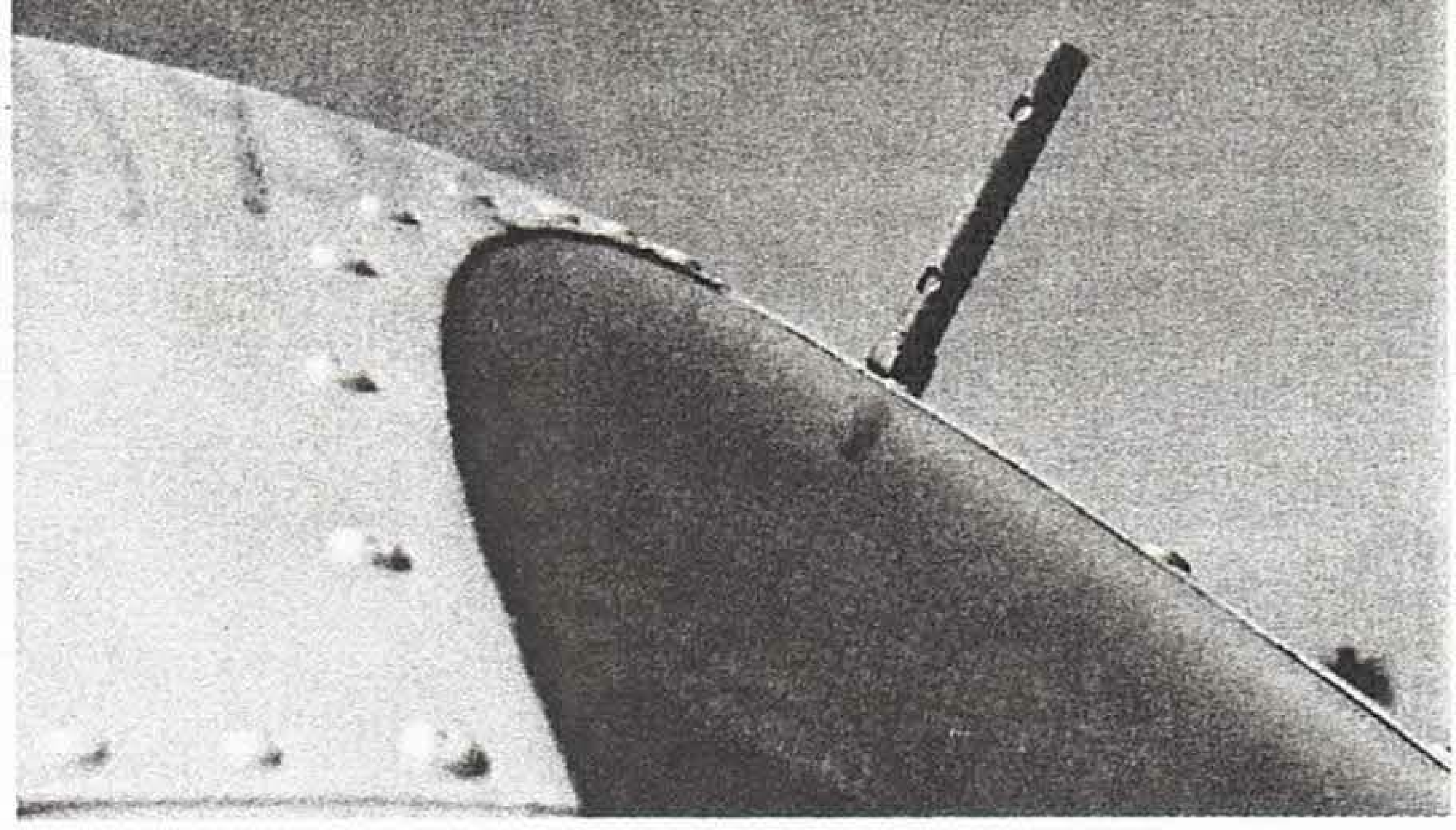

Considering drag, location of this OAT probe is the worst possible.

streamlined tubing to reduce drag.

Another common drag culprit on light airplanes is the outside air temperature (OAT) probe. This often sticks out perpendicular to the skin near the top of the windshield. This is a particularly high drag location because the air is locally accelerated as it flows over the crest of the windshield. Putting the OAT probe there guarantees that the high-drag probe is sitting in an area of high-speed airflow, where its drag can be as high as possible.

Locks are another area where people get lazy about drag. Many airplanes have multiple door locks on cabin doors and baggage doors. Often, the barrel of the lock sticks up at least one-quarter inch above the skin.

Bumps and Blobs

Many of the items projecting from the airplane surface have relatively smooth shapes. These bumps include hinges, lights, fuel filler caps and similar items.

The drag penalty of a smoothly faired bump is relatively small unless it is placed where the flow over the bump interferes with the flow over another part of the airplane. It can increase if the bump is in a critical area such as the upper surface of a wing or any region where laminar flow is possible. A bump will cause the boundary layer to become turbulent with an expanding wedge of turbulent flow behind it. If the bump is placed in such an area or in any area where it might cause the flow to separate, the drag penalty might be quite high.

Some bumps have shapes that are bluff and resemble hemispheres or flattened cylinders. The drag of these shapes is higher because the flow will separate from the bluff after-portion of the bump. This can be particularly bad if the bump is on the upper surface of the wing, where it acts as a small spoiler. A common culprit in this area is fuel filler caps. It is quite common for these to project above the wing surface and induce separation aft of the gas cap. The drag penalty of such a design can be large.

If it is necessary to put filler caps in the upper surfaces of wings, they should be as far aft as possible, and they should be flush with the wing surface. Such a cap will still trip laminar flow, but at least it will not cause a large area of separation on the vital upper surface of the wing.

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All of this makes common sense: Keep it smooth and faired, and drag will be minimized in most cases. **KP**

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plane wings are made, despite this enormous drag penalty. A quick look at these figures shows what degree of drag reduction can be achieved by sensible, conservative design, even before we add the benefits of laminar flow and other exotic technology.

A rear-facing step will force the boundary layer to transition from laminar to turbulent, and the airfoil will not have any laminar flow on its surface aft of the step. If a laminar flow wing is used, lap joints should be avoided entirely where laminar flow is expected.

Gaps and Holes

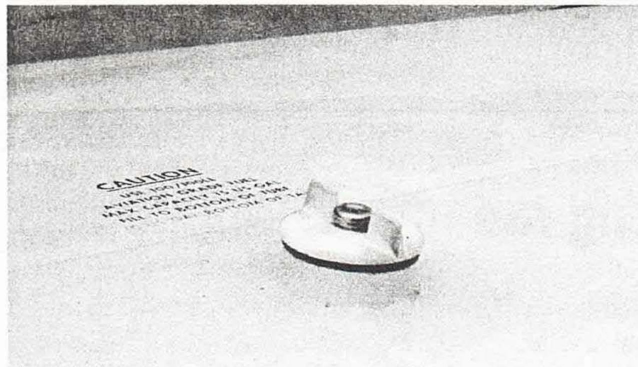
Gaps and holes in the surface of the airplane act very much like other surface blemishes. They produce some increase in drag and tend to trip the boundary layer and destroy laminar flow. As with other surface imperfections. they should be eliminated or avoided whenever possible.

Any gap that allows air to flow between two areas of differing air pressure will cause drag as the air flows through the gap. Leakage around poorly sealed doors and through control surface gaps are examples of such drag producers.

There is one situation where the drag of a hole or skin gap can be quite large. If the gap or hole allows a large enough amount of air to leak through, it can trigger flow separation. Because separation affects not only the area of the hole but a large area downstream of it, the drag it causes can be quite significant.

Wingwalks and Stripes

Many airplanes have wingwalks that are deliberately roughened to improve traction for people walking over the wing to get into an airplane. The idea here is to increase the friction between a shoe and the surface of the wing. It does this admirably, but in the process also increases the friction between the air and the wing thus increasing parasite drag. If wingwalks cannot be eliminated entirely, they should be made as small as possible, and the level of roughness used should be the absolute minimum that will provide acceptable traction.



A gas cap and filler neck on top of the wing act like a spoiler.

Fancy paint jobs can have an unexpectedly negative effect on the drag of an airplane. Many paint stripes have steps in the paint between the stripe and the base color. These "thick" steps can affect the airflow in much the same way as a skin lap joint. There are documented cases of paint stripes on wings tripping the boundary layer and destroying laminar flow over the entire wing. This can double the drag of a laminar-flow wing, which seems a rather large penalty to pay for pretty paint.

Cylinders

Many airplane components are cylindrical in cross-section. Among these are landing gear legs, exhaust pipes, antennas, boarding steps, primitive bracing struts, bracing wires, vents and drains. These are very high drag for their size. A cylinder at 90° to the flow has approximately 7.5 times the drag of a turbulent airfoil of the same thickness. To put this in perspective, a tube 1 inch in diameter has the same drag per foot of length as an average, turbulent-flow wing with a chord of 5 feet.

The drag of cylindrical projections can be minimized three ways. First, eliminate cylindrical projections or keep them as small as possible. Second, fair the cylinders into a more streamlined shape, and third, sweep the cylinder forward or back relative to the airflow.

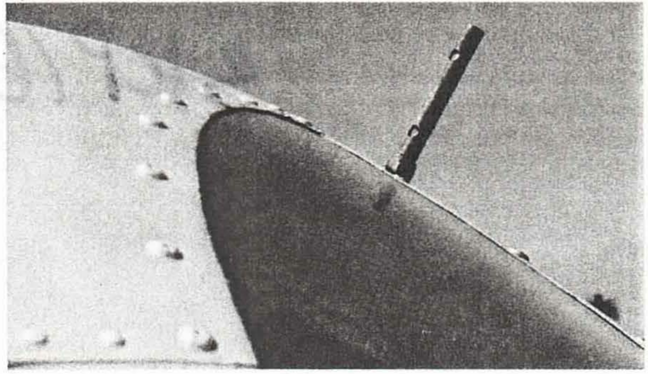
For fixed components like struts, wires and landing gear legs, drag can be reduced by as much as 90% by adding relatively simple fairings. Even a simple straight-sided fairing mounted on the back side of the cylinder can decrease its drag by 60%.

Wires are difficult to fair. Streamlined bracing wires can be used in place of cylindrical wire. In the early days of aviation, the drag of cylinders was not properly appreciated. Designers did not believe that the drag of the bracing wires was significant. The development and acceptance of streamlined wire did much to improve the performance of the airplanes of the 1920s and '30s.

Many ultralights still fly with what seems to be miles of cylindrical cross-section wire exposed to the air stream. This is to minimize cost and/or to increase drag to remain below ultralight speed limits. Streamlined wire is very expensive and must be custom made to the desired length. One company is now offering a streamlined PVC extrusion that fits over conventional round wire to give it a low drag cross section.

Where fairing is impractical, sweeping can reduce the drag of cylinders. Exhaust pipes, which tend to be hot, and antennas that cannot be covered without losing effectiveness should be swept as much as possible to reduce their drag. Exhaust pipes are a good example. They are rather large and hot enough to melt a composite or plastic fairing. Sweeping an exhaust pipe back 45° can reduce its drag by 65%, and sweeping it back 60° can reduce its drag by as much as 85% .

Many production airplanes have fixed boarding steps. Usually, these consist of a step mounted on a piece of cylindrical tubing. Often, the step itself is also a cylindrical tube. A typical step can cause as much parasite drag as several feet of wing. A boarding step should be retractable, removable or, at the very least, made of



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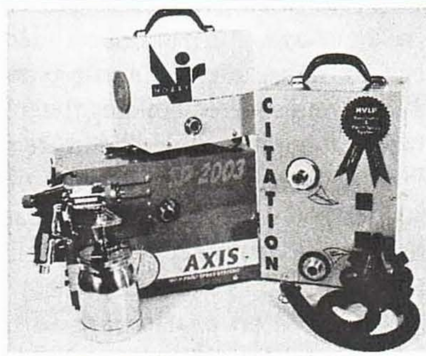

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