The Life of an Exhaust Valve

By Dave Pasquale

I have recently been combining what I have learned through borescope cylinder inspections with autopsies of cylinders that have been removed due to burned valves. The results have been quite interesting. It turns out that most Continental exhaust valves tell the same story about how they reached their overheated demise.

Photo 1

Our story begins when the cylinder is new. As you might expect, there are rarely issues with a new valve. It has no deposits on the head and it tracks in a straight line when it closes. It takes approximately 30 hours for the normal ring-shaped exhaust deposits to form.

After 100 Hours

After about 100 hours the valves can be seen sidestepping when they contact the valve seat. When I first observed sidestepping I was surprised, and my customers were a little alarmed by the videos. What several years and looking at dozens of engines have taught me is that virtually all Continental exhaust valves do this.

It is worthwhile to describe valve sidestepping for a moment. What I'm talking about is seen through a borescope as the valve comes down and approaches the seat. If the alignment isn't perfect, one edge will contact the seat first and then sidestep slightly as it drops into the seat as the valve descends. Seeing this, and making a video of it, was not possible until recent improvements in borescopes.

While I don't yet have a large sample size, it is important to note that all the valves I've been allowed to view from the stem side move in the same direction when they sidestep into the seat. The geometry of the valve stem to rocker arm interface causes the valve stem to move away from and parallel to the rocker arm. For the time being, this sidestepping doesn't adversely affect the function of the valve or the heat signature. The yellow arrow in **photo 1** shows the direction of movement when viewed from the stem side.

Middle Age

The middle portion of an exhaust valve's life is one of gradual wear of the guide and, more importantly, the valve rotator. Large bore Continental engines are fitted with a garter spring valve rotator. The function of the valve rotator is to – you guessed it – rotate the valve as it opens and closes. This distributes the wear around the seating area of the valve. It also evens out the heat that is

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

Photo 7

Photo 8

dissipated out of the valve and into the cylinder head. If the rotator is working correctly the exhaust deposits will have an even, bullseye appearance on the top of the valve.

It helps to understand the inner workings of the valve rotator before we continue our story. The rotator is comprised of four parts: the top and bottom end caps, the garter spring, and a Belleville washer (**photo 2**). If you cut a rotator open you will find one end cap has the Belleville washer seated into it and the other has an annular raceway. The garter spring is sandwiched between the washer and raceway. The garter spring is approximately the diameter of the average pen spring and about twice as long. The coils of the spring are much closer together (**photo 3**).

When the valve opens, the spring is compressed from both sides. This compression causes the spring coils to tip, which rotates one end cap in relation to the other. The amount of compression is limited by stops built into the housing of the rotator. The spring coils stand back up once the valve closes.

The valve remains in its rotated position because of friction between the valve and the valve seat. This means the spring coils slide as they stand back up. That sliding happens mostly on the Bellville washer side since the contact area is smaller. The sliding wears a flat spot in the spring that eventually causes the rotator to slip due to a smoother contact area and less compression of the spring.

If you watch a valve closely, as the rotator fails you will see the bullseye-shaped exhaust deposits start to change. The center of the bullseye starts moving toward one side (**photo 4**). At the same time the outer ring of the bullseye gets thinner in the spot the center is moving to (**photo 5**). This is because the valve is not rotating enough to distribute the wear caused by sidestepping. The wear degrades the contact area of the valve with the seat. If the valve loses contact, it can't dissipate heat into the cylinder head and a hot spot develops (**photo 6**).

This is the stage when you should lap the valve and replace the rotator. I also replace the valve springs for good measure since they are inexpensive, and I've encountered a few that didn't meet the minimum compression force. My January 2018 *ABS Magazine* article showed the results of lapping a valve in place. The valve from that article has flown approximately 300 hours since it was lapped and still has a normal heat signature.

If you don't intervene and continue running the engine, the center of the bullseye will get oblong and the outer ring of the bullseye will separate (**photo 7**). The bullseye continues to become more oval until it reaches a point where the end toward the hot spot dissipates and the heat signature takes on the classic bell-shaped curve of a burned valve (**photo 8**). A valve in this condition has reached the point where the cylinder should be removed from service for repair, replacement, or overhaul.

Photo 9

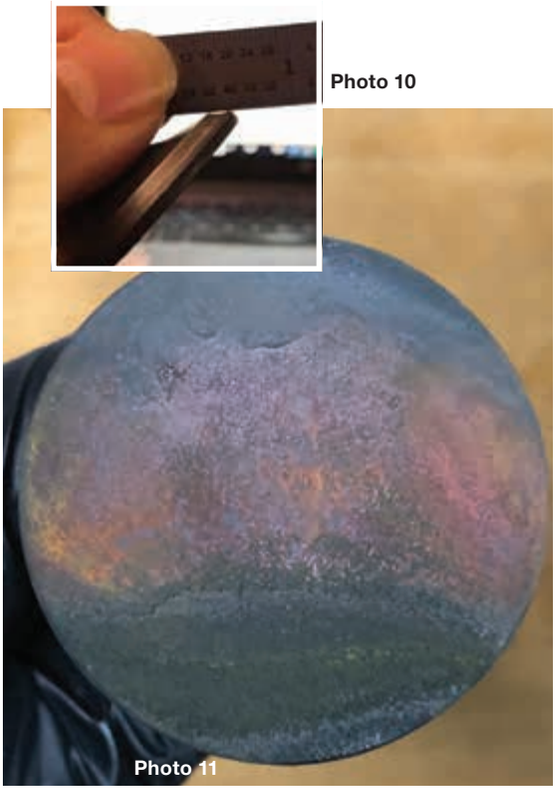
Photo 10

Photo 11

Photo 12

Photo 13

Post-mortem

I usually perform an autopsy of the valve to identify the cause of the failure. You already removed the rocker arm from the cylinder during the removal process. Take a close look at the tip of the valve stem. If your rotator quit a while ago, you will see a linear witness mark on the tip of the valve stem from the rocker arm (**photo 9**). You can test the rotator by tapping on the tip of the valve as you would if you were staking the valve. If the rotator is working the rotation will be obvious. If it is not working and you remove the valve, you will find that the seating area is cupped in the location of the hot spot (**photo 10**).

While almost every cylinder seems to follow the above pattern, there is always an outlier. I recently pulled a cylinder from an IO-550B that was just that. The first indication that this cylinder was an outlier was the burn pattern on the valve. The valve had two hot spots 180 degrees apart (**photo 11**). When it was removed from the cylinder it was clear that the valve head was warped like a taco (**photo 12**). There was no linear witness mark on the valve stem and the rotator was working correctly. The interesting piece of evidence from this cylinder was a cracked intake gasket (**photo 13**). There was a corresponding witness mark on the cylinder and the intake manifold flange that indicated the crack had been present for some time (**photo 14**). Unfortunately, the engine monitor did not have a data card installed. My theory is this cylinder was operated at takeoff power with an excessively lean mixture due to the intake leak. The engine monitor would have provided the smoking gun.

When I started working on Continental engines, the only way we could judge the performance of a cylinder was compression. The only option I could offer a customer with a cylinder problem was "remove and repair." Borescopes have given us a chance to watch the life of cylinders and get a fine-grained sense of how they degrade. Lapping a cylinder and replacing a worn-out rotator cap can add hundreds of hours of life, but careful borescoping is key. The heat signature on a partially burnt exhaust valve can be seen. Caught in time, a successful lapping will improve the valve

seal, raise compression, and improve the heat signature. Doing this requires careful borescope work and good technique to get the lapping right.

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Dave Pasquale *owns Pasquale Aviation in Pottstown, Pennsylvania. Contact Dave at 484-336-0158,* airdave@ptd.net, *or* www.facebook.com/pasqualeaviation.