TURBINEPILOT

A SPECIAL SECTION FOR THE TURBINE OWNER-PILOT

MENTORING MATTERS

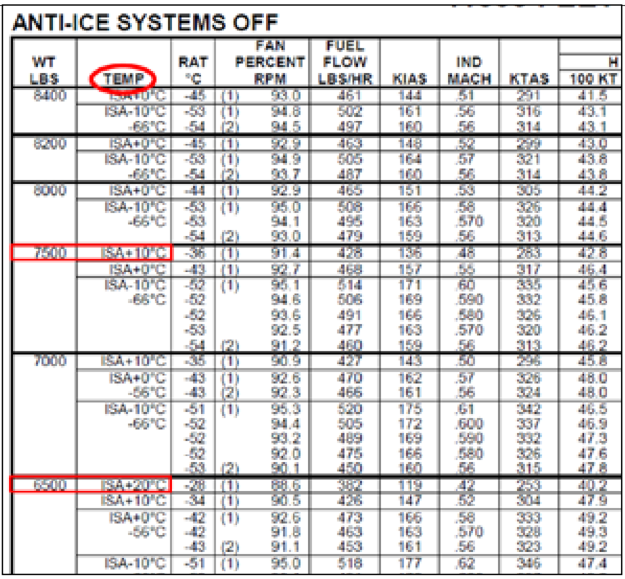
ISA and cruise planning

When 45 below zero isn't cold enough

BY NEIL SINGER

Jet pilots quickly learn that when it comes to cruise planning, higher is almost always better. Ignoring a very small increase in engine efficiency at high altitude, jets cruise at an indicated airspeed that is solely a function of fuel flow. That is, for given factors the pilot cannot control—such as temperature and weight—the airplane will essentially fly at the same indicated airspeed for a given fuel burn, whether down low or up high. What does change with altitude, however, is the true airspeed that will result from that "fixed" indicated airspeed.

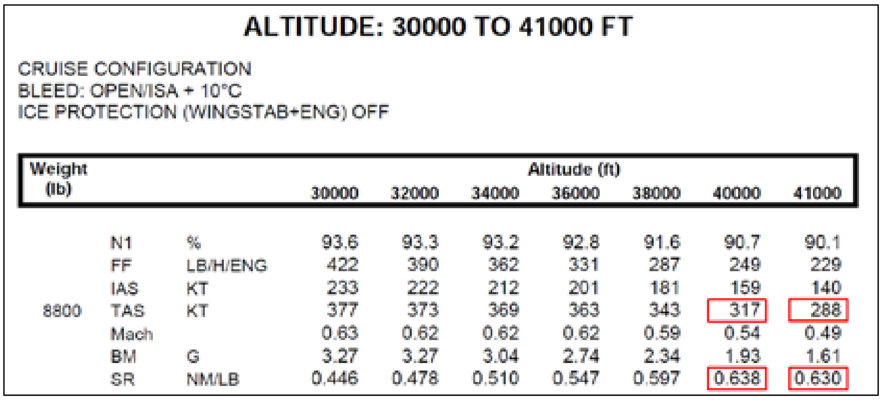
So although a popular light jet with engines set to burn 600 total pounds of fuel per hour may indicate 190 knots regardless of altitude, at 26,000 feet the corresponding true airspeed (TAS) will be 280 knots, while at 39,000 feet the TAS will be 350. What this means is the aircraft at 39,000 feet is flying 25 percent farther for every gallon of fuel burned. Seem like something for nothing? Most of the time, it is. With the exception of flight in strong winds that vary greatly with altitude, it is always more fuel efficient to fly higher than lower.



ANTI-ICE SYSTEMS OFF

WT LBS	TEMP	RAT °C	FAN PERCENT RPM	FUEL FLOW LBS/HR	KIAS	IND MACH	KTAS	H 100 KT
8400	ISA+0°C	-45	(1) 93.0	461	144	.51	291	41.5
	ISA-10°C	-53	(1) 94.8	502	161	.56	316	43.1
	-66°C	-54	(2) 94.5	497	160	.56	314	43.1
8200	ISA+0°C	-45	(1) 92.9	463	148	.52	299	43.0
	ISA-10°C	-53	(1) 94.9	505	164	.57	321	43.8
	-66°C	-54	(2) 93.7	487	160	.56	314	43.8
8000	ISA+0°C	-44	(1) 92.9	465	151	.53	305	44.2
	ISA-10°C	-53	(1) 95.0	508	166	.58	326	44.4
	-66°C	-53	94.1	495	163	.570	320	44.5
		-54	(2) 93.0	479	159	.56	313	44.6
7500	ISA+10°C	-36	(1) 91.4	428	136	.48	283	42.8
	ISA+0°C	-43	(1) 92.7	468	157	.55	317	46.4
	ISA-10°C	-52	(1) 95.1	514	171	.60	335	45.6
	-66°C	-52	94.6	506	169	.590	332	45.8
		-52	93.6	491	166	.580	326	46.1
		-53	92.5	477	163	.570	320	46.2
		-54	(2) 91.2	460	159	.56	313	46.2
7000	ISA+10°C	-35	(1) 90.9	427	143	.50	296	45.8
	ISA+0°C	-43	(1) 92.6	470	162	.57	326	48.0
	-56°C	-43	(2) 92.3	466	161	.56	324	48.0
	ISA-10°C	-51	(1) 95.3	520	175	.61	342	46.5
	-66°C	-52	94.4	505	172	.600	337	46.9
		-52	93.2	489	169	.590	332	47.3
		-52	92.0	475	166	.580	326	47.6
		-53	(2) 90.1	450	160	.56	315	47.8
6500	ISA+20°C	-28	(1) 88.6	382	119	.42	253	40.2
	ISA+10°C	-34	(1) 90.5	426	147	.52	304	47.9
	ISA+0°C	-42	(1) 92.6	473	166	.58	333	49.2
	-56°C	-42	91.8	463	163	.570	328	49.3
		-43	(2) 91.1	453	161	.56	323	49.2
	ISA-10°C	-51	(1) 95.0	518	177	.62	346	47.4

The Cessna Mustang cruise table (left) for its ceiling of 41,000 shows that at ISA+10 cruise flight is impossible unless weight is at or below 7,500 pounds. At ISA+20 weight must be at or below 6,500 pounds. A Phenom 100 flying at 41,000 feet (below), and weighing 8,800 pounds is capable of cruise at 41,000 feet, but it will fly 30 knots faster—and achieve better mile per pound efficiency—at 40,000 feet.



ALTITUDE: 30000 TO 41000 FT

CRUISE CONFIGURATION
BLEED: OPEN/ISA + 10°C
ICE PROTECTION (WINGSTAB+ENG) OFF

Weight (lb)			Altitude (ft)						
			30000	32000	34000	36000	38000	40000	41000
	N1	%	93.6	93.3	93.2	92.8	91.6	90.7	90.1
	FF	LB/H/ENG	422	390	362	331	287	249	229
	IAS	KT	233	222	212	201	181	159	140
8800	TAS	KT	377	373	369	363	343	317	288
	Mach		0.63	0.62	0.62	0.62	0.59	0.54	0.49
	BM	G	3.27	3.27	3.04	2.74	2.34	1.93	1.61
	SR	NM/LB	0.446	0.478	0.510	0.547	0.597	0.638	0.630

Given these facts, it's understandable that most pilots flying a trip of any substantial distance will flight plan based on climbing to the airplane's ceiling. Most of the time this works well, and the pilot can be lulled into a sense that a direct climb to the aircraft's ceiling will always be practical. A trap lurks, however, in the form of nonstandard temperatures aloft.

The international standard atmosphere (ISA) is a model of temperature and pressure across altitude. It was created to provide a baseline reference, and is used as the basis for performance calculations. Every pilot is familiar with the concept that as temperature rises, aircraft performance decreases. Jets are not immune to this basic fact, but the issue can be clouded to jet pilots by two facts: The first is the fact that even a warmer-than-standard temperature at high altitude still seems pretty cold. It usually isn't intuitive to a new jet pilot that a temperature of minus 40 degrees Celsius is actually quite warm if encountered at 34,000 feet. The second trap is that when speaking of high altitudes, the outside temperature can be *decoupled* from geography and season in a way that seems illogical. For example, on a chilly winter day in New England, a pilot may climb to 40,000 feet to find temperatures are 10 degrees C warmer than standard, or ISA+10. At that same moment the temperature over Florida at the same altitude could well be ISA minus 5.

For these reasons, a careful jet pilot needs to always be aware of the forecast deviation from ISA at high altitudes. This information should be applied when selecting, or accepting from ATC, a cruise altitude. For example, most modern light jets are capable of taking off at maximum takeoff weight (MTOW) and climbing directly to 41,000 feet, as long as the temperature aloft does not exceed ISA. But if the temperature at 41,000 feet is forecast to be minus 47 degrees C, or ISA+10, those same airplanes would need to burn off well more than 1,000 pounds of fuel before they will be capable of sustaining cruise flight that high.

A pilot who ignores these limits risks a high-altitude stall. The same airplane that may be climbing more than 2,000 fpm at 5,000 feet msl will barely be making 200 fpm if it climbs through 40,000 feet at ISA+10. The temptation may be great for the pilot to raise the nose and climb at a lower speed to get up that last 1,000 feet. As the airplane slows, it crosses onto the back side of the power curve, where it will now climb at a lower rate with a speed decrease. If the pilot fails to recognize the situation, the end result could be an aerodynamic stall. Given that the aircraft is already putting out maximum power, recovery from such a stall will require a dramatic pitch-down input from the pilot, an action the pilot may not anticipate—or perform adequately.

The good news is that this situation is completely preventable with basic preflight preparation. The cruise performance charts published in the aircraft flight manual (AFM) or pilot's operating handbook (POH) show very clearly what the weight, altitude, and temperature limits are for cruise. If a given set of parameters isn't published in the cruise tables, it simply isn't possible.

Looking at the cruise performance table for the Cessna Citation Mustang, for example, we see that after a MTOW takeoff, cruise flight at 41,000 feet is only possible if the temperature is ISA or colder. Data for ISA+10 isn't published until weight drops to 7,500 pounds; for ISA+20, the weight must get down to 6,500 pounds. It will take nearly two hours of flying for the weight to reach 7,500 pounds after a MTOW departure.

The Mustang isn't at all unique in this; the similarly sized Phenom 100 would experience the same requirement for fuel burn prior to being able to reach 41,000 feet with temperature aloft at ISA+10. Even aircraft with much higher thrust-to-weight ratios, such as a Citation CJ4 or Phenom 300, may be unable to climb directly to their ceilings at some combinations of weight and temperature.

While the aircraft, after enough time, may reach a weight where it is able to climb up a few more thousand feet, doing so may not be the most efficient choice. Looking at the cruise chart for the Phenom 100 for ISA+10 conditions, we see that once weight has been reduced to 8,800 pounds, the airplane is capable of flight at 41,000 feet. However, after limping up from 40,000 feet, the low thrust output of the airplane will result in a 30-knot-lower cruise speed, combined with a slight drop in per-gallon efficiency. Slower speed for more fuel? Clearly the prudent pilot would recognize that, in this case, higher is not at all better.

Neil Singer is a Master CFI and a mentor pilot in Cessna and Embraer jets.