

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



WPR23FA323

MATERIALS LABORATORY

Factual Report 24-064

September 6, 2024

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Location: West Jordan, Utah
Date: August 23, 2023
Vehicle: Hensler Howard Cassutt, N6291N
Investigator: Stephen Stein (AS-WPR)

B. COMPONENTS EXAMINED

Crankshaft, connecting rod arms, bearing shells, camshaft, cylinders, pistons, and wrist pins from a Continental Motors O-200 series engine.¹

C. EXAMINATION PARTICIPANTS

Sr. Metallurgist Frank Zakar
NTSB
Washington, DC

D. DETAILS OF THE EXAMINATION

Figures 1 through 3 show photographs of the as-received crankshaft, connecting rod arms, bearing shells, camshaft, cylinders, pistons, and wrist pins. The crankshaft is numbered from aft to front, starting with the #1 main journal (#1MJ) and #1 rod journal (#1RJ) at the aft end, and ending with the #3 main journal (#3MJ) at the front end. Similarly, the cylinders, connecting rod arms and pistons are numbered "#1" through "#4" (aft to forward). This number convention is used throughout the report.

Identification Marks found on the Propeller Flange of the Crankshaft

The crankshaft contained a propeller flange at the forward end. The outer edge of the propeller flange was marked: "M010M/020P" indicating the main journals were grinded 0.01 inch undersize and the rod (pin) journals were grinded 0.02 inch undersize²; "RN" indicating the crankshaft received a nitride treatment after grinding; "24IIII32" which are marks used for timing of the engine; and "S238646-1" indicating a work order number from "Aircraft Specialty Services". According to the work order records from Aircraft Specialty Services, the crankshaft was overhauled in 1976, which included work to grind the main and rod journals undersize by the amount indicated earlier.³ The aft face of the crankshaft cheek between #1RJ and #2RJ was stamp marked "42428".

¹ The company is currently referred to as "Continental Aerospace Technologies".

² Also referred to as grinded minus 0.01 inch below standard and minus 0.02 inch below standard, respectively.

³ The work order indicated all work was in accordance with Supplemental Type Certificate (STC) No. SE09002SC, which includes the work to grind the rod journals 0.020 undersize.

Crankshaft

The crankshaft was intact (no evidence of a fracture). The crank cheek portions of the crankshaft exhibited a dull silver-like tint. The surface of the main and rod journals contained evidence of a wear pattern, indicated by brackets in figure 4, at locations that corresponded to the contact areas on the bearing shell. The wear pattern extended all around each journal. Stereo microscope examination of all the journal surfaces revealed the relief radii contained no evidence of circumferential scoring marks⁴ or a crack. The #2RJ and #3RJ showed evidence of blue-purple heat tint at several locations, whereas the remaining main and rod journals showed no evidence of heat tinting. The oil passages on the crankshaft were inspected for debris and obstruction. A long and round wood stick at the end of a cotton swab applicator was inserted into each oil passage. The wood stick was inserted into each oil passage with no resistance. No evidence of debris was found at the end of the wood stick when the wood stick was removed from the oil passages.

The diameter of the main and rod journals were measured with a digital micrometer and the results are shown in tables 1 and 2. The measured diameter of the main journals were less than that for an "010" undersize main journal designation marked on the propeller flange of the crankshaft. The measured diameter of the rod journals were less than that for an "020" undersize rod journal designation marked on the propeller flange of the crankshaft.

Bearing Shells

The bearing shells⁵ typically are made from a sandwich structure that contains a backing layer of steel; a middle layer of an aluminum alloy that contains copper or a middle layer of a bronze alloy; and an inboard layer of lead-tin combination.

The steel backing layer for the four rod bearing shells (#1RB, #2RJ, #3RB, and #4RB) were stamp marked "01-14-112 FAA-PMA S639640M020". "S" indicates bearing shells that were manufactured by "Aircraft Specialty Services". "020" indicates the parts are minus 0.020 inch below standard size (0.020 inch undersize).

The steel backing layer for the #1MB was marked "04-15K GVBS VP3N FAA-PMA SA643222M10; the #2MB was marked "06-15 G GVBS VP3N FAA-PMA SA633398M10"; the #3MB was marked with a capital letter "E" that was rotated 90 degrees clockwise followed by "A0913 A-1 AF GVBS VP3N FAA-PMA SA627246M10. "SA" indicates the bearings shells were manufactured by "Superior Air Parts. "010" indicates parts are minus 0.010 inch below standard size (0.010 inch undersize).

⁴ Scoring is a type of abrasive wear and refers to a rough surface that usually appears as long scratches in the direction of motion.

⁵ There are two halves of a bearing shell for each main and rod journal.

The inner surface of the bearing shells for the #1MJ and #2MJ each contained a circumferential recessed groove at the center portion whereas those on the #3MJ contained five circumferential recessed grooves (locations indicated by unmarked arrows in figures 1 and 5).⁶ The inner surface of the bearing shells for the #1RJ through the #3RJ did not contain circumferential recessed grooves. The inner (inboard) surface of the #2RJ, #3RJ, #4RJ, #1MJ, and #2MJ contained severe wear damage that exposed the copper-containing layer portion (red color). The inner (inboard) surface of the #1RJ and #3MJ contained wear damage that exposed isolated areas of the copper-containing layer portion (red color).

Cylinders

The combustion chamber of the #1 through #4 cylinders showed evidence of scoring marks. The scoring marks were oriented parallel to the length of the combustion chambers (see figure 6). Coating (film layer) was peeling from the combustion face of all exhaust ("EX") valves with the exception of that from the #4 exhaust valve. Coating (film layer) was peeling from the combustion face of the intake ("IN") valve of the #4 cylinder but were not peeling from those of the remaining three intake valves.

Pistons

The crown portion of all the pistons contained a beveled (tapered) corner edge, see figure 7. The crown portion of each piston and the tapered edges exhibited an olive-like tint that showed no evidence of erosion or cracking. The sidewall of the piston in the area that extended between the tapered corner edge and the first groove for a ring contained longitudinal scoring marks.

The piston contained three rings (first and second ring are the compression rings and the third ring is the oil ring). The three piston rings were intact. The outer wall of the rings showed evidence of scoring marks (oriented parallel to the longitudinal axis of the cylinder).

The skirt portion of the piston (below the three rings) contained longitudinal scoring marks. The portions of the skirt that showed no evidence of scoring marks exhibited a black-dark gray tint.

⁶ The circumferential recessed grooves are passages for delivery of lubricating oil.

Camshaft

The camshaft was intact and showed no evidence of a crack. The body of the camshaft contained a stamp mark "626608-X".

Submitted by:

Frank Zakar
Sr. Metallurgist

Table 1. Diameter of Main Journals (inches)			
Item	Specified diameter for 0.010 inch undersize	Measured at wear pattern locations that corresponded to the contact areas on the bearing shells.	Measured in areas that corresponded to the recessed groove (oil passage) areas on main bearing shells.
#1MJ	1.862-1.863	1.8551-1.8619	1.8631-1.8676
#2MJ		1.8517-1.8592	1.8638-1.8683
#3MJ		1.8613-1.8616	1.8623-1.8624

Note: For reference purpose, the diameter of a standard size main journal is 1.872-1.873 inch.

Table 2. Diameter of Rod Journals (inches)		
Item	Specified diameter for 0.020 inch undersize	Measured
#1RJ	1.916-1.917	1.9145-1.9158
#2RJ		1.9107-1.9156
#3RJ		1.9148-1.9153
#4RJ		1.9123-1.9140

Note: For reference purpose, the diameter of a standard size rod journal is 1.936 inch-1.937 inch.

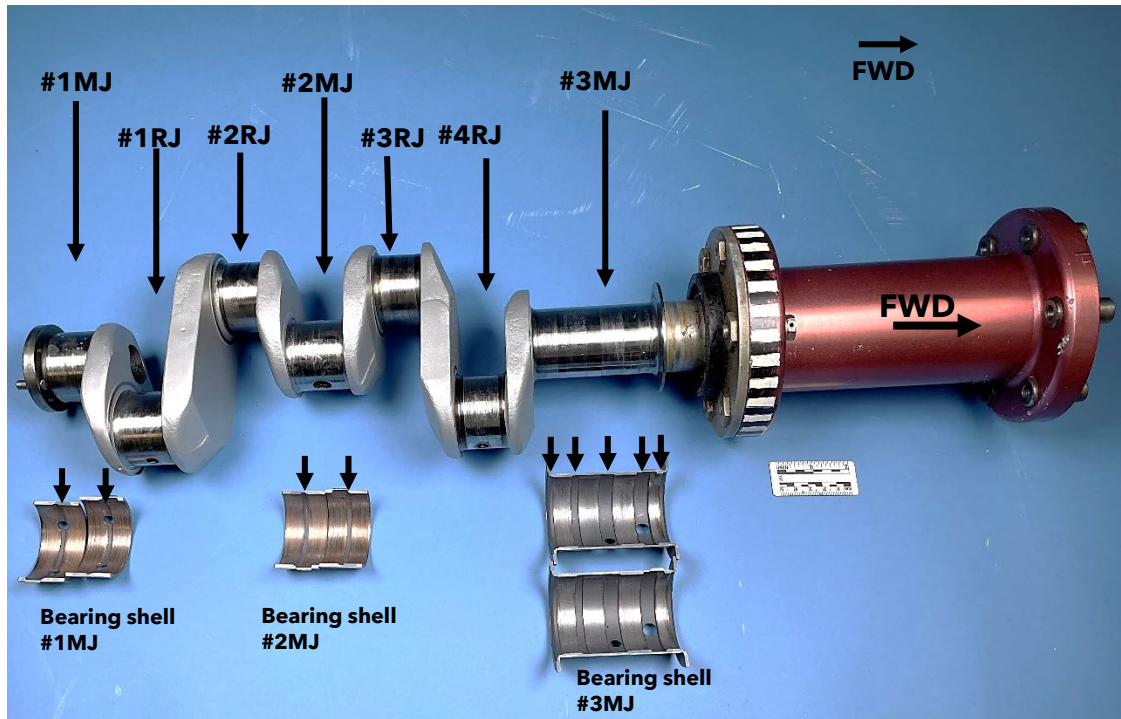


Figure 1. As-received crankshaft and bearing halves from the #1MJ, #2MJ, and #3MJ. The crankshaft is numbered from aft to forward, starting with the #1 main journal (#1MJ) and #1 rod journal (#1RJ) at the aft end, and ending with the #3 main journal (#3MJ) at the forward end. Unmarked arrows point to positions on the inner surface of the bearing shells that contain circumferential recessed grooves (for oil passage).



Figure 2. As-received cylinders, connecting rod arms with bearing shells, and pistons with corresponding wrist pins, numbered #1 through #4 (left to right).

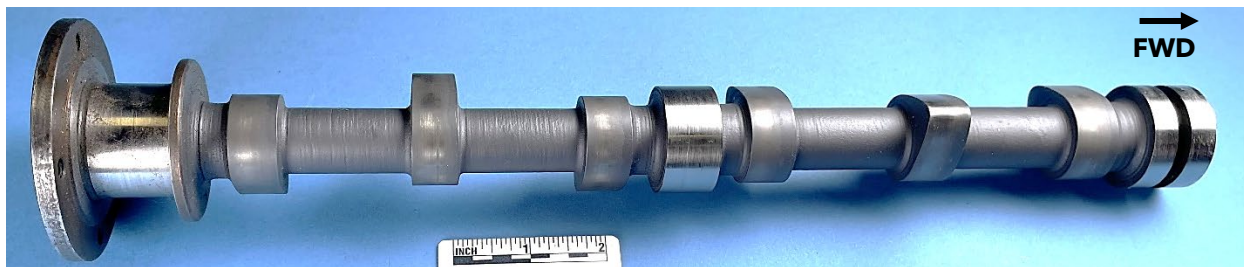


Figure 3. As-received camshaft.

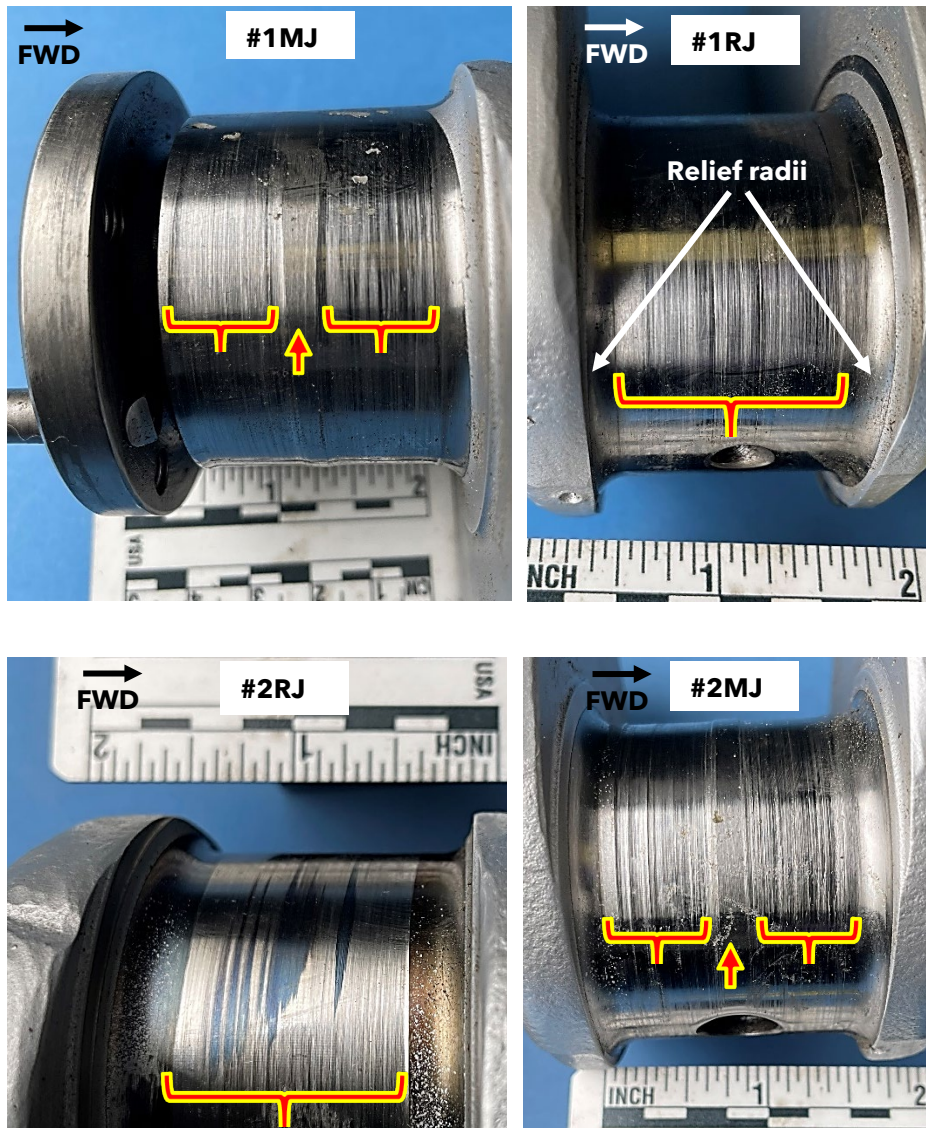


Figure 4. Close-up of the main and rod journals. Brackets indicate location of wear pattern. Unmarked arrows point to positions on the journals that exhibited evidence of metal deformation/lip that extended above the worn surface (these areas correspond to circumferential recessed grooves on inner surface of each bearing shell).

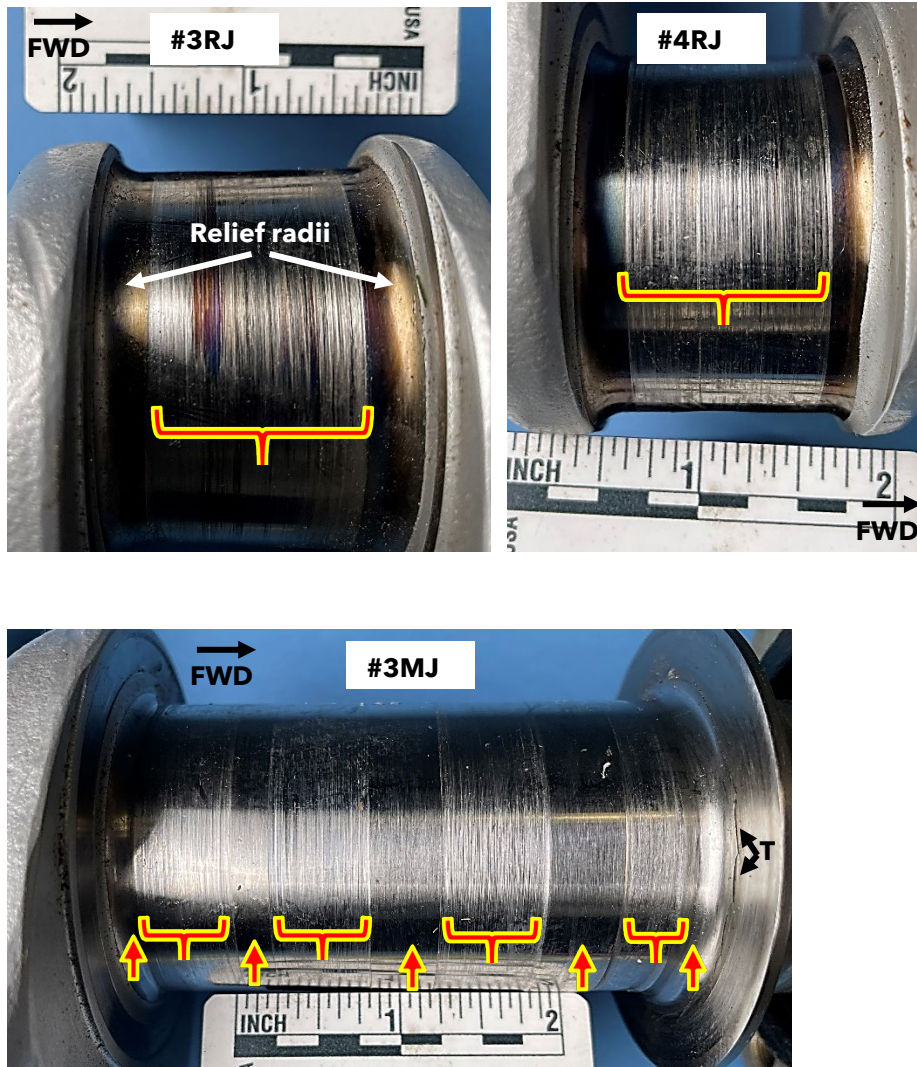


Figure 4 (continued). Close-up of main journals and rod journals. Brackets indicate location of wear pattern that extended all around the circumference of the journal. Unmarked arrows point to positions on the journals that correspond to circumferential recessed grooves on inner surface of each bearing shell. The area outside of the relief radius, in the general area indicated by arrows "T", contained many circumferential-like cracks that extended all around the flange.

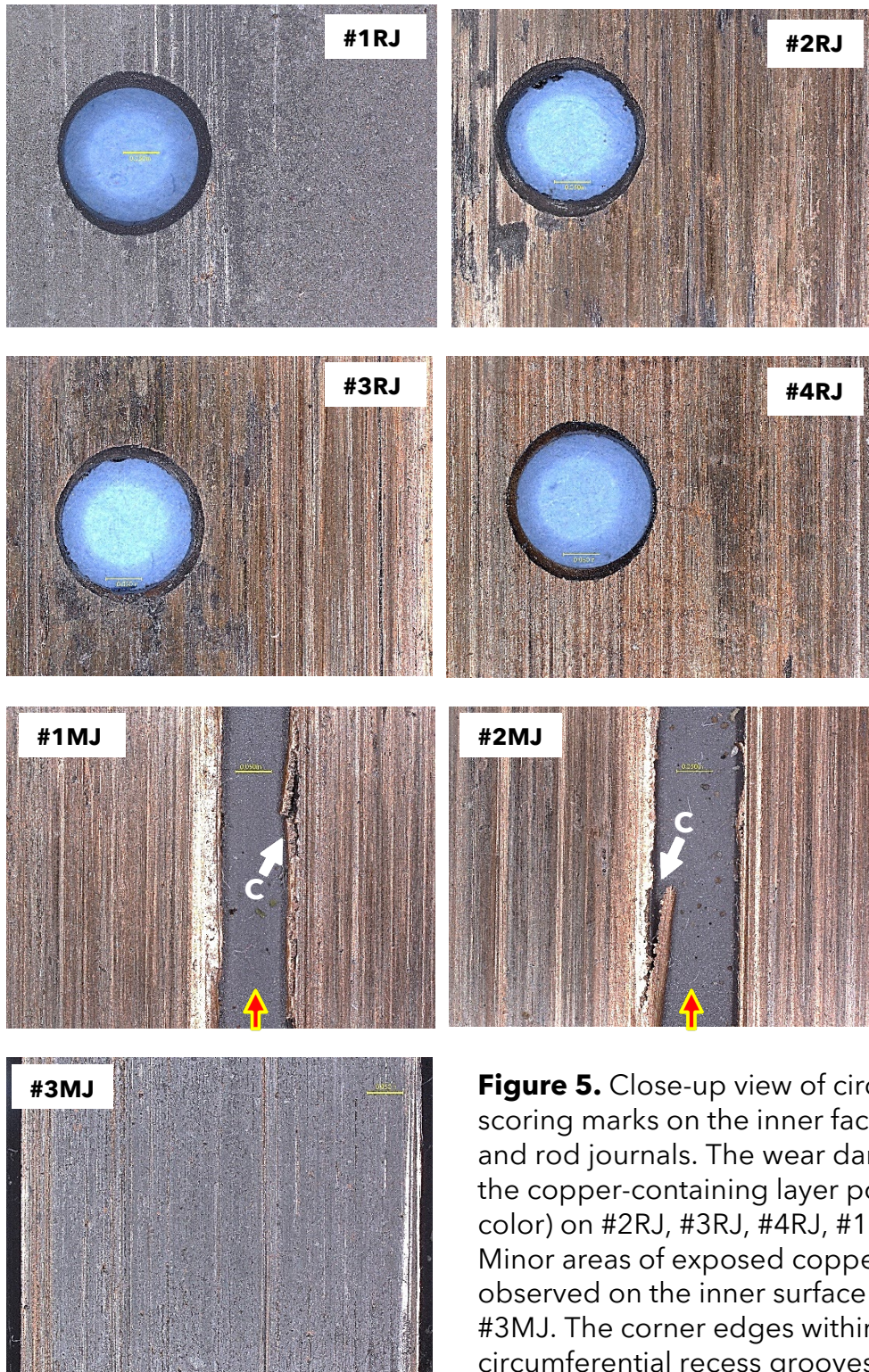


Figure 5. Close-up view of circumferential scoring marks on the inner face of the main and rod journals. The wear damage exposed the copper-containing layer portion (red color) on #2RJ, #3RJ, #4RJ, #1MJ, and #2MJ. Minor areas of exposed copper were observed on the inner surface of the #1RJ and #3MJ. The corner edges within the circumferential recess grooves of the #1MJ and #2MJ exhibited evidence of a crack and compression damage in the areas indicated by arrows "C".

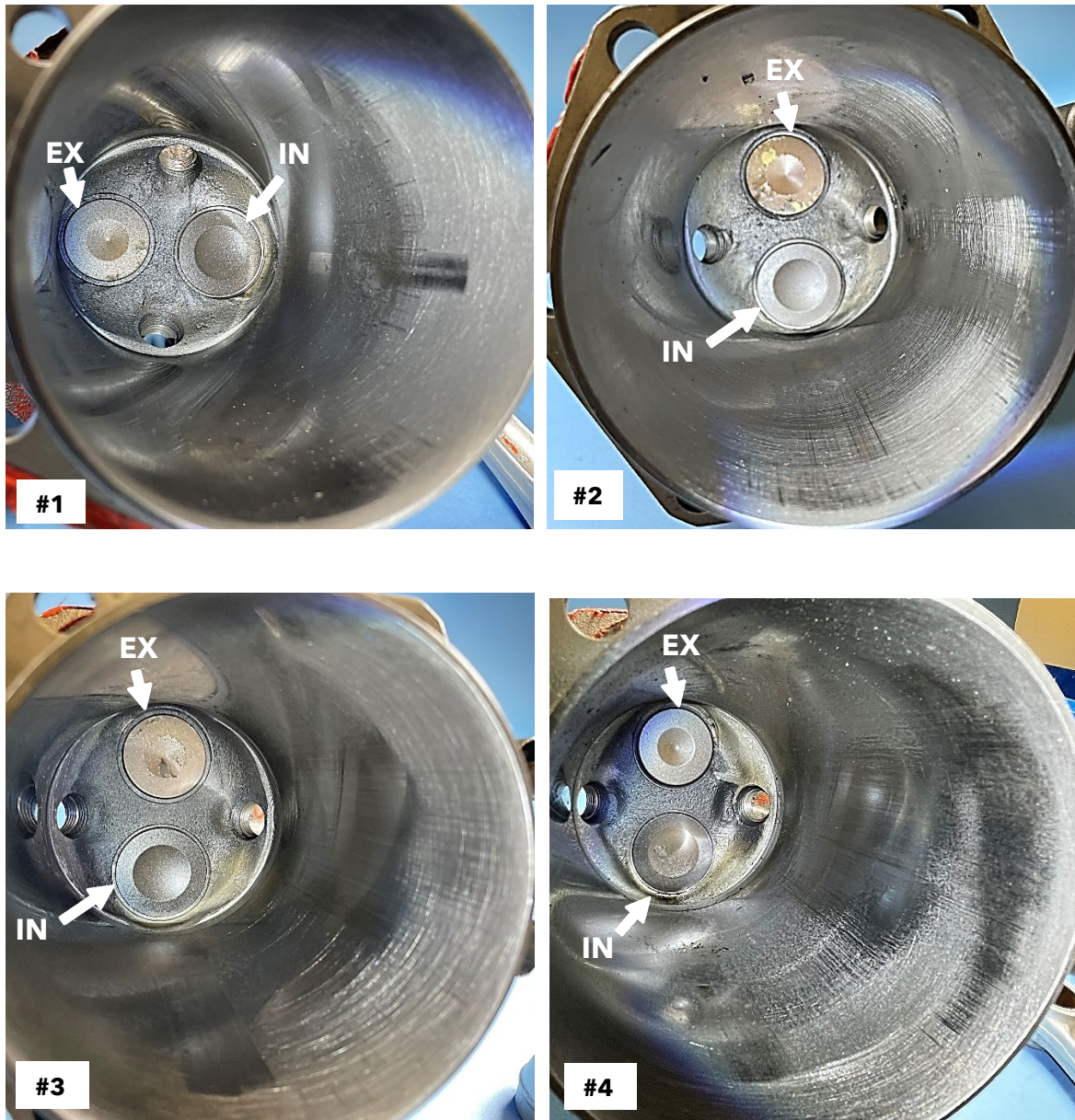


Figure 6. View looking into the combustion chamber of the cylinders. Coating (film layer) was peeling from the combustion face of all exhaust ("EX") valves with the exception of that from the #4 exhaust valve. Coating (film layer) was peeling from the combustion face of the intake ("IN") valve of the #4 cylinder but were not peeling from those of the remaining three intake valves. The diameter of the head portion from the exhaust piston was smaller compared to that of the intake piston.

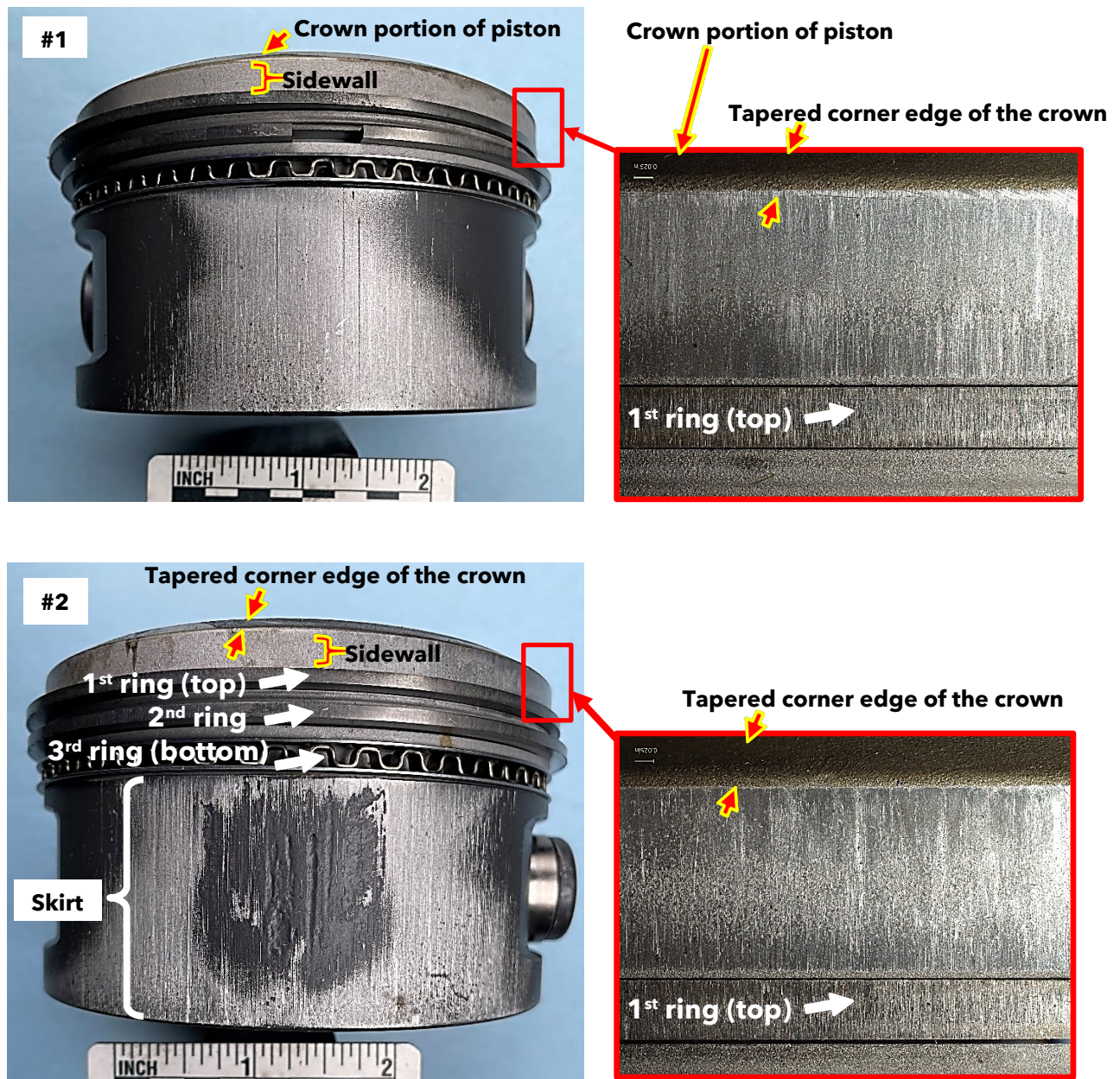


Figure 7. Side view of the pistons showing scoring marks in the skirt area and sidewall in the area above the top piston rings.

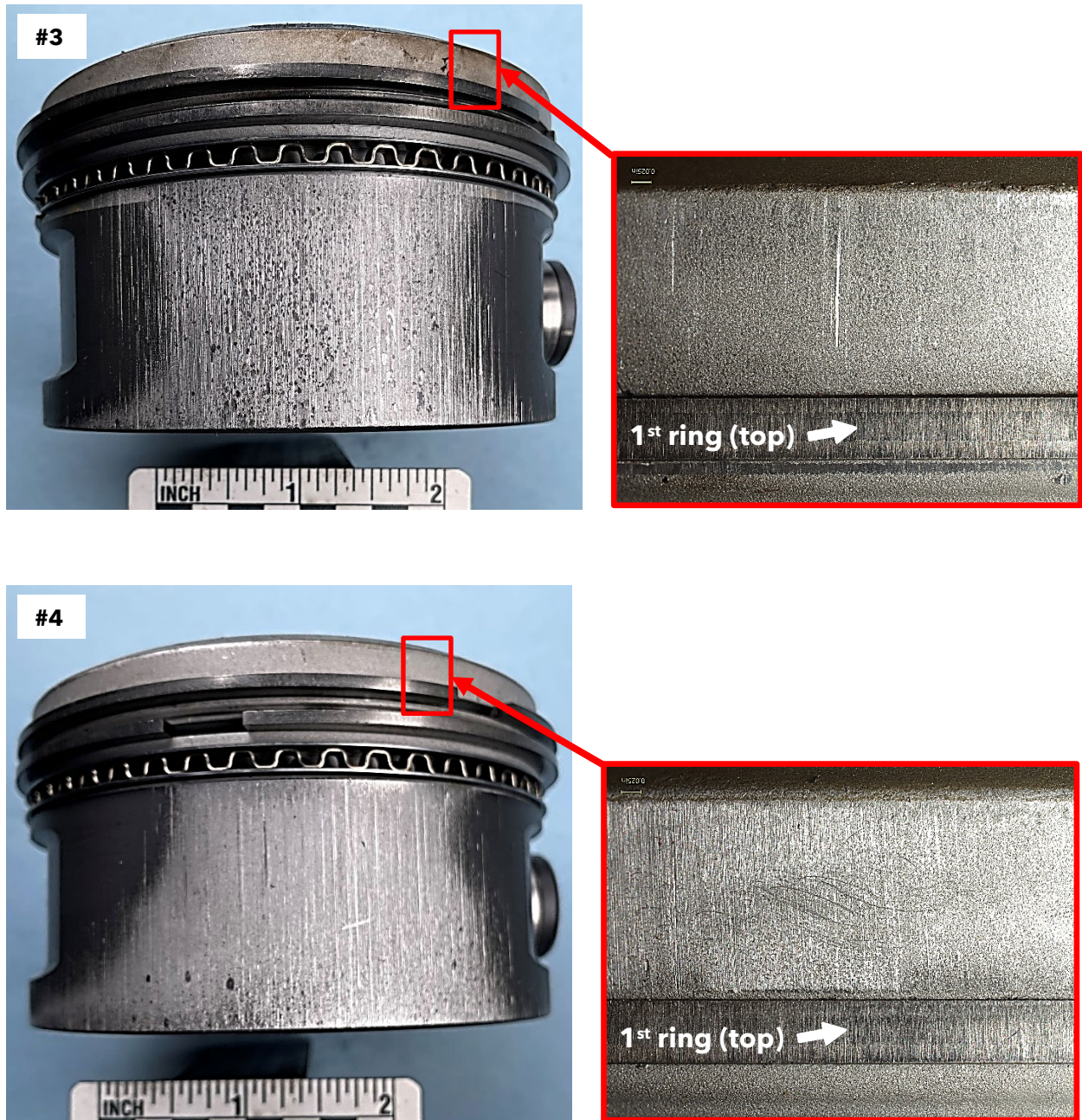


Figure 7 (continued). Side view of the pistons showing scoring marks in the skirt area and sidewall in the area above the top piston rings.