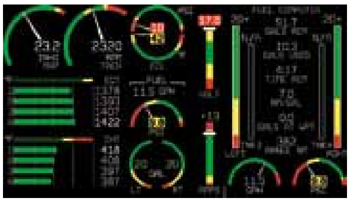

Quantity & Consumption

The Building Blocks of Fuel-Management Systems

BY SCOTT M. SPANGLER

Pilots have been flying their airplanes out of gas ever since the Wright brothers first put wings on a powerplant. Then, as now, it makes the news.

Datelined March 18, 1906, *The New York Times*, under the headline "Aero Club Honors the Wright Brothers," reported one of the earliest incidents: Talking about the success of the Flyer III, the article said, "With this improved machine, six notable flights were made between Sept. 26 and Oct. 5 (1905). That of Oct. 5 was the most successful, for the machine remained in the air 38 minutes and 3 seconds and traveled a distance of 24 1/5 miles. Exhausting of fuel was the cause of stopping."

Wilbur Wright was at the controls on this record-setting flight, and one might rightly suppose he planned to run out of gas, using every drop to set a new endurance mark. This posed little risk because he was flying a three-quarter-mile circuit above his landing field, Huffman Prairie. It might well have been the last time a pilot ran out of gas on purpose.

From there forward, running out of gas was the result of poor planning and execution or a mechanical problem (the reliability of early engines left much to be desired). Either way, the risk increased as pilots ventured cross-country, and, of necessity, they kept an eye out for suitable landing sites within gliding distance.

Time and technology have done much for reliability and fuel management. From the first fuel gauge to the latest flight management system, innovation continues to give pilots the tools needed to safely and efficiently manage the gasoline or Jet A powering their flights. To one degree or another, no matter how flashy or capable the device, they all work on a simple equation: Quantity divided by consumption equals hours and minutes of powered flight.

Yet, pilots still manage to run out of gas. The reason is succinctly stated in the 2008 "Nall Report," published by the AOPA Air Safety Foundation: "Machines are always much more reliable because they can be redesigned. Human nature is not so easily changed."

Analyzing the causes of the 1,385 accidents in 2007, involving general aviation aircraft weighing 12,500 pounds or less, the report found mechanical failures and/or maintenance-related issues caused 219 of them, 15.8 percent of the total. Powerplant failures accounted for 87 of those accidents, and the fuel system for 45.

One way or another, pilots caused the remaining 996 accidents, 71.9 percent of the total. Inadequate fuel management caused 90 of them. What's interesting is, more than half of the pilots ran out of gas when they were within 5 miles of an airport, and 88 percent of them did it during the daytime. Rarely did pilots run out of gas in instrument meteorological conditions, according to the Nall Report, which says something about the attention pilots give to the details of an IFR flight. When they did occur in IMC, or at night, they "were more apt to prove fatal."

The 90 gasless accidents in 2007, represented a significant decrease from the 120 fuel-management accidents in 2002. ASF director Bruce Landsberg attributes the improvement to technology, "where a microprocessor serves the role of a technically competent and persistent nagging passenger." Still, it is up to pilots to heed technology's nagging and to recognize "a lack of fuel onboard is non-negotiable, and landing while it is still optional."

FUEL MEASUREMENT

In the fuel-management equation, quantity is the most important variable. Every device conceived to help pilots manage an airplane's fuel — whether a standalone fuel monitor or part of an integrated flight management system — all ask the same question at the start of every flight: How much fuel is in the tanks?

Given the ever-growing reach of technology, pilots often ask why the fuel-management system doesn't autonomously read the fuel gauges. Part of the answer is found in the federal regulations guiding the certification of Part 23 general aviation and Part 25 transport category aircraft (and most business jets). Advisory Circular 23.1337, "Powerplant Instruments Installation," and AC 25.1337, "Powerplant Instruments," both say the same thing: There must be some indication of the useable fuel in each tank, and "each fuel-quantity indicator must be calibrated to read 'zero' during level flight when the quantity of fuel remaining in the tank is equal to the unusable fuel supply."

Accuracy only when empty means everything else is close. When it comes to measuring the quantity of measurable fuel, close doesn't cut it. How accurately the pilot answers the fuel-management system's initial question determines the flight's outcome. When the tanks are full, the answer is visually clear. Don't guess with partial fuel: AC 23.1337(b)(4) requires some method of indicating "the amount of useable fuel in each tank when the airplane is on the ground (such as by a stick gauge)."

Pilots also must remember to verify the line crew has properly filled the plane with the proper fuel. Contamination, either from water or filling avgas tanks with Jet A, caused two accidents in 2007, both of them fatal.

Whether starting with tens of gallons in a light-sport aircraft or thousands of pounds in an intercontinental business jet, fuel-management systems continuously measure consumption with fuel flow, subtracting the amount from the total quantity the pilot entered at the start of the flight.

Each Part 23 airplane with a pump-fed piston engine must have an indicator showing fuel flow or fuel pressure and which warns the "pilot of any fuel-flow trend that could lead to engine failure." Most fuel-management systems today measure both flow and pressure, and they offer equal benefits to pilots of high-wing piston airplanes with gravity-fed fuel systems.

Turbine airplanes, whether Part 23 or Part 25, must have fuel-flow and pressure indicators with appropriate low-level warnings. No matter what type of powerplant, the metering component installed in the fuel line must have a bypass that continues to feed to the engine should it malfunction.

CONSUMPTION CONTROL

In any airplane with a single power lever, from a Rotax-powered light-sport aircraft or a high-performance, advanced-technology piston single to anything with a turbine, a pilot's control of fuel consumption is limited to decisions made during flight planning. Three-quarters of all fuel-management accidents start here, according to the "Nall Report," because pilots plan flights requiring more fuel than they have onboard.

Single-lever engines determine the fuel flow that satisfies their power-setting needs for a given altitude; so, pilots must plan flights that marry a fuel-efficient cruising altitude with favorable winds aloft. From this union comes the flight time, which must be well within the fixed amount of time determined by the fuel onboard, minus the required VFR or IFR reserves — with some padding if uncertain weather lies in waiting.

Engines with mixture controls offer more opportunities for management failure. The FAA's "Pilot's Handbook of Aeronautical Knowledge" makes is clear that improperly leaning the mixture can affect the fuel flow by 10 percent. The airplane's approved flight manual will describe the proper leaning procedure, and an exhaust gas temperature (EGT) gauge makes the process of setting the optimum fuel/air ratio a snap.

The cooler the EGT, the more fuel in the mixture. The leaner the mixture, the hotter the temperature. Depending on the airplane, the optimum mixture is generally between 25 and 75 degrees richer than the peak (hottest) EGT.

EGT gauges are standalone instruments or are incorporated with multi-function engine moni-

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tors. Digital models of both usually include a mixture leaning function, which identifies the hottest cylinder and shows the differences between each cylinder, allowing pilots to tweak the mixture to perfection. As single-lever pilots must, mixture controllers also must plan flights well within the fuel onboard and lean the mixture to realize the planned performance.

In flying the plan, effective fuel management requires all pilots to continually match their in-flight numbers with those used to plan the flight, and adjust accordingly. Just because the flight plan says there's enough fuel to reach the destination, it doesn't really make it so — especially if the headwind is a few knots stronger than the forecast predicted.

Additionally, it is important to verify the accuracy of the planning numbers. Many pilots use performance and fuel-consumption numbers straight from the approved flight manual. And, as many pilots will attest, performance fades with the wear and tear of age. A fuel-flow indicator makes it easy to update the numbers to more accurately represent the performance of a middle-aged airplane, not that of a perfectly prepared newborn flying in an ideal sky under standard conditions.

Finally, pilots must know how their airplane's fuel systems work. Poor flight planning might be the cause of most fuel-exhaustion accidents; however, the "Nall Report" showed a quarter of them are caused by "improper operation of the fuel system leading to loss of fuel to the engine, even though fuel is available in at least one tank."

FUEL-MANAGEMENT TECHNOLOGY

Before technology took over, pilots were the primary processor in the fuel-management system, and they remain the fail-safe unit today. When pilots know the quantity of fuel onboard, how long they've been airborne and at what rate the engine is consuming it, doing some simple math, either with pencil and paper or an E6B whiz wheel, will provide answers to an important question: Do I have enough gas?

In aviation's analog era, fuel-management systems were expensive and usually seen in corporate cockpits, either as standalone units or as part of the then nascent flight-management systems just trickling down from airline cockpits. In the digital age, replete with wall-to-wall glass, fuel management is a menu item and standard equipment in new-technology airplanes, including light-sport aircraft.

The Dynon EMS-D120 engine monitoring system is popular in many LSAs. With a 7-inch diagonal color screen, it replaces 16 different instruments, continuously reads 27 different sensors, including every aspect of fuel management, and warns pilots immediately about any abnormality it detects. It has a lean function to optimize the mixture, and when connected to a GPS, it adds actual time and speed to its computation of fuel used and remaining, expected fuel quantity at upcoming waypoints and the destination, fuel economy in miles per gallon, and time to fuel exhaustion. Naturally, this data is worthless if pilots do not input the accurate fuel quantity at the start of the flight.

Only the airframe manufacturer can approve the installation of the Dynon unit in a light-sport aircraft, and Dynons are not approved for Part 23 aircraft. But owners of type-certificated aircraft can get the same capabilities and more in an ever-growing selection of engine monitors from manufacturers like Electronics International, JP Instruments, and Xerion Avionix. A step up would be one of the growing number of integrated avionics suites, such as the Avidyne Entegra, where the combination of navigation and fuel management makes simple work of picking an alternate within range. In addition, these systems and many like them store performance data pilots can download and evaluate on their personal computers.

A step in another direction would be a dedicated fuel-management system, such as Shadin Avionics' Digiflow-L, which fits in a standard round instrument cutout and provides all of the GPS-enabled information. In the same family are replacement fuel-flow and pressure indicators from Electronics International and JP Instruments.

Ultimately, technology can only do so much. It is up to pilots to plan the flight within fuel limits and to ensure the right amount of fuel is in the tanks. Regardless of certificate or experience, no pilot is immune to the possibility of fuel exhaustion.

The "Nall Report" showed more than half of the private pilots who ran out of gas had more than 500 hours. Three-quarters of the fuelish commercial pilots had more than 800 hours. Pilots at opposite ends of the certificate spectrum — students and ATPs — had the best safety records. Only two students ran out of gas in 2007.

Rare is the fuel-exhaustion accident involving a business jet. The reason is not owned only to sophisticated flight-management system; it is the team of crosschecking pilots whose jobs — and lives — depend on getting the company's personnel safely to their destination.

In short, fuel management is a state of mind. Equipment is but a tool. Safety depends not only on technology, but also how pilots use it. No pilot expects or intends to run out of fuel, at least not today, more than a century past Wilbur Wrights' record-setting flight to fuel exhaustion in 1905. And still, in the United States nearly two pilots a week fly their planes to fuel exhaustion and finish their flights as a glider. ❑