Borescope Imaging: Getting the Inside View

If your shop says you need new cylinders, ask if it performed a borescopic inspection. Our research revealed it may be worth the effort.

by Rick Durden

Ever since the Wrights, one of the vexing problems of aircraft maintenance has been access to the nooks and crannies of the machine. Maintenance technicians have spent major portions of their lives with flashlights and mirrors peering through inspection ports trying to assure that all is well within; at significant expense, major assemblies have been unbolted and removed to allow visual inspection of their insides because of a symptom of illness—often to find that they are healthy—while the act of removal and replacement itself caused damage.

The first borescope—a skinny tube with an objective lens on one end and eyepiece on the other with a relay optical system in between—was developed shortly after the first World War . It proved effective; although the miniaturized optics meant it wasn't cheap and getting effective illumination to the area of interest was a challenge.

The aviation applications proved self-evident. Engine manufacturers begin recommending their use in the piston world and mandating it in turbine applications. Because they were expensive and not absolutely required for piston engine aircraft, it was rare to find a borescope in a shop that didn't cater to the turbine set. (There is now at least one AD that requires borescope use in a piston engine cylinder inspection.)

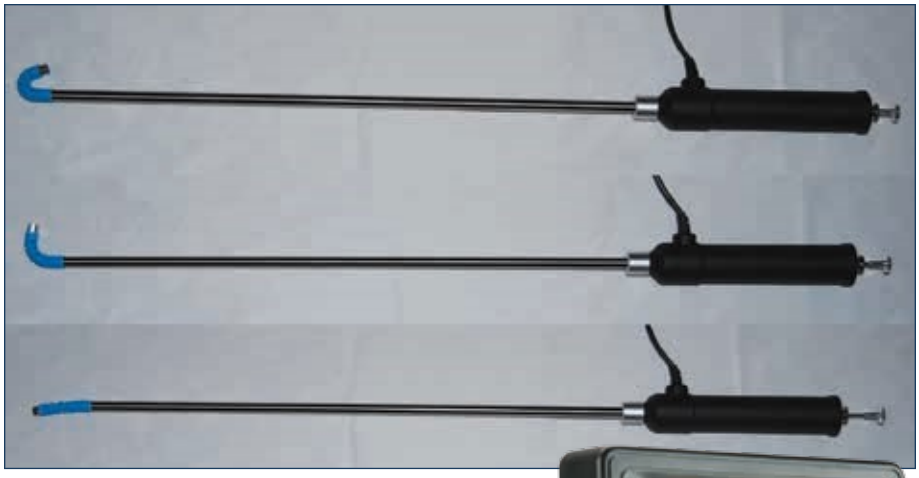
Another problem was that the original, rigid tube borescopes were

CHECKLIST

- Prices are down, quality up; we think every shop should have a borescope.
- Using a borescope can save an owner $ in unneeded cylinder work.
- More training aids for borescope use are needed for technicians.

Scott Utz of Arapahoe Aero uses his shop's GE XL VU videoscope to examine the engine of a Cessna 340, left. Using the articulating camera head, a healthy exhaust valve can be seen clearly, below.

Three shots of a ViVidia Ablescope showing tight radius of rotation of its articulating camera head, right. Gradient Lens Hawkeye V2 Videoscope with LCD display, below right.



limited to straight line applications. One could be inserted through a spark plug hole of a cylinder and get an excellent view of the top of the piston and a little of the cylinder walls. Even with a mirror or prism arrangement, it could be tough to see what was most often the area of concern, the valves.

The advent of fiber optics allowed flexible borescopes to become a reality—suddenly it was possible to snake the tip into more locations and find corrosion that had been hiding. Articulated tips were developed so that they could be turned to look back in the direction from which the scope had arrived—getting an excellent view of valves and their seats. Still, cost stayed high as it took a lot of fibers in the fiber optic relay to give acceptable image quality.

MINIATURE CAMERAS

The borescope world changed with the advent of the inexpensive, high-resolution miniature video camera and LED lighting. Now, what is technically referred to as a videoscope—a tiny camera mounted on a flexible or rigid tube—has become ubiquitous. We are of the opinion that a videoscope with image quality suitable to be a useful tool in a maintenance technician's arsenal to help make an informed decision about the health of a cylinder and find corrosion in hidden areas of an airframe can be purchased for under $1000.

We think that there is no longer an excuse for a shop not to own one. We also recommend that any owner who has been advised of low compression on a cylinder not agree to pulling that cylinder until it's been inspected with a some type of borescope—even if that means going to another shop to have it done.

When we surveyed the market for videoscopes, we found some for under $50 that may well be just the thing for looking into the tight places in the airframe. However, without an articulating head, we don't think they're adequate for getting a good view of all of the inside of a cylinder. As with much in aviation, you get what you pay for with a borescope or videoscope and image quality is everything. When it comes to assessing the condition of the inside of a cylinder, we think that it's possible to buy an adequate unit for under $500.

When it comes to inspecting turbine wheels and blades for FOD and cracking, the need for precise imaging and significant magnification as well as being able to take and record measurements means going to a much higher quality, precision videoscope. Our market survey indicated that a shop should be prepared to spend on the order of $10,000 to $25,000 and work with vendors to get a scope that is right for the inspections the shop does.

Another factor to consider in selecting a scope is the risk of damage to the head should it be dropped or jammed against something during an inspection in a tight area. The less expensive scopes are not particularly damage tolerant, so what might be considered a low-speed impact may mean it becomes junk. The high-end scopes have camera housings made of tungsten or titanium.

Some videoscopes have displays included with the kit, others must link to a computer, smart phone or tablet to display the image.

DEMONSTRATION

We were given a demonstration of a GE Measurement and Control XL Vu Videoprobe, a $17,000 precision instrument, by Scott Utz, principal of Arapahoe Aero Aircraft Maintenance at Denver's Centennial Airport. The unit included a display that was far clearer than our iPad, with better contrast.

Utz told us that it's a regular practice to connect the videoscope to a large computer monitor when showing a customer the condition of his or her engine. He told us that while the display on the GE unit is excellent, the resolution of the optics can be best appreciated on a computer monitor. When a customer can clearly see an area that a maintenance tech is concerned about, it helps the decision process.

As with other videoscopes, still images and video from the GE unit can be emailed or streamed in real time to allow a customer to see them from anywhere in the world or a maintenance tech to get a second opinion on an issue.

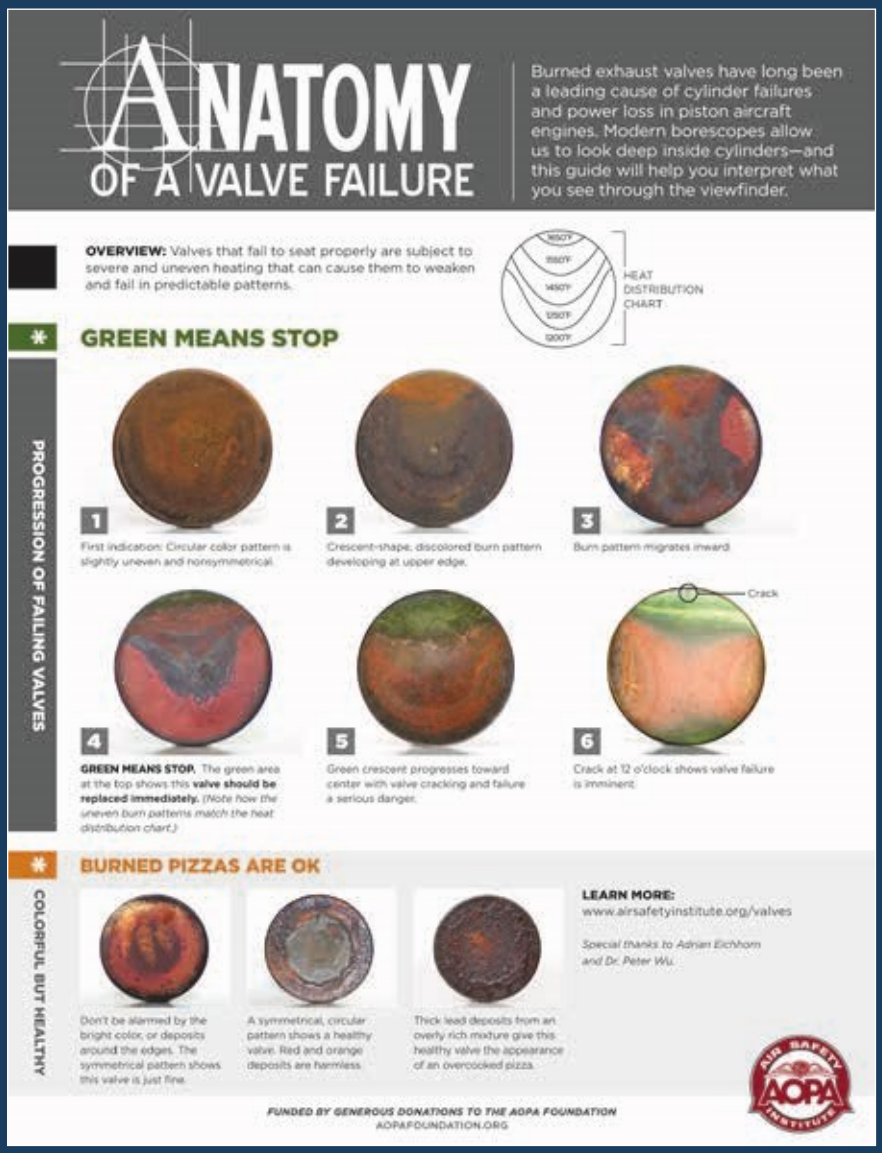
IS AN EXHAUST VALVE REALLY FAILING?

Twelve years after Continental issued service bulletin SB03-3 directing maintenance technicians to use a borescope to inspect each cylinder every time a compression test is performed, its instructions are being routinely ignored—at a high cost to aircraft owners.

A compression test is one of the valuable tools available to a mechanic to diagnose cylinder health, yet it requires a degree of skill to perform accurately and even the best techs admit that they may not get the same results twice in a row. Above all, it is only one tool in the tech's arsenal and should never be used by itself to make the decision to pull a cylinder off an engine. Too often low compression accompanied by a leaking exhaust valve has resulted in a yanked cylinder only to find that the valve and its seat are perfectly healthy.

Continental makes it clear, and we think it's applicable for Lycomings, that a borescope must be used to check on exhaust valve condition. If it's in good shape—AOPA's poster below is a great reference for what it should look like—there is no reason to pull the cylinder.

If the borescope discloses signs of valve distress, pull the cylinder—if not, that borescope exam just saved you significant money.



Utz went through a routine cylinder exam, first looking at the top of the piston for evidence of overheating, burning or detonation. The resolution of the image on the attached display was such that it almost seemed to be in 3-D.

Using one hand on the controls just below the display, Utz articulated the camera head slowly, allowing a close-up view of the cylinder walls. They were smooth and shiny through much of their length until some small corrosion pits became visible near the very top. Utz said that for the calendar age of the engine and the number of hours on it, such pitting is not unusual on a Continental engine—or of concern.

EXHAUST VALVE

With the camera head articulated nearly 180 degrees, Utz focused on the exhaust valve. It displayed a symmetrical, circular color pattern on its face, with no indications of burning, cracking or uneven deposits. Utz explained that with a little maneuvering it is possible to see much of the valve seat.

Utz then used the videoscope to look over the inside of the cylinder head, the spark plug that was still in the cylinder and the intake valve. All areas looked normal and healthy with no indications of distress.

As we discussed the capability of the borescope, Utz said that for piston-engine airplanes, "We don't want to pull a cylinder unless we absolutely have to. The borescope is a powerful tool, one of many that we use to make a decision about pulling a cylinder. The others are a compression check, regular oil sampling, the history of the engine and the time on the engine."

We commented on how smoothly the scope articulated, but that it sometimes took a few moments to get oriented when looking at the display. Utz said that the technicians in his shop had gone through the training provided by the manufacturer when they bought the videoscope. As with any sophisticated tool, there's a learning curve involved with making effective use of it. The literature on borescope use and human factors in borescope inspections refers to the situational awareness needed in using a borescope much as a pilot needs it when flying an airplane.

SELECT VIDEOSCOPES

PRODUCT	PRICE	COMMENTS
AGPtEK 16-FOOT WATERPROOF BORESCOPE INSPECTION CAMERA	$12.15	Image sensor: 1/6 CMOS sensor. Resolution 640 x 480. Illumination: adjustable LED lights. Camera head diameter 14.5 mm. View angle 52 degrees, but no mirror for angled viewing is included. USB interface is used for viewing on a computer monitor. No articulating head. At the price, an inexpensive tool for looking at areas in the airframe.
VIVIDIA 9mm PORTABLE FLEXIBLE INSPECTION CAMERA WITH 2.4 INCH LCD MONITOR	$69.98	Image sensor: 0.3 MP color CMOS sensor. Monitor: 2.4 inch full-color LCD, resolution 640 x 480. Focal range 4 cm to infinite. Illumination: four white LED lights. Camera head diameter 9 mm. Kit includes four AA batteries and mirror for angled viewing. This basic unit does not have an articulating head; display resolution low; cannot save images.
LEMONBEST HD 720p HANDHELD WIRELESS WIFI INSPECTION BORESCOPE WITH 2.0 MEGAPIXEL CAMERA	$87.69	Image sensor: 2 megapixel CMOS. Resolution 1280 x 720. Illumination LED lights. Camera head 8.5 mm, 60 degree viewable angle. Wi-Fi transmits image to a smartphone, tablet or computer and can capture snapshot or video. No mirror for angled viewing. A higher resolution basic unit without an articulating head.
VIVIDIA ABLESCOPE HD USB BORESCOPE WITH 180 DEGREE ARTICULATING 8.5 mm PROBE	$149.98	Image sensor: CMOS. Resolution 640 x 480. Illumination six LED lights. Camera head 8.5 mm, 60 degree viewable angle. Camera head articulates 180 degrees in a 30 mm radius. USB interface for viewing on a computer monitor, capture still images or video. An example of the minimum unit needed for a good view of valves in a cylinder.
VIVIDIA HIGH PERFORMANCE BORESCOPE SYSTEM WITH ARTICULATING 5.5 mm DIAMETER PROBE AND WIRELESS 3.5	$569.98	Image sensor: 1/13-inch CMOS. Resolution 640 x 480. Illumination four LED lights. Camera head 5.5 mm, field of view 54 degrees, 110 degree sweep and 340 degree rotation in 45 mm bending radius. 3.5-inch detachable LCD display. Can capture still or video images on micro SD card and data can be transferred to a computer via USB cable.
GRADIENT LENS HAWKEYE V2 VIDEOSCOPE	$8995.00	Basic model of a sophisticated line of videoscopes designed for turbine engine inspection with a 6 mm camera head with 150-degree articulation, 70-degree field of view with a 90-degree prism tip attachment. Tungsten braid sheath, detachable micro LED light illumination and 5-inch LCD display. 640 x 480 still and video format.
GE MEASUREMENT AND CONTROL XL Vu VIDEOPROBE	$17,000.00	Kit meets multiple MIL-specs for imaging equipment and includes multiple camera heads to allow best imaging for specific tasks. Image sensors are SUPER HAD CCD cameras in titanium housings with pixel counts of 290,000 and 440,000. The system has continuous 5x digital zoom, 360-degree joystick control tip articulation and graphic and text annotation of imagery. It is an example of the type of equipment that meets the needs of a sophisticated turbine-engine shop.

Utz told us that the controls on the GE scope were easy to use and became easier with experience. As a tech used the videoscope more and more, he or she rapidly developed a feel for where it was pointed when being articulated.

Our research found that one common complaint among borescope users was non-intuitive articulation movement. Many of the systems use a small joystick, so movement can be described as akin to flying an airplane in three dimensions. If the design is such that the camera head doesn't go where the user anticipates when moving the stick, the learning curve for the user is going to be steep.

Utz told us that it was common for techs to involve other techs during borescope exams, both to get the thoughts of those had more experience and help educate those with less experience.

In researching this article, we found that there were a number of organizations that offered training for borescope use in turbine applications, but a dearth of training information for piston engine aircraft. We also received word from aircraft owners of mechanics who didn't understand what they were seeing through a borescope—notably two that were convinced that an exhaust valve that had red deposits was distressed and about to fail. That's not the case, red on an exhaust valve is not a bad thing, green is—see the sidebar on the opposite page.

We think that a shop that is buying a borescope for the first time should explore what sort of training materials are included with the scope. There is a learning curve.

Finally, we were told to make sure to clean the borescope after use following the manufacturer's instructions. The chances are high that the head will have come into contact with fluids or debris that can degrade viewing clarity or damage the unit if not removed.

CONCLUSION

With the radical leap in capabilities and concurrent drop in prices, we think that every aircraft maintenance shop should have and use a borescope at least capable of doing a full cylinder examination in conjunction with every compression check performed. We think the ability to look into otherwise inaccessible areas of our aircraft is essential.