Best time to your destination: fly as high as possible?

Marcus Bicknell analyses the optimum flight levels of high performance light aircraft

After years of pottering about in club Cherokees there comes a moment in a private pilot's career when the opportunity to fly a faster aircraft presents itself. Years of saving, a windfall on the stock exchange or a massive inheritance… it does not matter. The issue is, can I fly higher, faster? Can I get that instrument rating? Can I handle the machine-gun radio when climbing out under instruction from London Air Traffic Control? Can I master the waypoints of Europe's upper airspace?

In my own case I flew a Mooney 231 turbo of my own for six years: Flight Level 240 was the ceiling, so that's where I headed whenever possible, canulas screwed to my nostrils to keep my brain from frying, wondering whether the ice on the inside of the windows would ever come off. As the family got bigger and the post-flying migraines deepened, my mind turned towards something more middle-aged, and maybe even faster.

So since January 1999 I have flown 150 hours in my 1997 Piper Malibu Mirage PA46-350 out of Wycombe. I have the pressurisation to ease the pressure on the body. I have 350 HP and twin turbos to provide 205 knots true at Flight Level 250. I have de-ice boots, hot prop, heated windscreen, weather radar, stormscope, rate of climb select, altitude pre-select, Garmin 430 GPS slaved through the Sandel glass HSI to the autopilot, and SkyWatch Traffic Collision Advisory System. 6 seats, air-conditioning, a little table and a CD player for the kids. It's all bliss.

Now comes the serious bit. We all know a plane goes faster the higher you fly. Some of us take into consideration the engine's critical altitude when the power starts to drop off.

But does it really make sense to take the aircraft to its ceiling on every flight?

In favour of flying as high as possible…
1) Get above nasty weather, both ice and storm build-ups,
2) Seek out the jet stream if it's favourable in direction,
3) Benefit from the higher cruise speed,
4) More time to assess options and glide to an airport in the event of engine failure in a single-engined aircraft, and
5) Some more direct routes in the Upper Airways.

In favour of flying lower when the higher cruise is not going to save much time…
1) Better engine care; lower altitudes for most engines mean less heat and longer TBO time,
2) If that IR clearance is subject to delays maybe you can depart VFR,
3) Less risk of explosive depressurisation of the aircraft,
4) Less time to descend in the case of an engine fire or other time-critical emergency,

5) Less cycles of the pressurisation and depressurisation of the fuselage which is known to reduce the life of the fuselage, and

6) Less hassle (if you have an unpressurised aircraft) filling up the oxygen bottles and putting on canulas or masks.

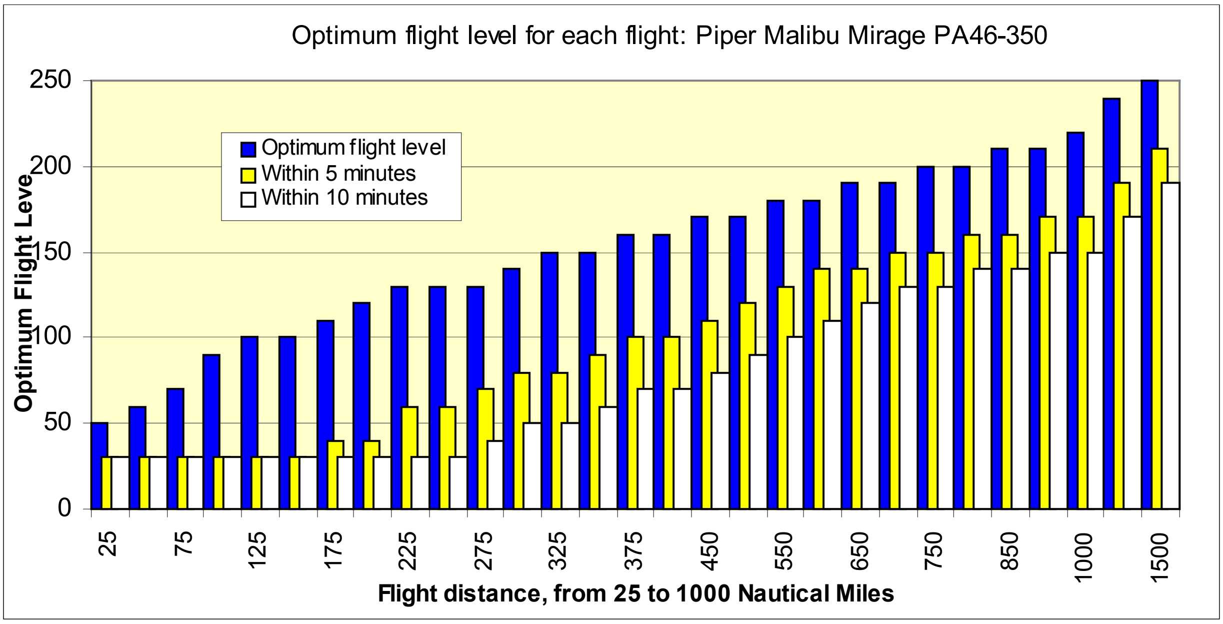
It's your call. But at the least you would like to know if the **optimum** cruising altitude (the altitude which gets you to your destination fastest) is in fact less than the aircraft's ceiling, then you can make an informed judgement. The optimum cruising altitude depends on the length of the flight. Well, how long does the flight have to be? It also depends on the rate of climb and your speed in the descent. Look in the Pilot's Operating Handbook and try to work it out.

So I constructed an Excel model to tell me the optimum flight level for a flight of any distance. E-mail me at mbicknell@compuserve.com to get a working copy. The results are quite revealing. For example:

✈ Unless the Malibu is going to fly **further than 450 nautical miles** (from London that's Bordeaux, Lyon, Zurich, Munich, or Hamburg) you are not going to get there any quicker by going higher than **FL170.**

✈ For trips **of 600 nautical miles** (Barcelona, Nice, Venice, Prague, Oslo) you still only need **flight level 180.**

✈ Even for such a long trip, **FL110 would only be ten minutes slower.**



Graph 1

Graph 1 shows the optimum flight level (i.e. the level at which you get to your destination quickest) for journeys 25 to 1500 nautical miles long (not to scale).

For example the graph says that for a trip of 1000 NM you still only need to chose FL 220… the Malibu's ceiling of FL 250 is not going to get you there faster! It also shows that for this same trip of 1000 NM, you could get there only 5 minutes slower by taking FL 170, or ten minutes slower at FL 150. Only when you're going to fly 1500

NM would it make sense, all other things being equal, to fly at the service ceiling of the aircraft… but the endurance of the Malibu with IFR reserves at 22 gph U.S. in the cruise is only 1000 NM anyway.

The Model and my Assumptions

Why is this the case, and what assumptions have I built into the calculation?

1	**Calculation of optimum cruise altitude dependent on distance of journey**													
2								**Piper Malibu Mirage PA46-350**						
3	Insert altitude of departure aerodrome in feet AMSL					500								
4	Insert altitude of destination aerodrome in feet AMSL					0								
5	Insert total trip distance in Nautical Miles					300								
6	**Optimum Flight Level (calculated below)**					160								
7														Etc.
8			Flight level in the cruise (hundreds of feet)											
9	Cruise level		30	40	50	60	70	80	90	100	110	120	130	140
10	Climb speed (KTAS)	115												
11	Rate of climb (fpm)		1200	1150	1100	1050	1000	950	900	950	900	850	800	750
12	Time to climb (mins)		2	3	4	5	7	8	9	10	12	14	16	18
13	Distance to climb (NM)		4	6	8	10	12	15	18	19	22	26	30	35
14														
15	Cruise speed (KTAS)	65%	151	154	157	160	163	166	169	172	175	178	181	184
16	Cruise distance (NM)		286	280	274	268	261	254	247	241	234	225	216	207
17	Time in the cruise (mins)		113	109	105	100	96	92	88	84	80	76	72	67
18														
19	Descent speed (KTAS)		168	171	174	177	180	183	186	189	192	195	198	201
20	Rate of descent (fpm)	800	800	800	800	800	800	800	800	800	800	800	800	800
21	Time to descend		4	5	6	8	9	10	11	13	14	15	16	18
22	Distance to descend (NM)		11	14	18	22	26	31	35	39	44	49	54	59
23														
24	Total elapsed time		119	117	115	113	111	110	108	107	106	104	104	103
25	Cruise level		30	40	50	60	70	80	90	100	110	120	130	140
26	Optimum time		102	minutes										
27	Optimum flight level		160											
28														
29	Cruise Distance (NM)		25	50	75	100	125	150	175	200	225	250	275	300
30	Optimum flight level		50	60	70	90	100	100	110	120	130	130	130	140
31	Lowest level within 5 minutes		30	30	30	30	30	30	40	40	60	60	70	80
32	Lowest level within 10 minutes		30	30	30	30	30	30	30	30	30	30	40	50

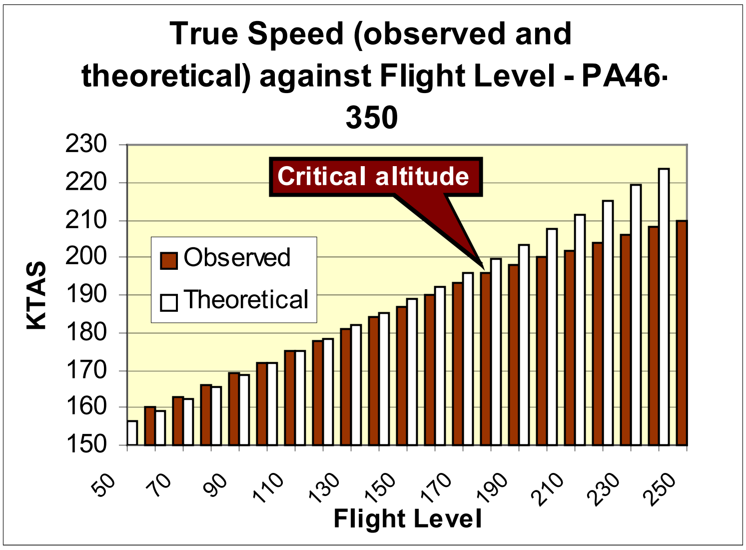
This is just an excerpt from the spreadsheet which is available on request (mBicknell@compuserve.com).

1) The model divides the flight into its three sections; climb (lines 10 to 13), cruise (15 to 17) and descent (19 to 22). It assumes you can start climbing immediately after take-off. For a typical departure from the London area this is pretty rare, so bear in mind that your optimum level is likely to be lower than the model shows.

2) Climb. The model also assumes a "real" climb rate, not the manufacturer's book climb rate. For example, in the Malibu you can certainly pull 1200 feet per minute for the first few minutes, but in a long climb to the flight levels the need to keep temperatures down, and the need to look after the engine, take precedence. I have taken 1000 feet per minute in the example, and 100 KIAS climb speed. You can put in the value for the rate-of-climb (line 11) and climb speed (line 10) for your own aircraft.

3) Cruise. The true airspeed (line 15) at each flight level is brought forward from a spreadsheet which allows you to correct the rule-of-thumb speed according to your observations in your actual aircraft (for example at flight levels above your engine's critical altitude when power drops off, Graph 2).

Graph 2

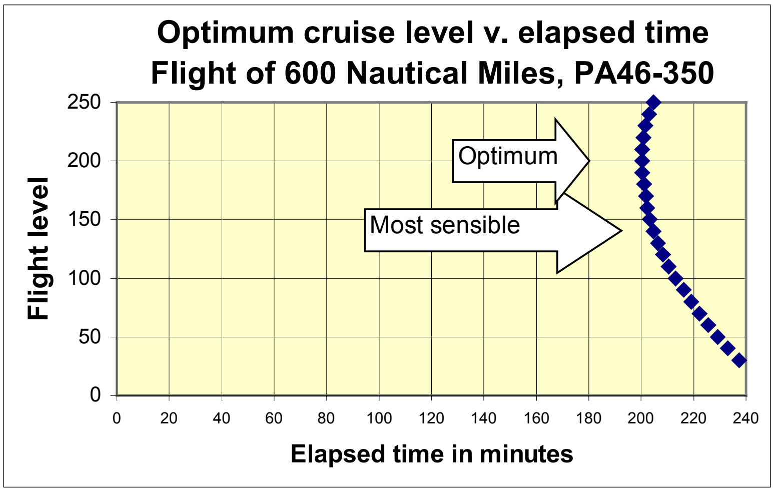


4) Descent. Both the descent speed and the rate of descent can be entered as averages (lines 19 and 20), in my case 200 KIAS (not adjusted for KTAS) and 700 feet per minute.

5) Total time. When you insert the total trip distance (line 5) then Excel calculates the time for the trip for each of the flight levels (line 24) and then selects for you the optimum flight level (line 27, repeated in line 6).

The Results

Graph 3



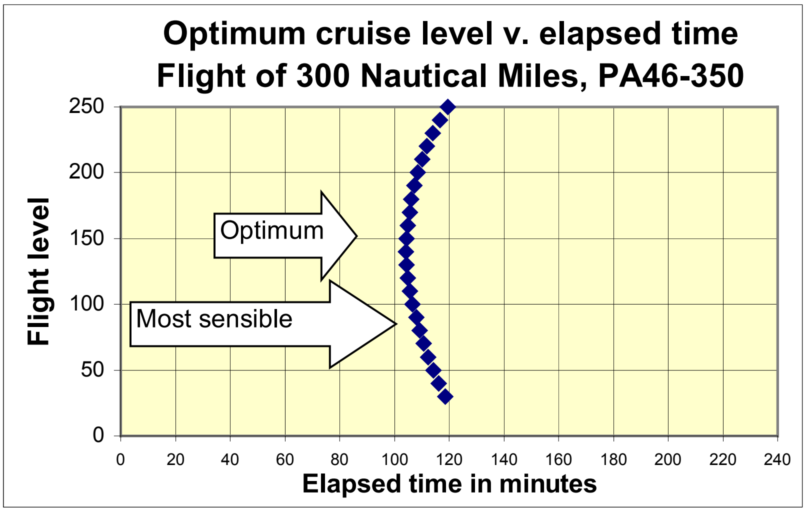
In Graph 3 alongside, the elapsed time of the trip in minutes is plotted against the flight level selected, for a trip of 600NM in the Malibu. The *"optimum"* flight level (FL200 for this trip) is the quickest way of completing the trip. But at FL140 you are going to get there within 5 minutes of the quickest time, which over 3 hours flying is not that significant. So I call it the *"most sensible"* Flight Level.

Between ground level and FL150 there is a more-or-less linear relationship between FL and time. But above FL150 (the most sensible flight level to choose) there is a marked drop-off in advantage.

In Graph 4, for a trip of 300NM, the curve is more pronounced and the result more evident.

There is no doubting that about FL150 is the quickest, but FL80 is only 5 minutes slower.

Graph 4



Work it out for your own aircraft

The last part of the exercise is to plot the optimum flight level for any distance of trip. You can put in the assumptions for your aircraft and keep the chart near your flight planning stuff. Or maybe the guys from NavBox could work it into the options of their excellent flight planning software. My Excel skills found their limit here, so lines 29 to 32 of the worksheet are calculated by running the model for each distance and typing in the flight level.

The result in Graph 1 is conclusive. Between 300 and 450NM there is no point in flying at any level other than FL 150 or160 in this aircraft (winds, clouds and other factors being equal).

Graphs 3 and 4 look as though the critical altitude of the engine is an important factor. The power drop off above FL160 would account for the flattening of the curve between 300 and 450NM.

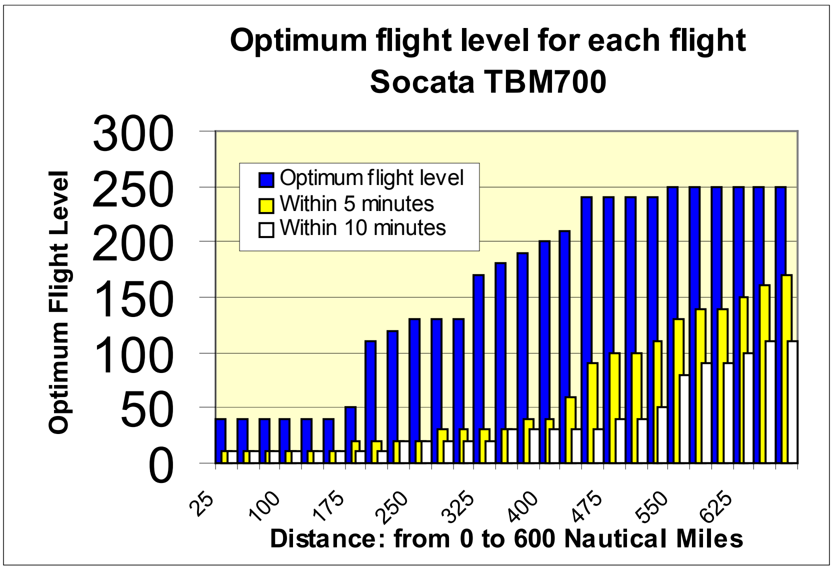
To perfect the model I will send this off to the Piper factory to see if an engineer can give me the formulae for the power of normally aspirated and turbo-charged piston engines at above their critical altitude (unless some high-powered reader would like to wade in).

In any case, a real aeroplane, well-maintained but handled with engine life in mind, does not perform by the manufacturer's figures. And when that is the case, it does not reduce journey times by as much as you would.

Is the Malibu an isolated case? I do not think so.

Turboprop single: the SOCATA TBM700

Graph 5



The TBM700 is a hefty and powerful turbo-prop of similar shape and equipment as the Malibu. It is an interesting performance reference point for the forthcoming Piper Meridian, the Malibu with a turboprop on the front.

The TBM has startling climb performance, averaging 2000 fpm up to its ceiling of 30,000 feet. This is the principal reason why it is worth selecting 25,000 feet for the cruise for journeys as short as 475 NM (Graph 5). But even more remarkable that it performs so well at low level that you would fly those 325 NM only 5 minutes slower at FL90.

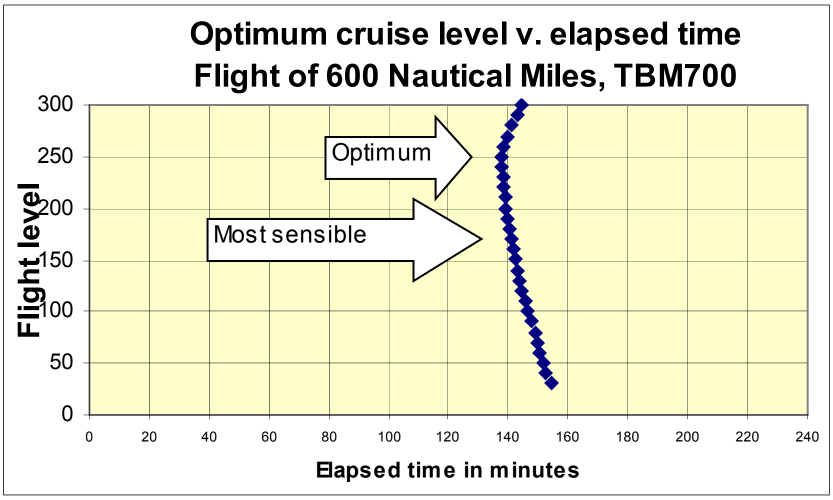
The TBM700 Pilot's Information Manual shows up an anomaly. The true airspeed of the aircraft drops off above 25,000 feet at all engine settings and weights except at ISA –20°. So if you fly in the Artic Circle a lot, this is the plane for you, and you should fly it high!

My assumptions are the same as with the Malibu, except that the figures are manufacturer's figures. When I can get some observed figures on the TBM700 I will rework the calculations.

1	**Calculation of optimum cruise altitude dependent on distance of journey**													
2									TBM 700					
3	Insert altitude of departure aerodrome in feet AMSL					500								
4	Insert altitude of destination aerodrome in feet AMSL					0								
5	Insert total trip distance in Nautical Miles					600								
6	**Optimum Flight Level (calculated below)**					250								
7														
8			Flight level in the cruise (hundreds of feet)											
9	Cruise level		30	40	50	60	70	80	90	100	110	120	130	140
10	Climb speed (KTAS)	130												
11	Rate of climb (fpm)		1000	2425	2410	2395	2373	2350	2300	2250	2200	2150	2100	2050
12	Time to climb (mins)		3	1	2	2	3	3	4	4	5	5	6	7
13	Distance to climb (NM)		5	3	4	5	6	7	8	9	10	12	13	14
14														
15	Cruise speed (KTAS)		235	238	240	242	244	246	249	252	255	258	261	263
16	Cruise distance (NM)		586	586	582	578	575	571	567	563	559	555	551	547
17	Time in the cruise (mins)		150	148	146	143	141	139	137	134	132	129	127	125
18														
19	Descent speed (KTAS)	200												
20	Rate of descent (fpm)	1200												

21	Time to descend	3	3	4	5	6	7	8	8	9	10	11	12
22	Distance to descend (NM)	8	11	14	17	19	22	25	28	31	33	36	39
23													
24	Total elapsed time	155	152	152	151	150	149	148	147	145	144	143	143
25	Cruise level	30	40	50	60	70	80	90	100	110	120	130	140
26	Optimum time	138 minutes											
27	Optimum flight level	250											
28													
29	Cruise Distance (NM)	25	50	75	100	125	150	175	200	225	250	275	300
30	Optimum flight level	40	40	40	40	40	40	50	110	120	130	130	130
31	Lowest level within 5 mins	10	10	10	10	10	10	20	20	20	20	30	30
32	Lowest level within 10 mins	10	10	10	10	10	10	10	10	20	20	20	20

Graph 6

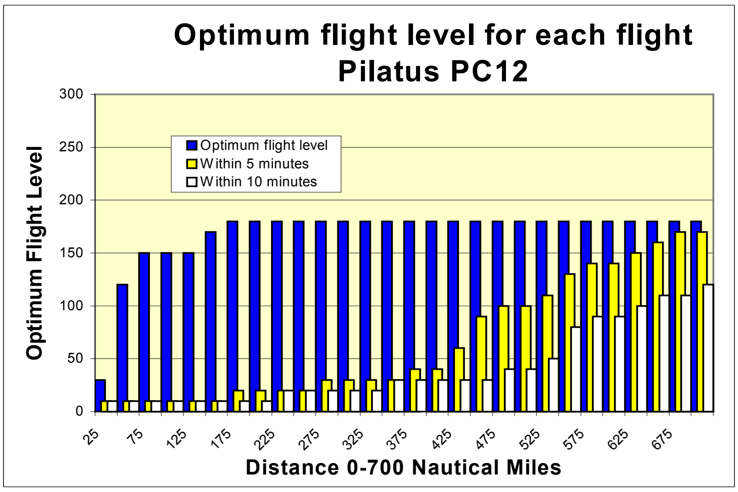


The graph of the journey time against selected flight level (Graph 6) shows a similar picture as the Malibu. The curve is less curved because of the aircraft's good performance at low levels.

For this 600NM trip to Cannes, my principal objective (if I bought one) would be fastest at FL250 but only five minutes slower at FL 170.

The Pilatus PC12

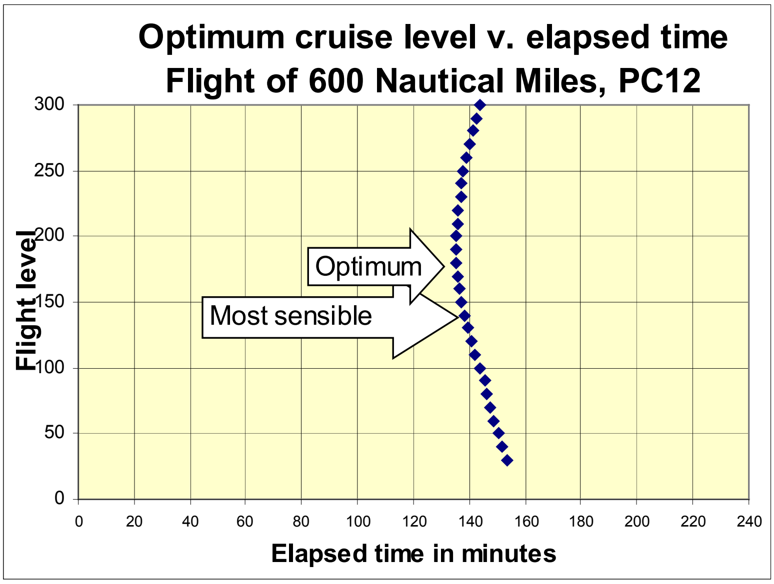
Graph 7



The PC12 is bigger than the other two aircraft but has the same engine as the TBM 700 and the forthcoming Malibu Meridian.

The most remarkable feature of the performance figures in the PC12 Pilot'sOperating Handbook is that the maximum speed of 271 KTAS is reached as low as Flight Level 180. So however far you want to fly you are not going to get there quicker even if you fly higher than Flight Level 180 (graph 7). I am referring to Cruise speed by the book at "maximum cruise power", ISA –10°.

We hear the Meridian will also reach 270 KTAS. The TBM700 book, by comparison claims max speed of 296 KTAS at FL 250 (graph 5), i.e. it goes on getting faster as you climb above FL 180. Some pilots I have spoken suggest that the TBM figures might be “factory theoretical” rather than measured. I hope to be able to obtain some demonstrated in-flight figures for the various aircraft to be able to compare like with like.



The Piper Malibu PA46-350 needs its ceiling of FL250 to get to its maximum speed of 210 KTAS.

So the PC12’s optimum cruise level for a 600 NM trip (in fact for any trip over 150 NM) is Flight Level 180 (no higher of course). And at FL140 you will be there only 5 minutes faster.

Conclusions

The conclusions are yours to make. But like many disciplines in flying it is worth thinking things through yourself. Just because your plane can fly high, don’t assume you need to fly at its ceiling on every flight. I have pointed out on the first page the other arguments in favour of flying high, like weather avoidance. You will use your own criteria in decision-making. But at least I will have made you consider the other factors.

Highest is not always quickest! Fly safely…

Marcus Bicknell

Please e-mail me your words of wisdom so that I can knock this into shape and hopefully make it useful. My e- mail address is mBicknell@compuserve.com

30th August 2000

Subsequently published in the newsletter of the PPL/IR group and MMOPA magazine (Malibu and Mirage Owners and Pilots Association)

\c\My Documents\Word\MB personal\Aviation\Optimum flight levels V4 0800.doc