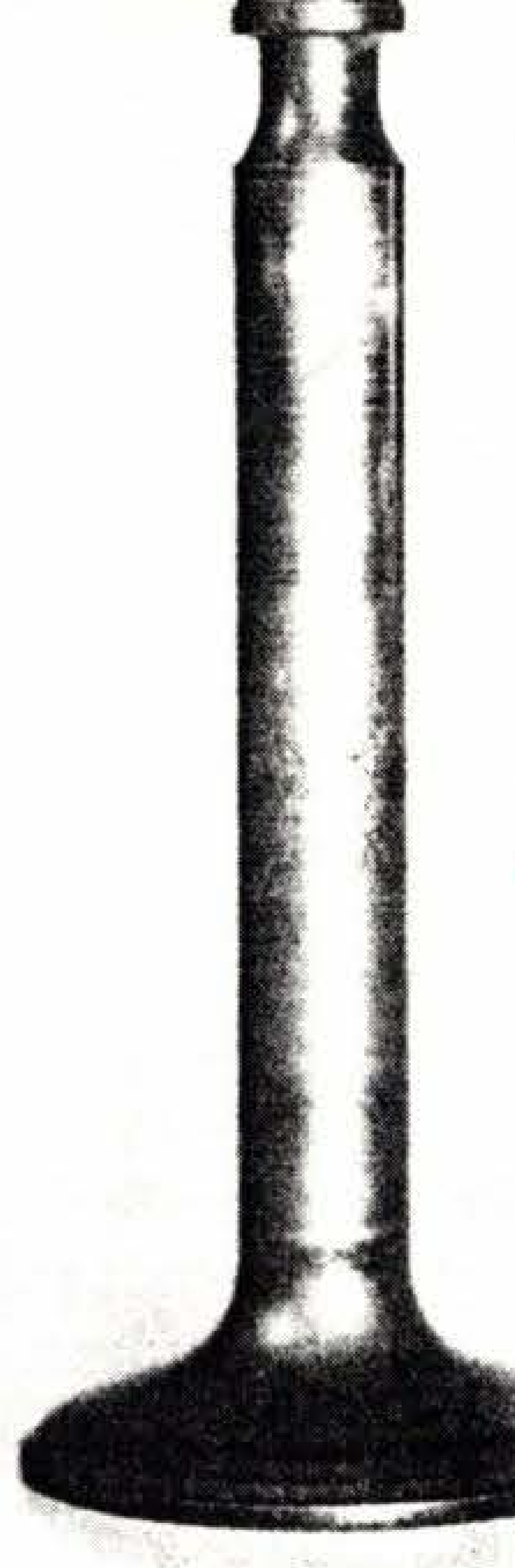
Valve Erosion in Lycoming Engines

Will there ever be a cure? Superior Air Parts, armed with German know-how, says yes



The P/N 74541 sodium-filled valve is used in almost every low compression engine Lycoming makes.

by Kas Thomas

Lycoming hasn't exactly had the best of luck with valve-trains. Between the O-235's pushrod problems, cam and lifter troubles with the O-320-H and O-360-E, and a vexacious fleet-wide problem with valve-sticking (not only in the O-320 but a wide variety of models), Lycoming has had more than its share of valvological distress.

One problem that just won't go away is the old thermal erosion (or "80-octane valves in 100-octane engines") bugaboo. Mounting evidence now suggests, in fact, that thermal erosion and head cracking have never been worse in parallel-valve Lycomings. Particularly hard-hit are engines with P/N 74541, P/N 76081, and P/N 75068 exhaust valves—which is to say, just about every low-compression engine with a Lycoming data plate, from 150-hp O-320 to parallel-valve O-540.

Thermal erosion of Lycoming valves is an old problem. Extensive testing of O-290 and O-435 engines (to determine optimum valve/guide combinations to reduce erosion) was done by Lycoming after World War II under the auspices of the Ethyl Corporation and the U.S. military. (See the paper by Robert V. Kerley in SAE Quartlerly Transactions, Vol. I, No. 2, April 1947.) The deleterious effect of leaded fuels on exhaust valves has been known to Lycoming for well over 40 years.

Valve erosion in the civil fleet wasn't much of a problem for the years 1945 to 1970, because 80/87 avgas (with only 0.5 gram of lead per gallon) was plentiful, and it met the needs of the majority of operators whose engines were originally certified on that fuel. (The few high-performance engines that required 100/130 avgas did well with it; but then, TBOs for big engines, in the Viet Nam years, were only 1,200 hours or so.) The problem came when oil companies began phasing out 80/87, and owners of low-comprssion engines were forced to turn to 100LL (with quadruple the lead content). All of a sudden, valve erosion was a Big Problem.

Lycoming issued Service Bulletin No. 404 in September 1976 specifically to address this situation. Lycoming attributed some of the erosion problem to overleaning, but nevertheless mandated repetitive inspections of valves for operators using high-lead fuel in 80-octane engines (regardless of leaning procedure). Under S.B. 404, engines that'd gone past the 1,000-hour mark and spent more than 25% of that time on grades of fuel higher than 80/87 were to get repetitive 100-hour inspections of exhaust valves for rim cracking, necking, and burning. The inspection procedure: "By means of a borescope or other suitable optical device, examine the exhaust valve through the spark plug hole. Especially look for sharp, well-defined, carbon-free rim formed on the face of the valve around the outer circumference." Cracks were known to form radially around the feathered edges of eroded valves, eventually resulting in a pie-shaped piece of valve coming loose in service, if the condition was not caught in time.

Lycoming's 1976 bulletin introduced a "cure" for the valve-erosion phenomenon in the form of P/N 74541 valves (which had already been used in Lycoming's higher-compression engines, with good success). The P/N 74541 exhaust valve was essentially the same as the older, low-compression-engine P/N 75068 valve—both were sodium-filled and made of XB-type steel—but the P/N 74541 valve had a nichrome overlay on the head end for better resistance to lead oxide attack. Lycoming thus encouraged owners of 80-octane engines to convert to the P/N 74541 exhaust valve at the earliest opportunity.

There is little question that the P/N 74541 valve is more erosion-resistant than the old P/N 75068 valve it replaced. (NTSB reached precisely this conclusion last June after reviewing over 200 reports of valve distress in O-320 engines. See LPM, Sept. '87, pp. 8-10.) But unfortunately, erosion and rim cracking are still problems in low-compression Lycomings, even with the P/N 74541 valve. (Some actual failures reported by LPM readers were recounted in September 1986, pp. 17-18, and June '87, pp. 19-20, involving O-360-A and TIO-540-C engines, respectively.)

Failure Mode

Where erosion bad enough to cause head cracking has occurred, the big end of the valve generally has a black, mottled, crusty appearance suggestive of over-heating. Wear along the edge of the valve face is typically quite advanced, with a sharp, feathered edge formed on at least part of the circumference. Stress risers form along the thin edge, eventually causing fatigue cracks to appear and progress radially inward toward the stem. Before the cracks can reach the center (stem) portion of the head, however, overload failure causes a fragment (usually representing a third or more of the valve face) to break off. When this happens in flight, EGT for the cylinder drops; also, the piston crown gets peened as the valve fragment ricochets around on its way out. In turbocharged aircraft, the turbo generally incurs fatal shrapnel damage.

Heat and lead (from 100LL) are the main culprits in the above scenario. Lead combustion products are extremely corrosive at temperatures of 1,500 or more degrees Fahrenheit; in fact, the higher the temperature, the more rapid the corrosion. (See SAE Quarterly Transactions, April 1947, pp. 253-260.) Leaning to peak EGT under sustained high-power cruise sets up conditions ideal for corrosive attack.

Considering the harsh operating environment—and the ever-longer TBOs being seen by the fleet—it's a wonder more valves don't fail on the way to TBO. It may well be that the only thing preventing early failure of P/N 74541 valves (particularly those being subjected to worst-case conditions) is the sodium cooling feature. (In a hollow, sodium-cooled valve, molten sodium inside the valve stem physically carries heat from the head to the stem during reciprocation of the valve.) Without sodium to carry heat up the stem, the valve head takes on thermal loads for which it may or may not be designed. Continental gets around the problem in its solid-stemmed valves by making the valve head itself massive and constructing the valve entirely of Nimonic 80A (or lately, Nimonic 90) superalloy. Unfortunately, the Lycoming P/N 74541 valve has a less massive head design and the low-nickel steel of which it is made is not suited to ultra-high-temp operation.

In short: If either the nichrome face overlay is breached, and/or the sodium cooling feature is lost, severe erosion and head cracking are virtually certain to be the outcome.

Superior Air Parts' ad for the improved SL17540 valve (a direct replacement for Lycoming P/N 74541 and LW19001) touts strengthened keeper groove, extra head metal, and patented zirconium gas process for filling stem with sodium.

Low-Sodium Valves

In late 1986, overhauler James Wyatt of Homestead, Florida installed all-new P/N 74541 valves from Superior Air Parts in his Skyhawk's engine. (Actually, the valves were not genuine Lycoming parts but were PMA equivalents, P/N SL74541, made at the same Eaton plant that Lycoming's valves are made at.) The engine had hardly gotten through the break-in period when—at a little over 100 hours since major—an exhaust valve failed on takeoff.

"Thankfully, I wasn't over the Ever-

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glades," Wyatt muses. "The valve broke clean across the face, just like that picture in the July LPM. The head simply failed."

Wyatt returned the valve to Superior. Superior, in turn, determined that the valve broke due to "uneven valve seating which caused leakage and burning in the valve face area." This conclusion was based on the observation that there had been "extreme wear to the valve lock pieces and lock area of the valve."

Wyatt didn't buy this explanation. Instead, when he got the failed valve back from Superior, he sent it off to a commercial lab—QC Metallurgical, Inc., of Hollywood, Florida—for analysis. When the lab report came back, it laid blame for the failure on "thermal and possibly some bending stress." But there was one other interesting finding: "Also noted when cut [open] was that the valve stem was not filled with sodium."

Superior's Charles Dedmon told LPM that it was "extremely unlikely" that an Eaton-manufactured sodium valve could contain no sodium. (A senior Lycoming engineer we talked to echoed this sentiment. "The amount of sodium in each valve is closely controlled during manufacture," he told us. "Plus, Eaton x-rays the valves before releasing them to Lycoming, and Lycoming has its own quality-control checks.") Dedmon wouldn't totally rule out the possibility, however. "I haven't been to the Eaton plant since they moved a couple years ago," he confided, "but the last time I was there, I saw how the valves are made, and I can tell you this: The sodium is put in by hand, in the form of a pellet."

Dedmon pointed out that sodium doesn't have to be totally absent for valve cooling to be impaired; improper guide clearances, or loss of sodium to internal corrosion in the stem, can also have the same effect. The latter comes about when entrapped water vapor—retained in the valve stem during manufacture—reacts with the sodium (and valve metal) to form scale buildup along the inside of the sodium chamber.

How big a problem is scale buildup? TRW's Thompson Valve subsidiary in West Germany (which produces sodium-filled valves for numerous OEMs worldwide) considers it serious enough that its engineering staff developed and patented a zirconium-gas evacuation process for the manufacture of sodium-filled valves, specifically to avoid scale buildup problems. Superior now has valves made in West Germany using the zirconium process.

Phillips' Findings

Additional evidence for variations in the amount of usable (unreacted) sodium inside Lycoming's sodium-filled valves comes from, of all places, Phillips Petroleum. Two years ago, at the height of the X/C II oil controversy (in which X/C II oil was thought by some to be implicated in valve-sticking), Phillips acquired a number of corroded Lycoming valves, sent in by disgruntled owners. (Phillips paid for replacement valves for many of these same owners.) The corroded valves are still in Phillips' possession. Many of them have been subjected to x-ray analysis. A few were sectioned. Not all contained the same amount of sodium.

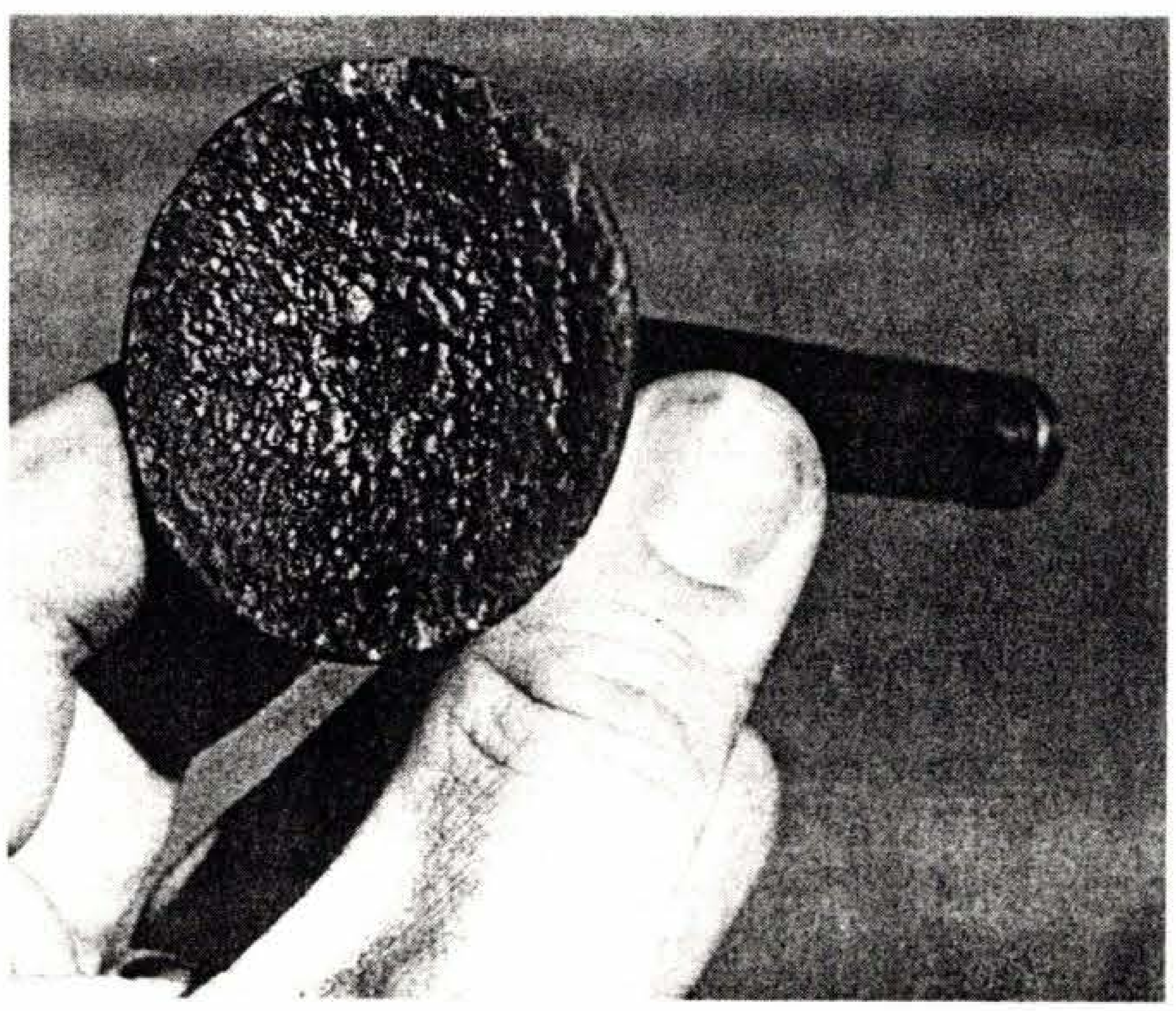
"I don't think we ever found one that had no sodium at all inside," a Phillips spokesman told LPM. "In fact, I tend to regard our results as inconclusive, because of the small numbers, and because of the difficulty in interpreting the x-ray results." The problem in interpreting the x-ray photos, the spokesman remarked, was due in part to variations in surface thickness of adhered sodium inside the valves. In other words, scale buildup in the sodium chamber may have been a factor.

The Phillips man we spoke to was reluctant to state flatly that Lycoming valves varied dramatically in sodium content. But Phillips' research to date has been unable, by the same token, to rule out scale as a factor in valve overheating, and overheating as a factor in deposit buildup. It is just possible that X/C II was the victim of a valve problem, rather than the cause of one.

The Solution

Lycoming and Superior Air Parts have each acted to remedy the head-erosion problem in P/N 74541 valves. Lycoming superseded the P/N 74541 valve with P/N LW-19001, which is dimensionally similar to its predecessor but constructed of Nimonic 80A. (The Nimonic alloy is approximately 75% nickel, and—unlike steel—retains good tensile strength and resistance to corrosion at temperatures of 1,500 to 1,600 degrees Fahrenheit). The P/N LW-19001 valve is approved for all parallel-valve Lycomings (provided ni-resist guides are used); list price is $299.50 each.

Superior Air Parts has taken a somewhat different approach, superseding its version of the P/N 74541 valve with an entirely new part number: SL17540. The SL17540 valve (introduced in May 1985) is made in West Germany for Superior. It sells for $150, dealer net; aircraft-owner net will be more, depending on dealer markup. (Linda Lou, Inc., will sell the valve direct to owners for $190. Phone 1-800-824-9912.)



Lead amalgamation claimed this valve at low total time. Burning and rim cracking would eventually have led to outright failure. Note the chipped or spalled appearance and the loss of material at 12 o'clock on the face.