IAS: A Handle on Range Performance

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Indicated airspeed (IAS) is a landmark for range performance. At one weight, an airplane will have an IAS for best range and least drag, Vbr, with a Specific Range, SR, nautical air miles/gallon (nam/g).

Vbr and SR vary with weight, by the formulas $\mathbf{Vbr_2 = Vbr_1 \sqrt{W_2/W_1}}$, and $\mathbf{SR_2 = SR_1 (W_1/W_2)}$. Vbr and SR are independent of altitude. For the V35TC, estimating Vbr 112KIAS, 14.3 nam/g at 3400#, the numbers can be expanded by the formulas over the aircraft's operating weight range, as in Table 1.

Weight	1.0 Vbr	1.0 SR
3800	119	12.8
3400	112	14.3
3000	105	16.2
2600	98	18.7

Table 1. V35TC. Vbr and nam/g

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1.16 Vbr	.96 SR
137	12.28
130	13.73
122	15.52
114	17.95

Table 2. V35TC at 1.16 Vbr and .96SR

These numbers can be expanded in another way (arrow to Table 2). A "Target IAS" flown can be a percentage above Vbr while accepting a predicted range loss. Range decreases more and more as IAS is increased. 1.07 Vbr still gives .99 SR; 1.11 gives .98; 1.16 gives .96 (Table 2); 1.26 gives .90; and 1.316 (Carson speed) gives .86 . A Bonanza has very long legs at 1.16 Vbr, if you have the patience.

In stable cruise flight, IAS is an index of thrust as well as drag. Thrust is a force, and does no work unless exerted over a distance. In table 3 below, that distance, over one hour, is TAS. At the same IAS and weight, fuel flow is proportional to TAS, and fuel to cover a distance the same, for any altitude (Table 3). Higher altitude is faster, but range is unchanged. Angle of attack here is constant.

Density altitude	KIAS	KTAS	nam/g	GPH	flying 200nm:
15,000'	130	164	13.37	12.3	1:13 on 15 gal
10,000'	130	151	13.37	11.3	1:19 on 15 gal
5,000'	130	140	13.37	10.5	1:26 on 15 gal

Table 3. V35TC, Lean of peak EGT.

It's important to realize at constant power, IAS decreases with altitude, while TAS increases- but in Table 4 below, why do TAS and nam/g fall at 24,000 feet at 10 gal/hr? The reason is that 92 KIAS is below the aircraft's Vbr. At IAS above Vbr, extra parasite drag reduces range; below Vbr, more induced drag reduces TAS and range. Here, at 24,000 feet, more power (11.8gph) is the solution, and is available, compliments of turbo-charging.

Density altitude	KIAS	KTAS	GPH	nam/g
24,000	117	172	11.8	14.6
24,000	92	134	10	13.4
16,000	113	144	10	14.4
8,000	125	140	10	14.0
SL	134	134	10	13.4

Table 4. V35TC POH, 3400 pounds, Lean of Peak EGT.

Accepting that there are benefits of cruising at higher density altitudes, what about the fuel cost to get up there? **Rate of Climb = Excess Brake HP X prop efficiency X 33,000/aircraft wgt.** (maintaining same IAS). Which means: all excess thrust HP over that needed for level flight at the same IAS will go into lifting the airplane. Likewise deficit power will result in descent. Climbing and descending LOP while maintaining a target IAS/Vbr for weight, for each segment, can recover a good part of the extra fuel for the climb, as range, at the lesser weight of the aircraft on descent. There are losses to prop efficiency and to increased airframe drag from propeller airflow, both more on climb than descent.

For range, consider this sequence: Take off, initial climb: full power ROP and Vy, to clear terrain and weather. Then, reduce pitch, accelerate to "target IAS", reduce RPMs and go lean of peak EGT. Now, faster, leaner, cooler, you are efficient with less hurry to get to cruise altitude. Normally aspirated, a step climb, or drift-up climb can work well. Turbo aircraft might go all the way up LOP without pausing to reduce fuel weight. Coming back down, start earlier, use target IAS, at peak or LOP EGT. Remember that climb performance isn't just about fuel and time to Top of Climb, but also distance downrange and cylinder head temperatures (CHT).

<u>Constant AOA or Target IAS</u>: Basically the same; this means gradual IAS reduction with fuel burn-off while NAM/gal increases. There are 2 ways to reduce IAS: power reduction, or **climbing** to a higher altitude. Constant AOA gives better range than a constant speed or constant power technique, especially when fuel is a high proportion of weight, like when tanked to 227 gallons, below.

<u>Cruise profile at a 1.16 multiple of Vbr</u> (15,000 feet, LOP, 227 gallons, no wind, V35TC)

	totals			next leg					"target	
weight	gal	time	nm	gal	time	nm	SR	gph	kias"	ktas
3800	0	0	0	6	:09	15		31	120	125
Taxi, take-off, ROP climb to 5000ft										
3764	6	:09	15	10	:33	87		17	137	158
Transition to LOP, climb to 15,000ft										
3704 TOC	16	:42	102	17.3	1:14	212	12.28	14	137	172
3600	33.3	1:56	314	33.4	2:34	434	12.97	13	134	169
3400	66.7	4:30	748	33.3	2:48	459	13.73	11.9	130	164
3200	100	7:18	1207	33.4	3:04	488	14.59	10.9	126	159
3000	133.4	10:22	1695	33.3	3:22	519	15.52	9.9	122	154
2800	166.7	13:44	2214	33.3	3:42	549	16.67	8.9	118	148
2600	200	17:26	2763	27	3:22	481	17.95	8	114	143
2438	227	20:48	3214							

Table 5. Take off and climb to 5000 feet, full power, ROP; climb to 15,000 feet LOP, 17 gph and 137kias; cruise at 15,000 feet with power reduction as each 200 pounds of fuel is consumed. TOC= Top of climb. E6B converts target IAS to TAS. Gal X SR= nm. Nm/ktas= leg time. Special Flight Permit for 10% overweight operation.

Advantages of LOP operations include lower CHTs and internal combustion pressures, cleaner engine, better range, and an elegant fit with turbo-charging. When LOP, there's more air than fuel, so just fuel flow determines power. Turbocharged aircraft like the V35TC commonly have a lower, less efficient, engine compression ratio to increase detonation margins, while turbo-normalized aircraft instead have an intercooler for the induction air as a better solution. With turbo-normalizing, 85% power at 100 deg LOP is an accepted cruise practice. That sounds contrary to good range technique, but not necessarily: Power stays proportional to LOP fuel flow, while high altitude can keep the IAS close to Vbr, which preserves range performance.

Fuel consumed to waypoints is a critical part of an oceanic flight plan, derived from forecast winds and known aircraft TAS/ff changes with fuel burn-off. Typically 110% destination plus alternate fuel is carried, plus 45-90 minutes holding fuel. Crossing oceanic waypoints with consumption beyond the 110% estimate is an early clue to turn back. Fuel meter linked to the GPS gives fuel at destination, a **false** assurance in that there is no input for the wind to be encountered further downrange. Progress should be judged against the flight plan, which has those wind forecasts factored in.

<u>Wind</u>

Some pilots believe it's a good strategy to speed up in a headwind, but that only makes sense if the flight is at Vbr, which isn't likely. The rule of thumb for range is to increase IAS over Vbr by 1/3 or 1/4 of the headwind component. Normally, Bonanzas are cruised well above Vbr, so slowing is more likely. Lower altitude might reduce the headwind component.

<u>Bottom Line</u>

Max range is at Vbr, LOP, at the altitude giving the best wind component. If time is of importance (as it always is), altitude offers higher TAS, which must be reconciled with winds. Fuel available can be balanced between using higher target IAS/Vbr and maintaining prudent reserves.