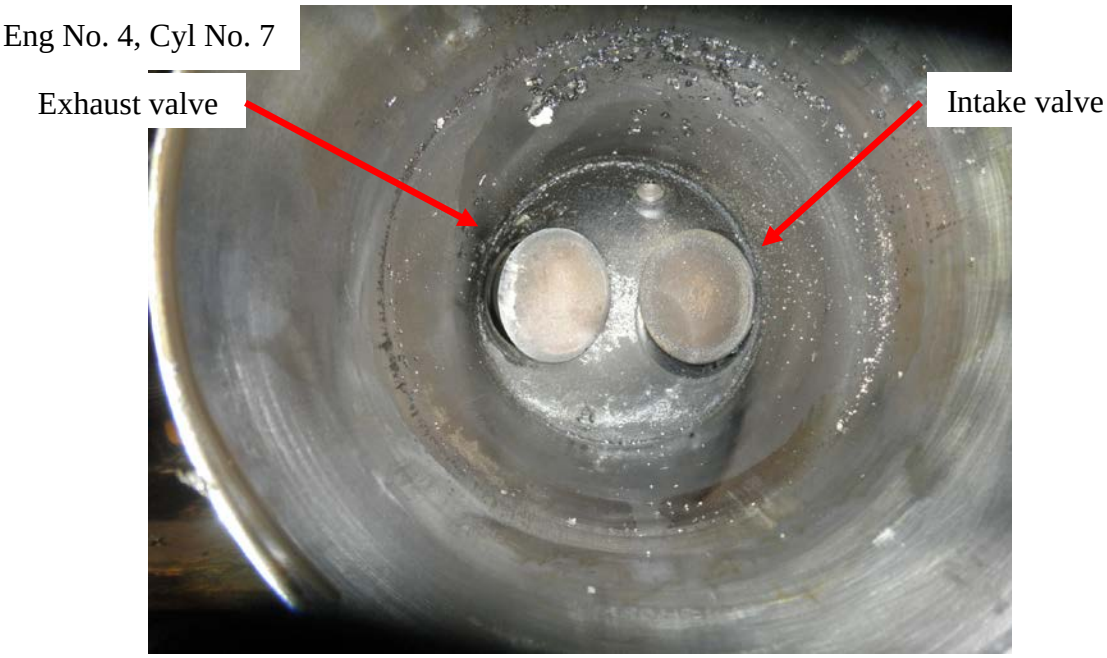

Photo No. 184: View of the inside of the No. 7 cylinder showing no damage to the barrel, although there were metal particles on the barrel wall and the two valves were open with the intake valve off center and the exhaust was off-center.

2.3.5.8 Cylinder No. 8

The No. 8 cylinder barrel was in place on the crank case. (Refer to Photo No. 151) The cylinder head was in place on the cylinder barrel, but the head was partially separated from the barrel. The front of the cylinder head was crushed and the cooling fins were bent over. The head was completely separated from the barrel at the front and by about four threads at the rear. The front of the cylinder head under the intake valve cover was broken open. The front of the intake and exhaust valve rocker arm housings were broken open exposing the end of the rocker arms. The front spark plug was bent over against the cylinder head and the aft spark plug was in place. The two ignition leads were broken.

The No. 8 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston was intact and all of the piston rings were in place. All of the piston rings were intact except the No. 1 ring, the upper most ring, that was broken and missing several pieces. There were small metal particles trapped on the sides of the piston between the rings. The head of the piston was a gray-color with small white-colored patches. There were axial scratches on the side of the piston and rings. (Photos Nos. 185, 186, 187, and 188)

Photo No. 185: View of No. 8 cylinder's piston in place on the articulating rod showing that the piston was intact and that all of the piston rings were in place. Also shown are small metal particles in the piston rings.

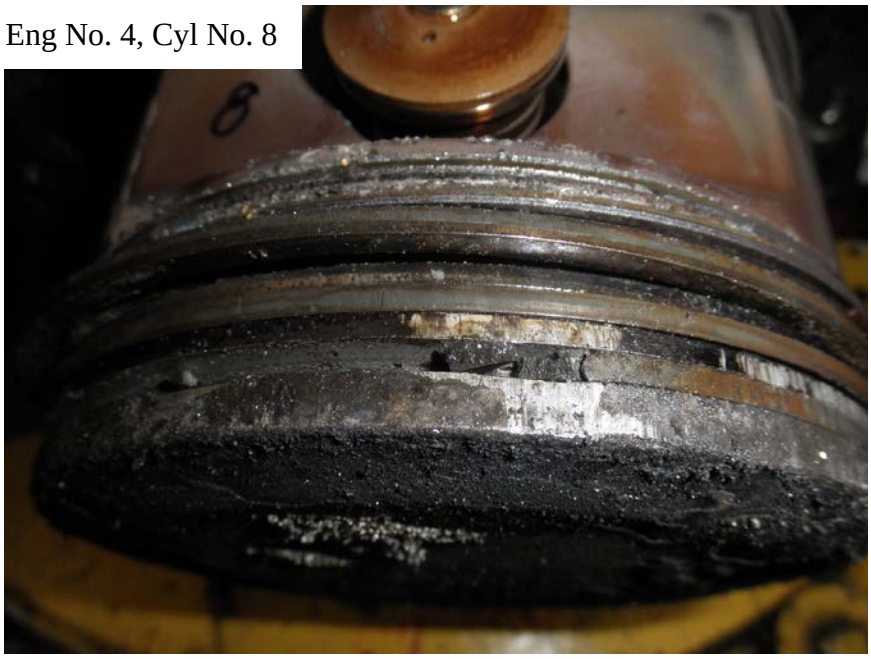

Photo No. 186: Close up No. 8 cylinder's piston showing broken No.1 piston ring.

Photo No. 187: Close up view of the No. 8 piston's head showing the dark gray color with the white-colored patches.

Photo No. 188: View of underside of No. 8 cylinder's piston along with the piston pin, piston pin buttons, and the cam followers showing all were intact and undamaged.

The cylinder barrel was intact. The interior surface of the barrel did not have any damage. There were metal fragments on the sides of the cylinder barrel as well as on the inside of the cylinder head. The valves were in place and did not appear to have any damage. Both of valves were in the closed position and were centered on their respective valve seats. (Photo No. 189)

Eng No. 4, Cyl No. 8

Photo No. 189: View of the inside of the No. 8 cylinder showing no damage to the barrel, although there were metal particles on the inside. Also shown is the cylinder head partially separated from the barrel, but the two valves are centered in the closed position.

2.3.5.9 Cylinder No. 9

The No. 9 cylinder barrel was in place on the crank case and the cylinder head was in place and intact. (Refer to Photo No. 151) The intake and exhaust rocker arm covers were in place on the cylinder head and did not appear to have any damage. The spark plugs were in place and the ignition leads were still attached.

The No. 9 piston was connected to the articulating rod with the piston pin and the piston pin buttons were in place. The piston was intact and all of the piston rings were in place and intact. There were small metal particles trapped on the sides of the piston between the rings. The head of the piston was a dark gray-color. (Photos Nos. 190, 191, and 192)

Photo No. 190: View of No. 9 cylinder's piston in place on the articulating rod showing that the piston was intact and that all of the piston rings were in place. Also shown are small metal particles in the piston rings.

Photo No. 191: Close up view of the No. 8 piston's head showing the dark gray color.

Eng No. 4, Cyl No. 9

Photo No. 192: View of underside of No. 9 cylinder's piston along with the piston pin, piston pin buttons, and the cam followers showing all were intact and undamaged.

The cylinder barrel was intact and the inner surface did not have any damage. There were metal fragments on the cylinder barrel walls. The two valves were in place in the closed position centered on the valve seats. The valves did not have any damage. (Photo No. 193)

Eng No. 4, Cyl No. 9

Photo No. 193: View of the inside of the No. 9 cylinder showing no damage to the barrel and the two valves centered in place in the closed position.

2.3.6 Spark plugs

The electro gap on all of the plugs were checked. All of the plugs had a gap that was in excess of 0.022 inches except the No. 1 front plug and No. 7 rear plug that were within the manufacturer's recommended gap of 0.016 to 0.022 inches. Table 3 lists the visual condition and gap measurements for each of the No. 4 engine's spark plugs. (Photos Nos. 194 and 195)

Table 3: No. 4 engine's spark plug visual examination

	Front		Rear	
Cylinder	Condition	Gap (inches)	Condition	Gap (inches)
1	The tip of the plug was oily. The tip appeared to be fouled with lead. The insulator was a light greenish color.	0.022	The tip of the plug was fouled with oil. The insulator was a light greenish color	>0.022
2	The tip of the plug was fouled with oil. The insulator was a light greenish color.	>0.022	The tip of the plug was fouled with oil. The insulator was a light greenish color	>0.022
3	The tip of the plug was wet. There did not appear to be any oil fouling. The insulator was a dark color.	>0.022	The tip of the plug was fouled with oil. The insulator was a dark color.	>0.022
4	The tip of the plug was fouled with carbon. The insulator was a dark color.	>0.022	The tip of the plug was wet, but it did not appear that the tip was fouled with oil. The insulator was a light greenish color.	>0.022
5	The tip of the plug was dry. There were no oil deposits on the tip. The insulator was a light greenish color.	>0.022	The tip of the plug had lead deposits on the insulator that was consistent with detonation. The insulator was a light greenish color.	>0.022
6	The insulator was cracked. There were heavy carbon deposits and some lead deposits on the tip. The insulator was a dark color.	>0.022	The tip did not have any oil deposits or carbon build up. The insulator was a light gray color.	>0.022
7	Missing		There were heavy oil deposits on the tip and the tip was fouled with lead deposits.	0.022

8	Missing		There were white specks on the tip that is consistent with detonation. There were lead deposits on the tip and insulator. The insulator was a dark color.	>0.022
9	There were no lead or oil deposits on the tip. The insulator was a dark color.	>0.022	There were small white specks on the insulator that was consistent with detonation. There were no lead or oil deposits on the tip. The insulator was a dark color.	>0.022

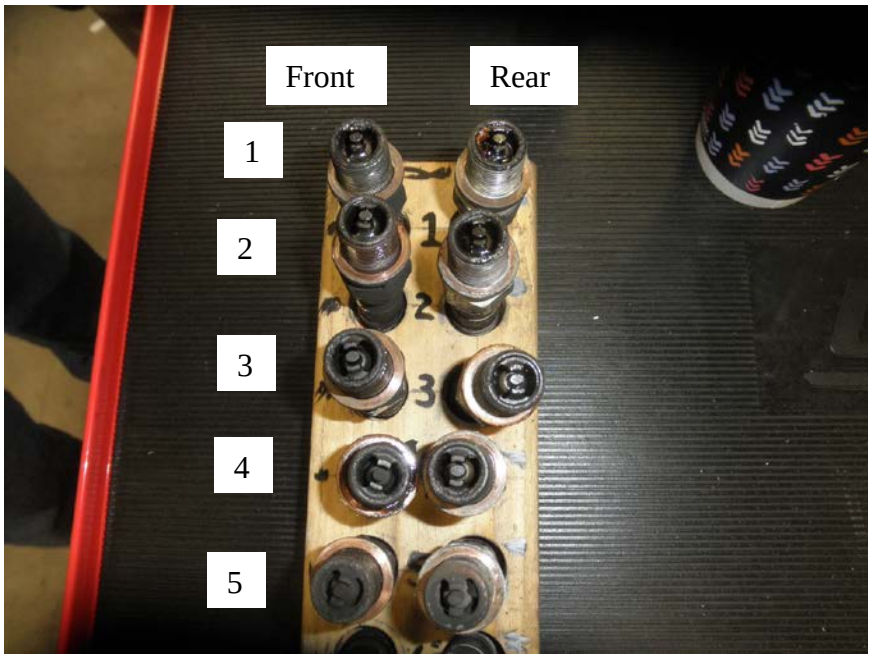

Photo No. 194: No. 4 engine's front and rear spark plugs from cylinders Nos. 1 through 5.

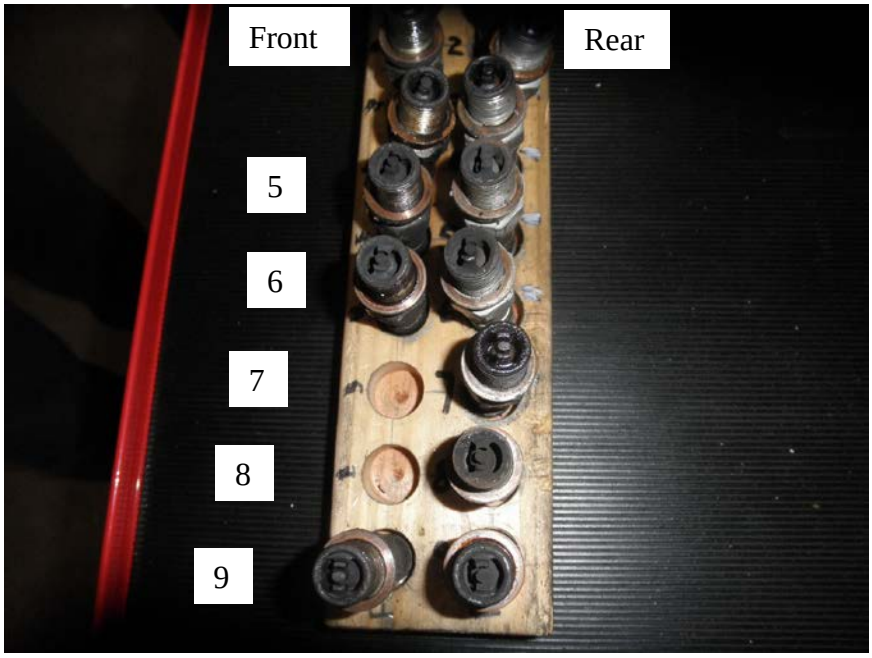

Photo No. 195: No. 4 engine's front and rear spark plugs from cylinders Nos. 5 through 9.

2.3.7 Accessories

The left and right magnetos (Refer to Section 1.0 for further details on the No. 4 engine's magnetos), starter, and carburetor were still in place on the back of the engine. The generator was not installed and the drive pad had a shipping cover installed. (Photo No. 196)

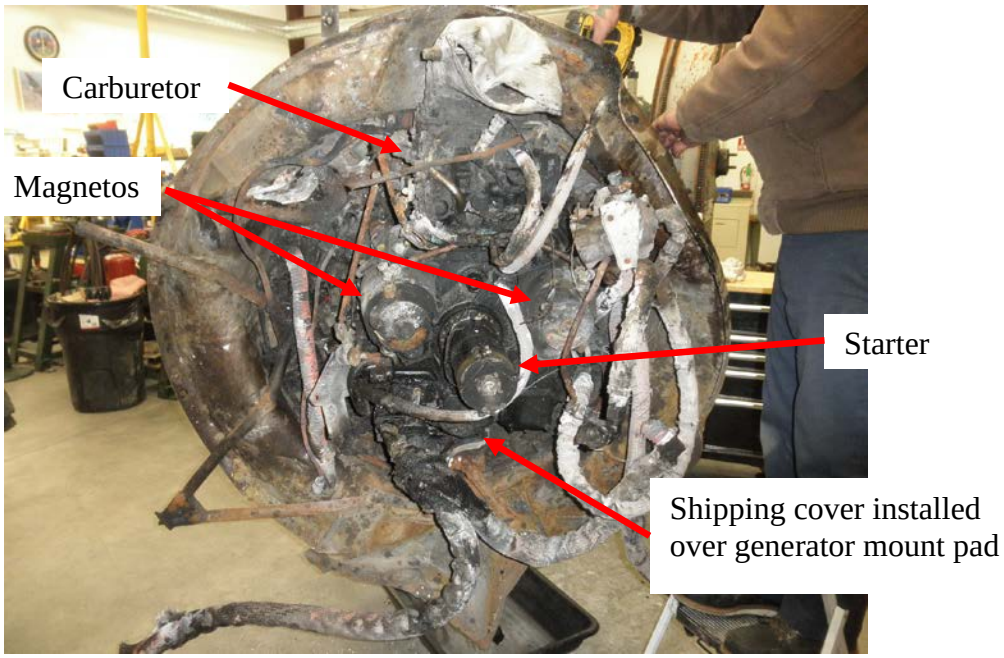

Photo No. 196: Aft side of No. 4 engine showing components still installed.

The Cuno oil filter was removed from the rear of the crank case. (Photo No. 197) The filter was disassembled. The filter elements were flushed out and they had a small amount of small brown and silver colored particles. (Photo No. 198) When touched with a magnet, all of the silver colored particles stuck to the magnet.

Photo No. 197: No. 4 engine's Cuno filter after it was removed from the engine.

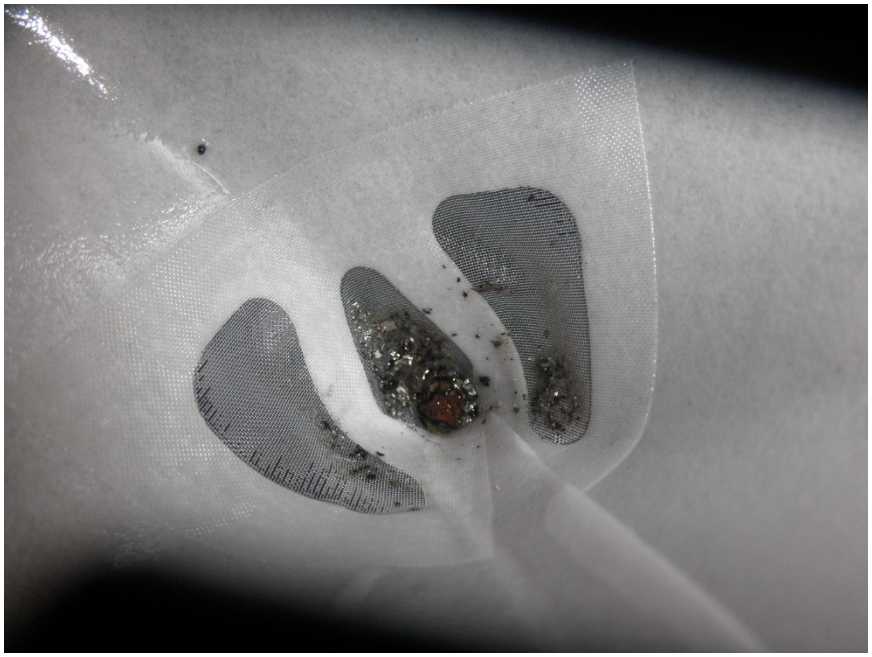

Photo No. 198: Debris that was flushed out of the No. 4 engine's Cuno filter.

The exterior of the carburetor was sooted. On the carburetor, the mixture was set in the run, or rich, position. The throttle was at the idle stop. The linkages on the carburetor could not be moved.

The supercharger vent port had the remains of a plastic cap melted inside the port. (Photo No. 199) When the supercharger impeller was rotated, the left and right magneto drive gears rotated concurrently.

Photo No. 199: No. 4 engine's supercharger vent port with the remains of a plastic cap in the port.

3.0 Propellers

3.1 Propeller description

The airplane was equipped with Hamilton Standard 23E50-473 Hydromatic three-bladed constant speed, quick feathering propellers . The Hydromatic propeller is composed of two major assemblies: the propeller assembly and the dome assembly. The propeller assembly consists of the steel-alloy spider that is the component that holds the blades in position, the steel-alloy barrel is the casing that goes over the spider, and the aluminum-alloy propeller blades. The dome assembly is the pitch change mechanism and consists of steel-alloy two cylindrical cams, an aluminum-alloy double-walled piston, and an aluminum-alloy dome. Hydraulic oil pressure moves the piston that turns the cams to move the blades to the desired position.

3.2 Propeller No. 3

The No. 3 propeller was received at Maxwell in a large wood crate that was opened in the presence of a member of the Powerplants Group. The serial number marked on the propeller hub was 146287 that corresponded to No. 3 propeller's serial number.

The propeller was received with all three blades in place on the spider hub. (Photo No. 200) The dome was separated from the spider hub, but was received with the propeller.

Photo No. 200: No. 3 propeller as received with all three blades in place, but with the dome separated from the spider hub.

The top of the dome was crushed inward slightly. The gear at the base of the dome was intact. (Photo No. 201) The cams in the in the dome could not be removed. According to Maxwell, the dome was in the service bulletin (SB) 473 configuration that utilized three indexing pins. (Photo No. 202) The dome stop rings were in the low pitch position. The gear on the dome was at 20°, which is the low pitch stop position. (Photo No. 203)

Photo No. 201: View of base of propeller dome showing gear was intact.

Photo No. 202: Enlarged view of propeller hub showing SB 473 three-pin configuration.

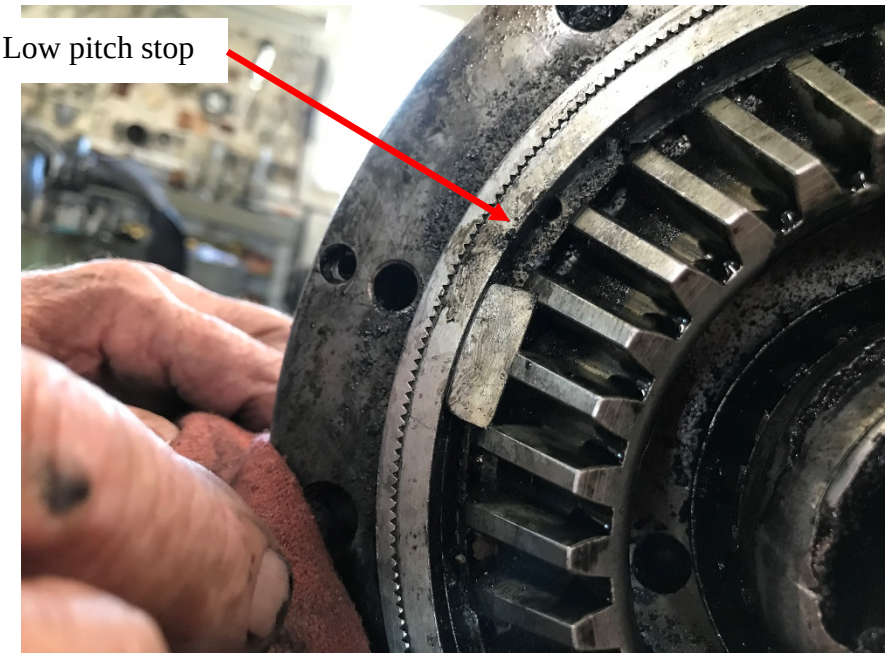

Photo No. 203: Close up view of base of dome showing the gear was at the low pitch stop.

The propeller barrel was in place, intact and all of the retaining bolts were in place with the castellated nuts and cotter pins still in place. All three of the dowel indexing pins were in place and intact, although two of the three were bent.

The spider hub was intact.

Blade No. 1 was full length and was essentially straight with a slight bend to the camber side. The paint at the tip of the blade was blistered and charred. The logo on the face of the blade was charred. (Photo No. 204) The blade had nicks and dents along leading edge between about 46 and 52 inches from the blade butt. There was material missing from the trailing edge between about 25 and 29 inches from the blade butt. The blade was rotated so that it was about 180° from the feathered position. The gear segment at the base of the blade was broken at the low pitch position. (Photo No. 205) The screws at the base of the blade were in place and intact. The bearing halves were intact with all of the rollers in place. (Photo No. 206)

Photo No. 204: View of blade No. 1 showing it was full length and essentially straight with the thermal damage along the camber side.

Photo No. 205: Close up view of blade No. 1's gear segment broken at the low pitch position.

Photo No. 206: Picture of the propeller bearing segments showing they were intact with the rollers in place.

Blade No. 2 was full length and was rotated backwards to its normal operating position. The blade was bent back towards the camber side at about 7-inches from the blade butt. There were nicks and dents along the leading edge and the trailing edge was gouged at about 36-inches from the blade butt. The paint on the blade did not appear to have any thermal damage although the bottom of the Hamilton Standard logo appeared to charred slightly. (Photo No. 207) The gear segments were intact and were not rotated. The screws at the base of the blade were in place and intact. (Photo No. 208) The bearing halves were intact with all of the rollers in place. (Refer to Photo No. 206)

Photo No. 207: View of blade No. 2 camber side showing the blade full length and the bend as well as no thermal damage.

Photo No. 208: Close up of No. 2 blade butt showing the gear segment was intact and the screws in place.

Blade No. 3 was missing the tip. The blade was rotated so that it was about 270° from the feathered position. The blade was bent back towards the camber side at about 12-inches from the blade butt. (Photo No. 209) The blade's leading and trailing edges had nicks and dents. The gear segments were intact. The screws at the base of the blade were in place and intact. The paint on the blade was blistered and charred. The Hamilton Standard logo on the blade face was also charred. (Photo No. 210) The bearing halves were intact with all of the rollers in place. (Refer to Photo No. 206)

Photo No. 209: View of blade No. 3 showing the missing piece of the tip and the bend to the camber side as well as the thermal damage.

Photo No. 210: Close up of No. 3 blade butt showing the gear segment was intact and the screws in place.

According to Maxwell, the damage to the No. 3 propeller was consistent with the propeller being in the normal operating position.

3.3 Propeller No. 4

The No. 4 propeller was received at Maxwell in a large wood crate that was opened in the presence of members of the Powerplants Group. The serial number marked on the propeller hub was P44285 that corresponded to the No.4 propeller's serial number.

The propeller was complete with the dome and all three propeller blades in place on the spider hub. There were two blades that were cut to facilitate shipping the propeller. (Photo No. 211) The tips of the blades were received with the rest of the propeller.

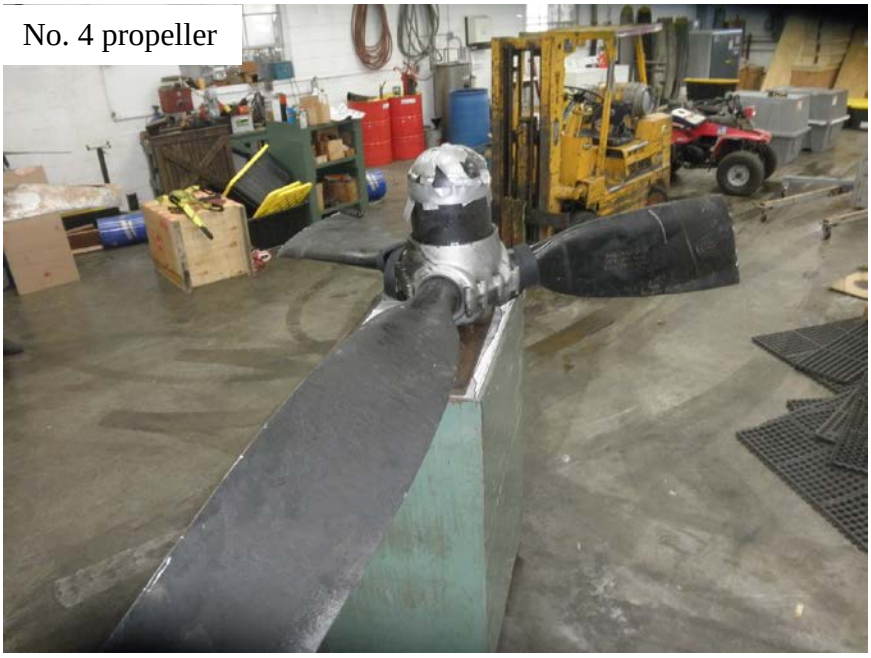

Photo No. 211: View of No. 4 propeller as received with two blades cut off.

The dome was intact. The top of the dome was crushed inward and buckled slightly. The dome retaining nut was tight. According to Maxwell, the dome was in the SB 473 configuration. (Photo No. 212) The gear at the base of the dome was intact. (Photo No. 213) The gear on the dome was almost to the feather pitch stop. (Photo No. 214) The barrel supports were in place and intact. The dome was not disassembled further.

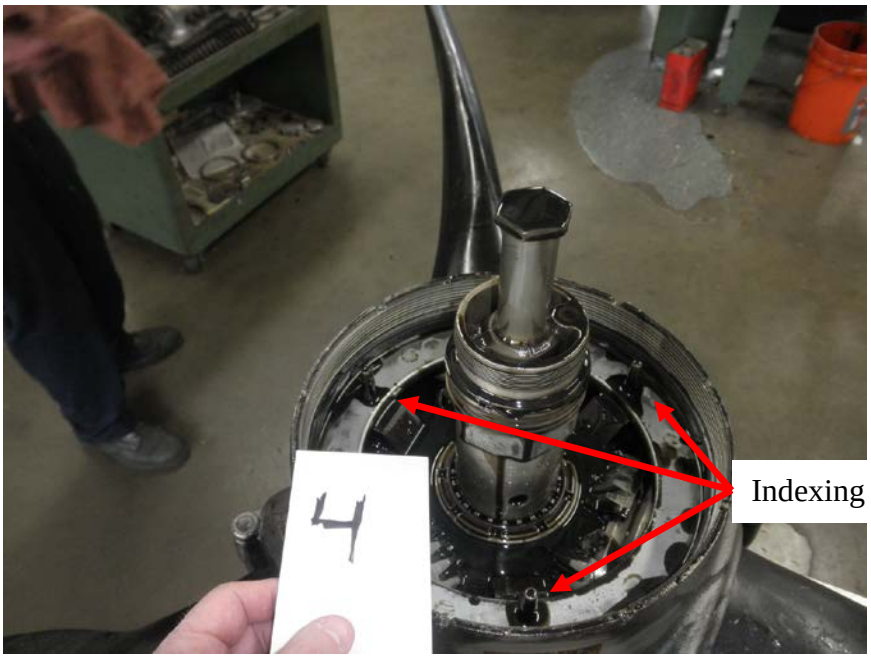

Photo No. 212: View of No. 4 propeller barrel showing the three indexing pins configuration.

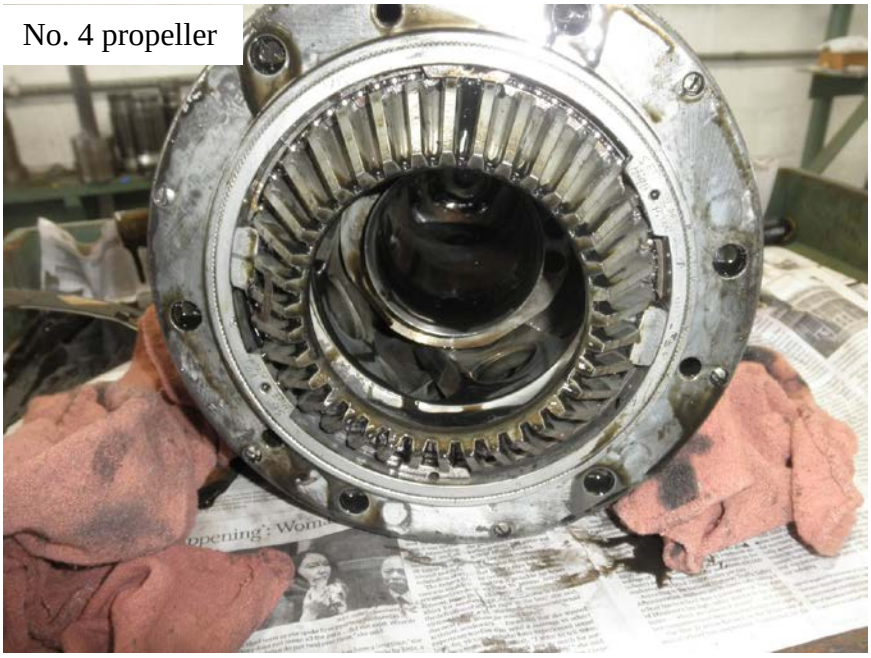

Photo No. 213: View of base of No. 4 propeller dome showing the gear ring was intact.

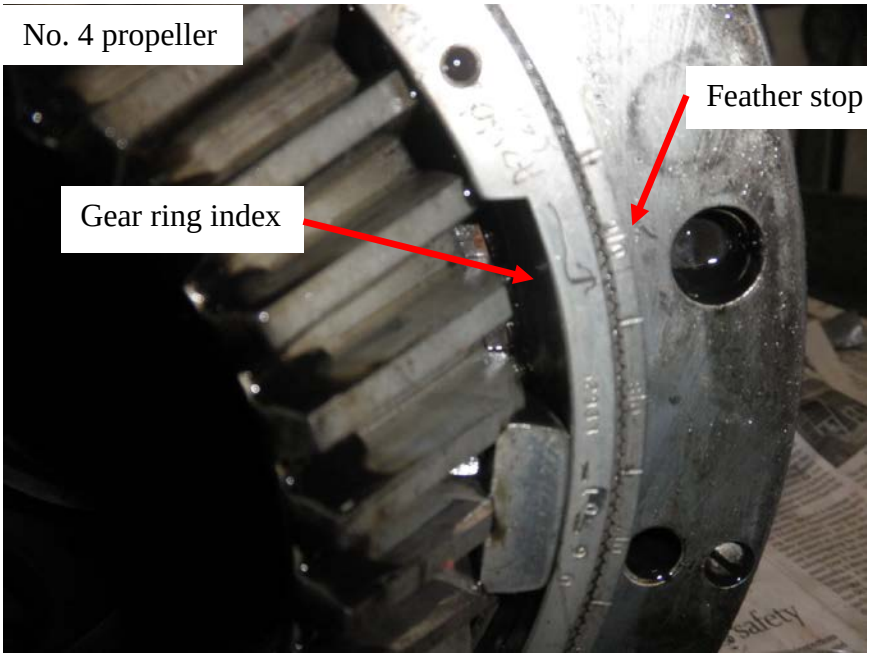

Photo No. 214: Close up view of the gear ring showing that it was rotated almost to the feather stop.

The propeller barrel was in place, intact, and all of the retaining bolts were in place with castellated nuts and the cotter pins still in place. All three of the dowel indexing pins were in place and intact.

The spider hub was intact.

Blade No. 1 was full length and was in the normal operating position.[15] The blade was essentially straight. There were some scratches that were on an angle on the camber side of the inboard end of the blade. The outboard end of the camber side of the blade had numerous scratches on various directions. The chafing ring was intact. The gear at the base of the blade was intact, but was rotated about 180 degrees from its normal position. (Photo No. 215) The screws were in place in the ring, but were sheared off flush to the underside of the gear ring. The bearing halves were intact with all of the rollers in place.

No. 4 propeller, blade 1

Photo No. 215: Close up view of No. 4 propeller, No. 1 blade's gear ring showing it was intact.

Blade No. 2 was full length and was in the feathered position. The blade was essentially straight. The blade had small nicks on the leading edge about 54, 56, and 59-inches from the collar. The camber side of the blade from the midspan area outboard to the tip was blistered. The gear was broken. (Photo No. 216) The gear was rotated. The screws were in place in the gear ring, but were sheared off flush to the underside of the ring. The chafing ring was broken. The bearing halves were intact with all of the rollers in place.

[15] The blade was cut across the airfoil about 29 inches from the collar to facilitate shipment.

No. 4 propeller, blade 2

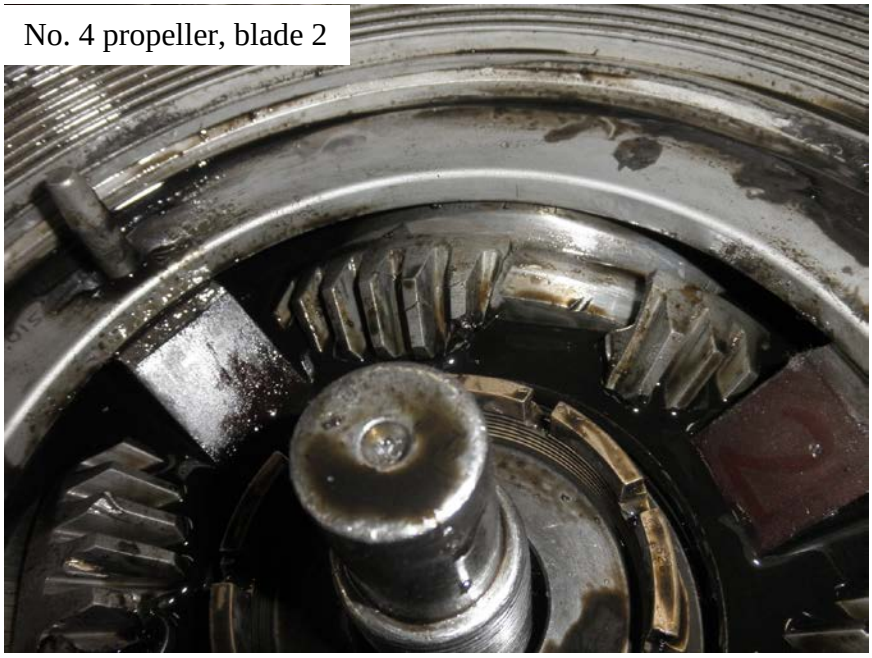

Photo No. 216: Close up view of No. 4 propeller, No. 2 blade's gear ring showing it was fractured.

Blade No. 3 was full length and was backward from its normal position.[16] The blade was essentially straight. The gear was in its normal position, but it broken in line with the leading edge of the blade. (Photo No. 217) The screws were in place in the gear ring. The chafing ring was broken. The bearing halves were intact with all of the rollers in place.

No. 4 propeller, blade 3

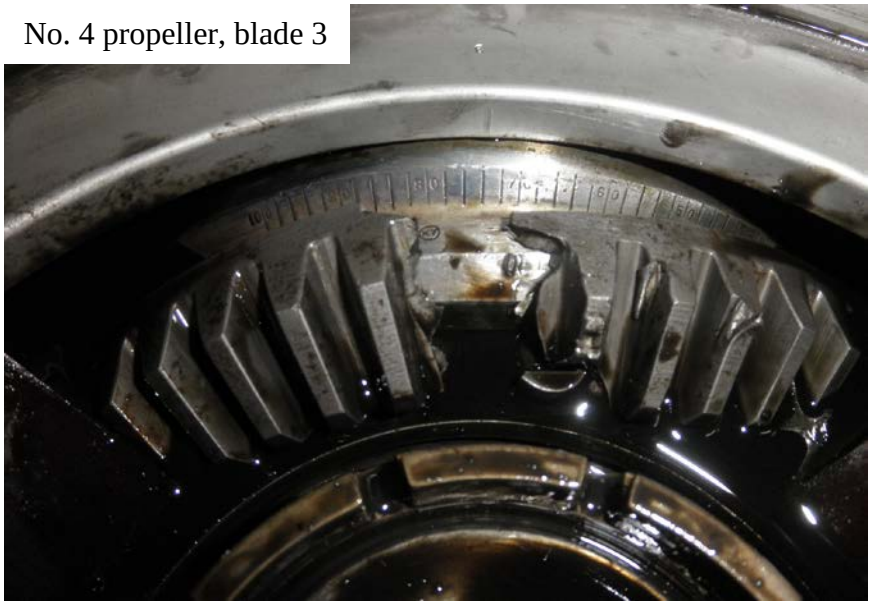

Photo No. 217: Close up view of No. 4 propeller, No. 3 blade's gear ring showing it was fractured.

[16] The blade was cut across the airfoil about 30 inches from the collar to facilitate shipment.

According to Maxwell, the location of the break in the Nos. 2 and 3 blades gear rings was consistent with the blades having been in the feathered position at the time of impact.