MiG-23ML Flight Model & Performances Identification

CREDITS - I particularly wish to thanks:
Mr. Tom Cooper (ACIG.info) for the fact that he has been the founder and leader of the ACIG working group, strongly stimulating its members by his considerable knowledge of military aerospace, and especially the history of this aircraft.
Mr. Mihai Vălceleanu for his patient and deep reading of the different drafts of this document and all the corrections, suggestions and comments he provided.

Table of Content

A. Purpose and scope.

The object of this piece of work is to identify a Flight Model for the MiG-23ML (izd.23-12A, also known as MiG-23MLA) powered by the Khatchaturov R35 turbojet engine that entered production in 1978 and is said being part of the second generation of MiG-23.

The performances of the MiG-23 that will be described here can be considered as the one of most MiG-23 of this second generation: izd.23-12A, izd.23-19B, and izd.23-22B. The planes of these different types can be named MiG-23ML, MLA or MLD depending on their operators and equipment, without strict relation between the Izdeliye and the version name (ML, MLA, MLD).

But there is an exception: some MiG-23MLD received aerodynamic improvements: additional saw tooth, vortex generators, replaced SOUA, Leading Edge Flaps used for maneuvering flight, new sweep wing angle value of 33 degrees instead of 45… that increase their performances. These planes are identified as izdeliye 23-18 and are mostly retrofitted from izd.23-12A, 19B or 22B airframes. The performances of this particular type is not documented as far as I know and will not be covered by this study. It seems that very few of them have been operated outside soviet air force (VVS).

In short, this document describes performances of all MiG-23ML, MLA and MLD but izdeliye 23-18.

This identification consists mainly in defining Lift and Drag coefficient laws as well as Thrust laws.

These data thus allow to build a performance model, using templates and conventions common to a set of aircraft to be compared, and mainly inspired by the Performance appendix of the US NATOPS manuals. The performance charts are available at the end of this document.

Then, it becomes possible to compare the performances of the MiG-23ML to other documented aircraft, focusing on close air combat capabilities.

The main candidates for such a comparison are the MiG-23ML's main opponents in the 1976-1988 [1] period, opposing Israeli and Syrian Air Forces during the Yom Kippur War on one hand, and opposing Iranian and Iraqi Air Forces during the first Persian Gulf War (IPGW) on the other.

I will first focus on already documented Israel's IAI Nesher and McDonnell Douglas F-4E blk41 and blk50 (without and with leading edge slats), and to the very close Iran's F-4E blk54/57.

In addition, the MiG-21bis can be considered in order to illustrate the benefits of the MiG-23ML over the last evolution of its standard predecessor in most Arabic air forces.

Lastly, the IPGW conflict will drive to build a comparative study of the MiG-23ML versus the Iran's F-14A (that I've still not identify a performance model allowing such comparison)

B. General data Collection

- Configuration

As the main focus are close-air-combat performances, I will focus on the so called "combat configuration", that is, a plane with half of its internal fuel, gun with full ammunition load and short range missiles.

The closest standard documented configurations are

- Four R-3S (AA-2 Atoll), one under each wing and two under the fuselage each with BDZ-60-23 (БДЗ-60-23; sometimes written BD3-60-23) pylons and APU-3S launching rails.
- Two R-3S, one under each wing with BDZ-60-23 pylons and APU-3S launching rails.
- Two R-3S under fuselage with BDZ-60-23 pylons and APU-3S launching rails.
- Two R-24, one under each wing with APU-23M1 (АПУ-23M1 or APU-23M1 for Soviet MiG-23ML, АПУ-23M1-Э or APU-23M1-E for export MiG-23ML) pylons

Other configurations also need to be taken into account: a configuration with four R-60 (AA-8 Aphid), or R-60M or R-60MK, equivalent in term of drag, but lighter; and one with two R-60M/MK under fuselage hard points and two R-24R, R-24T, R-23R or R-23T (AA-7 Apex), one under each wing, the most common configuration for Iraqi MiG-23ML between 1984 and 1987; and lastly, the one with two R-60M/MK, one R-24R/T and one ECM Remora pod, Iraqi standard configuration in 1987-1988.

An operational MiG-23ML will never be loaded with R-3S, sometimes with R-13M, but most of the time with R-60M/MK, so analysis of configurations with R-3S, APU-3S and BDZ-60-23KI/ML will take place only to define weight and balance of the chosen combat configuration (see above)

- Weight and Balance

The starting point is the documented take-off weight of 14,270 Kg for the MiG-23ML with

- 100% of internal fuel
- two BDZ-60-23KI wing pylons,
- two BDZ-60-23ML wing pylons
- one centerline pylon (name unknown)

14,670 Kg with addition of four R-3S and their launching rails.

14,806 Kg with addition of 2 R-24 (no launching rails required).

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[1] MiG-23 first flight occurred in June 1967. MiG-23M appeared in 1972. The MiG-23ML program was approved by a Soviet government decree in January 1974, and the first flight of the MiG-23ML took place on January 21, 1975, under the control of test pilot A.G. Fastovets.

The weight of the APU-3S launching rail is generally assumed to be 25 Kg each and of the R-3S missile 75 Kg each, so the weight of four rails and four missiles is assumed to be 400 Kg, which does fit the difference between the documented take-off weights of the two configurations.

The weight of BDZ-60-23KI and BDZ-60-23ML pylons is unknown but needs to be estimated as two of them have to be replaced by two APU-23M1 (pylon for R-23/R-24 missile that does not require any launching rail), weight of which is also unknown…

The centerline pylon weight is said being 25kg and it is included in all configurations that weight is documented, including the "zero fuel clean configuration" (here, clean means no weapons neither wing pylons nor rails).

The internal fuel capacity of the MiG-23ML is not clearly indicated, but is generally assumed to be 3,700 Kg.

So, we have an estimation of the zero-fuel weight of the MiG-23ML with four BDZ-60-23 of 10,570 Kg. If we also estimate the BDZ-60-23 at 25 Kg each, we can consider the zero-fuel weight of the MiG-23ML without pylons or weapons being 10,470 Kg.

The R-60 missile weight (or R-60M or MK or any known variant) is assumed to be 45 Kg and its APU-60-IM launching rail weight 35 Kg.

An average estimation of R-24 missile weight is 240 Kg (between 238 and 245kg) and its APU-23M1 pylon weight is estimated to be 53 Kg. The R-23 is supposed to be lighter (between 217 and 223 kg), so the R-24T will be kept as a reference.

The combat weight with four R-3S would then be 12,820 Kg or 28,300 lbs. (this is independent of the estimation of the BDZ-60-23 pylon weight)

• zero fuel clean weight	10,470 Kg
• 50% of the internal fuel	1,850 Kg
• 4 x BDZ-60-23	100 Kg
• 4 x APU-3S	100 Kg
• 4x R-3S	300 Kg

The combat weight with four R-60M/MK would then be 12,740 Kg or 28,124 lbs. (this is independent of the estimation of the BDZ-60-23 pylon weight)

• zero fuel clean weight	10,470 Kg
• 50% of the internal fuel	1,850 Kg
• 4 x BDZ-60-23	100 Kg
• 4 x APU-60-IM	140 Kg
• 4 x R-60M/MK	180 Kg

The combat weight with two R-60M/MK (fuselage) and two R-23R/R-24R (wing) would then be 13,116 Kg or 28,954 lbs.

• zero fuel clean weight	10,470 Kg
• 50% of the internal fuel	1,850 Kg
• 2 x BDZ-60-23	50 Kg
• 2 x APU-60-IM	70 Kg
• 2 x R-60M/MK	90 Kg
• 2 x APU-23M1	106 Kg
• 2 x R-24R/T	480 Kg

Remora pod and its pylon are not two separate devices, as the pylon includes the cooling air intake and circuitry of the pod. The Remora alone weight, whichever version (DB-3141 or DB-3163) is around 86Kg. With its integrated pylon, the total weight is said to be 175 Kg (so 89 Kg for the pylon with its cooling system).

The remora pod is mounted under the right fuselage station instead of one R-60, its rail and its pylon.

The combat weight with one R-60M/MK (one fuselage station), two R-23R/R-24R (wing stations) and one Remora ECM pod (the remaining fuselage station) would then be 13,186 Kg or 29,108 lbs.

• zero fuel clean weight	10,470 Kg
• 50% of the internal fuel	1,850 Kg
• 1 x BDZ-60-23	25 Kg
• 1 x APU-60-IM	35 Kg
• 1 x R-60M/MK	45 Kg
• 2 x APU-23M1	106 Kg
• 2 x R-24R/T	480 Kg
• 1 x Remora	175 Kg

In all cases, remaining fuel quantity is 1,850 Kg (4,084 lbs) or close to 2,300l

Since the two last payload configurations are very close in weight, it will be a bit more difficult to estimate the payload Drag of the Remora pod, so we will keep as the standard Close-Air-Combat configuration the following one:

• zero fuel clean weight	10,470 Kg
• internal fuel	1,734 Kg
• 2 x BDZ-60-23	50 Kg
• 2 x APU-60-IM	70 Kg
• 2 x R-60M/MK	90 Kg
• 2 x APU-23M1	106 Kg
• 2 x R-24R/T	480 Kg
• Gross Weight	13,000 Kg

The weight difference between this new reference configuration (GW=13,000 kg / 28,698 lbs, 2xR-24, 2xR-60) and the one with 50% fuel and 2xR24+2xR60 is 116 kg (256 lbs), in combat configuration at medium altitude (let say M0.75 and 15,000ft), the average fuel flow is around 40,000 lbs/h (see here), and so the 256 lbs are burned in less than 25s…

This confirms that this new reference configuration is able to describe MiG-23ML performance at what is usually called the Combat weight (close to 50% of internal fuel) and the two regular weapon configurations used by the Iraqi Air Force between 1984 and 1988. In this document, this configuration may appear as AA3.

For specific purpose, mainly flight model characterization, we will also use a "clean" configuration of the MiG-23ML (without any external loadout) which gross weight is set to 12,500kg. In that case we will investigate behavior with and without the activation of the AoA limiter system (the SOUA). In this document, these configurations may appear as AA1.

- Wing sweep angle.

The variable wing sweep angle is one of the main characteristic of the MiG-23. This device allows the pilot to choose the wing sweep angle between 3 values, for the particular type studied here (izd.23-12A), these values are 16, 45 and 72 degrees.

For all performances measured with a load factor close to one (level flight acceleration or constant speed climb) and especially in supersonic regime, a sweep angle of 72 degrees will be usually chosen.

For higher load factor, it is recommended to select the sweep angle of 45 degrees. But, at low speed (Mach number lower than 0.75) and moderate load factor (less than 4.5G), a sweep angle of 16 degrees may provide better performances.

It must be notice that this value can only be modified load factor up to 4.0G. This is very dimensioning in term of air combat performance, as it means that a MiG-23 pilot cannot change its wing sweep angle during an air combat. He can choose with which plane he will fight, but once chosen, he has to keep it to the end (with all limitations related to the chosen configuration)

Wing sweep angle and reference area: in "Applied Aerodynamic study…" page 14, table 1.4, a particular reference area value is indicated for each wing sweep angle value: 37.27m^2 for X=16°, 35.30m^2 for X=45°, 34.16m^2 for X=72°.

But it is also stated at page 8 that, for all computations (or drag, lift…), only the 34.16m^2 value must be taken into account.

- Speed limitations.

Maximum Indicated speed is 1,400 Km/h (756 Kts). As I do not have precise indication of speed indicator error, I consider this limit as a Calibrated Air Speed (CAS) limit.

Maximum Mach number is said to be 2.35, but 1.95 (or M2.0 for 5 seconds) when R-3S are carried. When R-60M/MK are carried by other aircraft (such as MiG-29G), Mach number is not limited (up to M2.35), which seems to indicate that the M2.0 limitation of the R-3S is related to its old generation IR seeker and does not affect missiles such as R-60 or R-24T.

For all configurations with R-3S, speed is limited by 1,400 Km/h – 756 Kts CAS or Mach 2.0 whichever less.

For all configurations without load or with R-60 or R-23R, speed is limited by 1,400 Km/h – 756 Kts CAS or Mach 2.35 whichever less.

Mach number is even more limited when wing sweep angle is set to 16 degrees, values mentioned are M0.74-0.77-0.80, so in all cases, wing sweep angle is assumed to be 45 or 72 as soon as Mach number is greater than 0.80.

As the flaps are said to be used only in take-off and landing conditions, and never in combat, I will not consider them in any case to determine combat performances.

- Load Factor limitations.

The text of "Applied Aerodynamic study…" document on the MiG-23ML does not provide clear description of the load factor limitations, but only the following:

For Mach number (M) lower than 0.85, load factor is limited to 8.5, above 0.85, limit is 7.5

At page 216, the table 6.1 give all load factor limitations for MiG-23ML at a weight of 13,050 kg and MiG-23UB at 13,700 kg in air-to-air weapons configuration (most left column)

In addition, at page 220, the figure 6.2, give MiG-23ML and MiG-23UB load factor at gross weight of 13,000 kg and 14,000 kg and sweep angle of 45° (and an altitude of 1,000m).

For the MiG-23ML at 13,000kg, limit is 8.5G, at 14,000kg limit is 7.5G

For the MiG-23UB at 13,000kg, limit is 8.0G, at 14,000kg limit is 7.0G

And lastly, we have to remember that these limitations are only prescriptions for the pilot and that there is no device to enforce them automatically.

In mixing all these data, I would propose the following limitations for gross weights of 13,000 Kg or lower, that cover the combat configurations studied here.

Wing sweep angle	M<=0.85	M>0.85
X = 16°	Ngz < 6.5	(not applicable)[2]
X = 45°	Ngz < 8.5	Ngz < 7.5
X = 72°	Ngz < 8.5	Ngz < 7.5

- Angle of attack limitations.

The MiG-23ML (and the MiG-23UB) has an angle of attack limiter coupled with a yaw damping system (the SOUA or COYA, transcription). When AoA reaches values close to the limit, it does push the stick forward to prevent overshoot.

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[2] As it is not allow to fly above M0.8 with wing swept at 16°, a load factor limitation for this wing configuration at Mach above 0.85 has just no meaning

The SOUA/СОУА system limit the AoA depending on wing sweep angle, but also depending on the working mode of the SAU-23AM system.

When SAU-23AM system is set to "Демпфер" mode, it eliminates sideslip and improves directional stability at high AoA, allowing the aircraft to be used to its full capability. Maximum allowed AoA, with the SAU-23AM in "Демпфер" mode operating, is increased by 3° - 5° due to this. See "Applied Aerodynamic study…" page 147.

It must be also notices that SOUA/СОУА system is not a strict limiter, the system only "push" the stick forward when maximum allowed AoA is reached, with a force of 18kgf, if the pilot pull the stick more than 18kgf, maximum allowed AoA can be exceeded (especially in case of dive recovery).

In this study, our purpose is to document MiG-23 performance in "combat configuration", and this imply SAU-23AM set to "Демпфер" mode and SOUA activated.

Nevertheless, one can often read that AoA limiters purpose is "make the plane easier to fly" and that if you want to fly her "at her best", pilot may disable it…

I will not discuss this here, but I do believe that in most of the cases AoA limiters just prevent the plane to reach departure conditions, and trying to surpass it is the best way to perform and ejection seat test, and in no way to win a dogfight.

So, my purpose in this study will be to document the aircraft performances with limiter activated, and, when possible, to evaluate the impact of its activation.

The angle of attack (AoA) is displayed to the pilot by an AoA indicator giving a value that is not the true AoA (angle in degrees between the velocity vector and the aircraft X axis), but an indicated AoA (noted as α_M as opposed to the true AoA noted as α_φ)

The relation between the two values is given at page 21 of "Applied Aerodynamic study…" as

$$\alpha_M = 2.\alpha_\varphi - 5.5 \quad or \quad \alpha_\varphi = \frac{1}{2}\alpha_M + 2.75$$

The following are the limits enforced by the SOUA device (система ограничения угла атаки - СОУА) described in "Applied Aerodynamic study…" at page 155 to 157.

We can summarize the maximum angle of attacked allowed by the SOUA / СОУА in the following table:

Wing sweep angle	α_M	α_φ
X=16°	$\alpha_M \leq 20$	$\alpha_\varphi \leq 12.75°$
X=45°	$\alpha_M \leq 28$	$\alpha_\varphi \leq 16.75°$
X=72°	$\alpha_M \leq 28$	$\alpha_\varphi \leq 16.75°$

As we will see later (lift), the angle of attack is also limited by the pitch command efficiency, as the Mach number increases above M1.0, the capability of the stabs to reach high AoA decrease, this being equivalent to the maximum AoA value as a function of Mach number (for each wing sweep angle)

C. Power Plant data

The Khachaturov R35 engine of the MiG-23ML (derived from the Khachaturov R29-300 of the previous version of MiG-23) is rated at 13,000 Kg.f (127,5 kN, 28 653,375 lbf) with full after-burner and 8,550 Kg.f (84 kN, 18,874 lbsf) in MIL power.

Its nominal specific fuel consumption is 0.0942 kg/N.h in MIL and 0.198 kg/N.h with A/B.

Max A/B regime performance is quite well documented, but not the MIL one (but as we will focus only on combat performances, MIL power thrust is far less relevant).

- Max A/B Thrust and Fuel Flow

The Max A/B thrust is described (with the specific fuel consumption) on page 79:

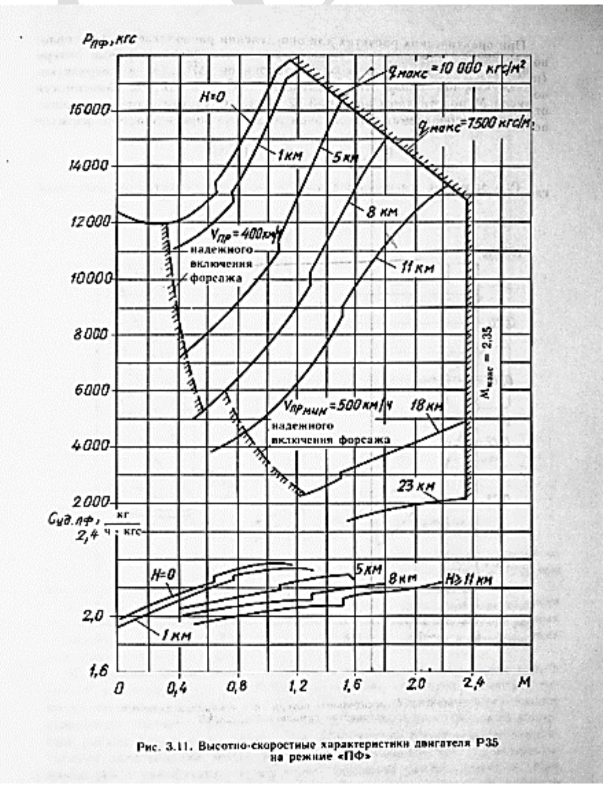


Рис. 3.11. Высотно-скоростные характеристики двигателя Р35 на режиме «ПФ»

And from this figure, we can interpolate the following values in lbsf all along the flight domain (from sea level to 75,000ft and from Mach number 0 to 2.40), result is available in the annexes: Figure I.1

From the same figure (page 79), we can read specific fuel consumption in Kg/Kgf.h (so the value is the same in lbs/lbsf.h), and consequently the instantaneous fuel flow at Max A/B in lbs/h, figure is available in the annexes: Figure I.2

- MIL Thrust and Fuel Flow.

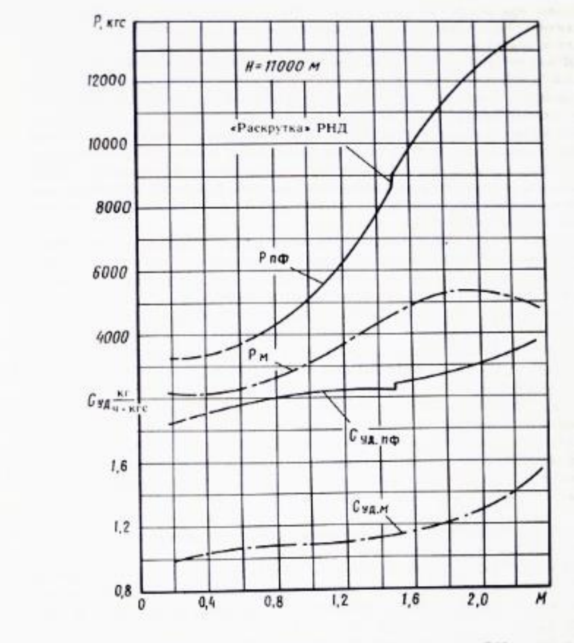


Рис. 3.9. Скоростные характеристики двигателя Р35 на режимах «ПФ» и «Максимал»

The only data available describing the MIL Thrust and Sfc along Mach number at 11,000m (FL360) is extracted from page 76 (that contains both MIL and Max A/B values).

This will at least allow us to compute basic performance (specific range and endurance at this altitude).

Values at other altitudes are roughly estimated in the following figures, but not used in any performance computation after that.

Figure are available in the annexes: Figure I.3 and Figure I.4

D. Aerodynamic data

- Lift

We will start with the general shape of the lift coefficient C_L (C_z or C_y) upon the AoA range as described in fig.2.2 page 22:

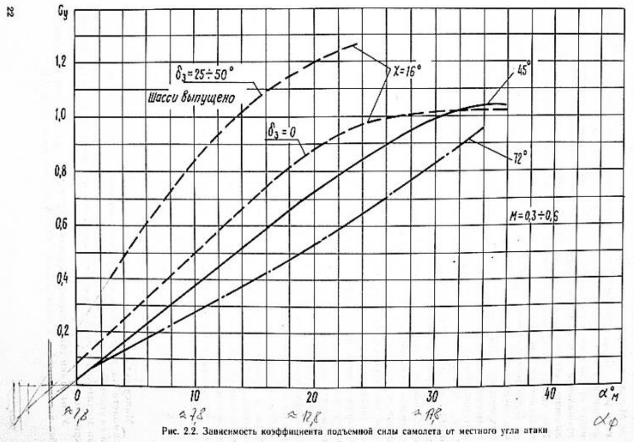
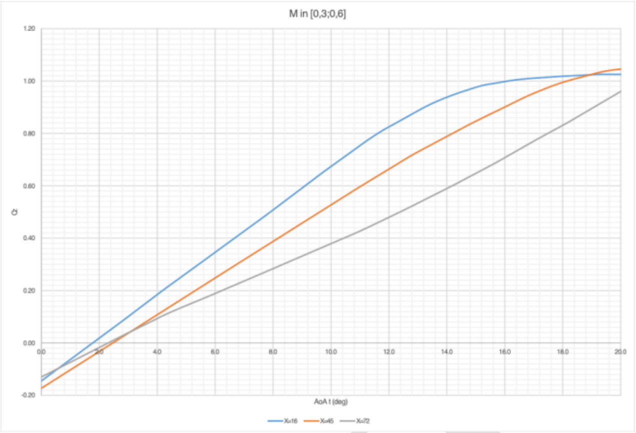


Рис. 2.2. Зависимость коэффициента подъемной силы самолета от местного угла атаки

Translated with α_φ instead of α_M it gives:



Larger scale picture Figure I.5

For the wing swept at 16 or 45, we can see a quite linear portion followed by a smooth approach to the maximum value, for wings swept at 72, the curve is globally more linear (may be just because, even with $\alpha_\varphi = 20$, we are still far away from maximum)

If we combine this with the figures fig.2.3, page 23:

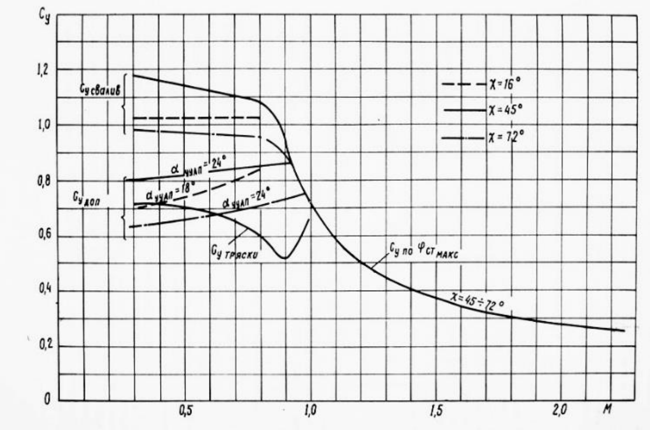


Рис. 2.3. Зависимость располагаемого коэффициента подъемной силы от числа M полета

We can see that, for every Mach value the $C_z(\alpha_\varphi)$function is driven by:

- The value of α_φ where $C_z = 0$
- The value of C_z at the end of the linear section ($\alpha_M = 18$ for $\chi = 16$), ($\alpha_M = 24$ for $\chi = 45\ or\ 72$)
- The maximum value of C_z

If we succeed in having these 4 values for every Mach number values, than we will be able to scale the fig.2.2

Determination of the actual values will be detailed in the different sections related to each wing sweep angle.

- Payload Drag

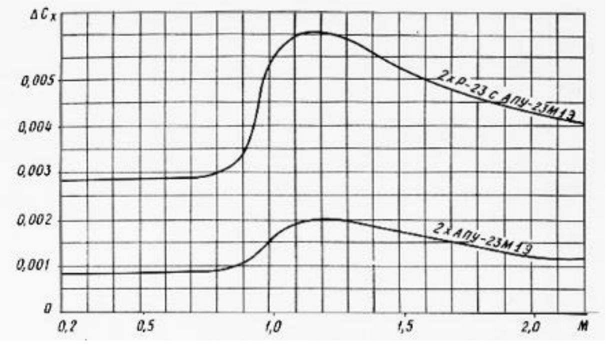
The Drag induced by weapons loaded is described on page 27 as an additional value of the Drag coefficient (ΔC_x) for different payload configurations.

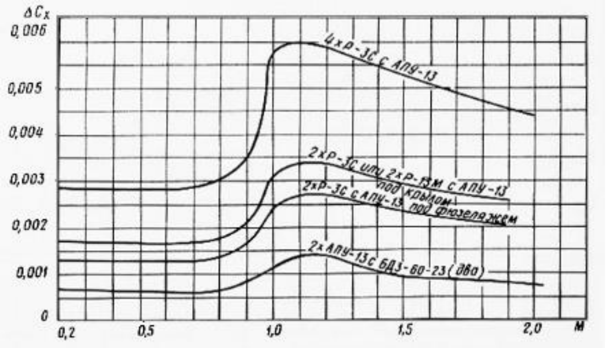
The way it is taken into account is the following:

$$Drag = \frac{1}{2}.\rho(Z).(C_x(\alpha_\varphi, M) + \Delta C_{x,i}(M)).S.V^2$$

With

- α_φ : true angle of attack
- M : Mach number
- $\Delta C_{x,i}(M)$: defined for each payload configuration by



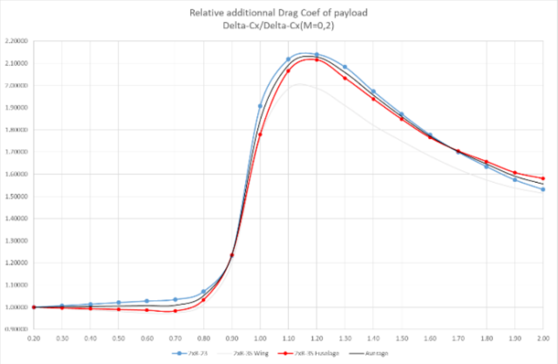


Usually, this additional Drag is computed from a Configuration Drag Index: each payload configuration having its own Index value, or each element (pylon, rail, weapon…) having its own Index value, with the one of the configuration being the sum of all objects. With such convention, we have:

$$Drag = \frac{1}{2}.\rho(Z).\left(C_x(\alpha_\varphi, M) + \frac{DI}{10000}.\Delta C_x(M)\right).S.V^2$$

With

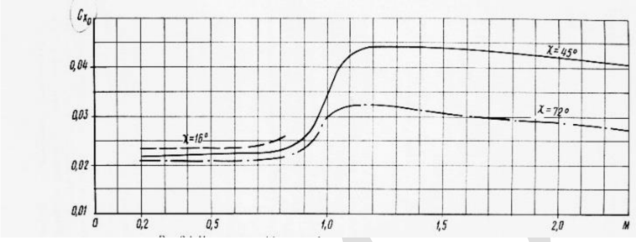
- DI : Configuration Drag Index
    - 14.2 for R-23 + APU-23M1
    - 6.4 for R-3S + APU-3S + BDZ-60-23 under fuselage station
    - 41.2 for the 2 wing mounted R-23 and 2 fuselage mounted R-3S. If we refer to MiG-21 documentation, we can see that Drag Index of R-3S + APU-3S is equivalent to the one of R-60M/MK + APU-60-IM, so this 41.2 value will also be kept for our Combat Configuration.
- $\Delta C_x(M)$ defined by the "Average" curve:



- Airframe Drag

Drag is described as the addition of the clean aircraft zero lift Drag (Cx0), the clean aircraft induced Drag (ΔCx depending on Cz) and the payload Drag (see previous section).

Figure 2.4 on page 25 gives Cx0 for each Mach number and the 3 sweep angles:



When ΔCx is given by figure 2.10 on page 30 (one global diagram and a zoom on the Cx[0;0.015] x Cz[0;0.2] domain:

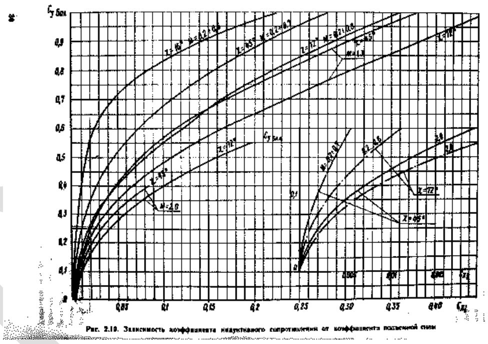


Рис. 2.10. Зависимость коэффициента индуктивного сопротивления от коэффициента подъемной силы

- Lift-to-Drag ratio

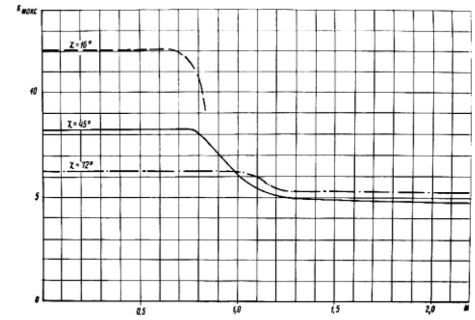


Рис. 2.14. Зависимость максимального аэродинамического качества самолета от числа М

The maximum lift-to-drag ratio for each wing sweep angle along Mach number is described in the figure 2.14 (see above)

The figure above shows a maximum Lift-to-Drag ratio with wing swept at 45° on par with common supersonic fighters of the early 70s when: a bit more than 8 in subsonic, and a bit less than 5 in supersonic.

MiG-21 is around 7.7, F-4 between 7.2 and 8.5 (with or without leading edge slats) and Mirage III is around 6.6.

This should lead to sustained turn performance equivalent to these planes (if thrust to weight ratio is equivalent).

But when the wings are swept at only 16°, the ratio climbs to 12, the value only reached by the F-5E-3 with its adaptative slats and flaps. This kind of value became common only with the next generation of fighters (F-14, F-

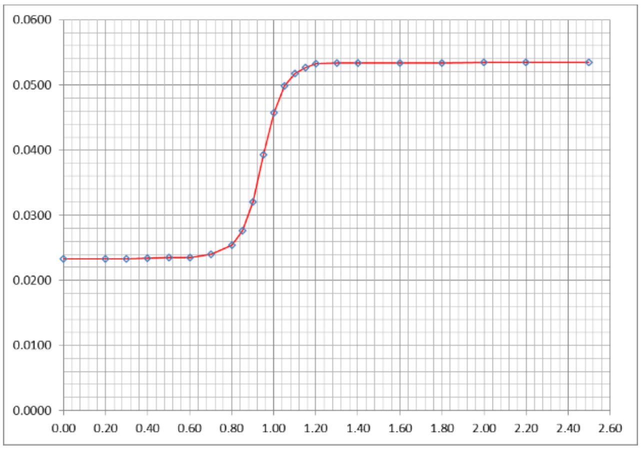
16 and MiG-29, Su-27). This may lead to superior sustained turn performances in this configuration (but only may as it will be stated in § G)

Therefore, this 2.14 figure is not coherent with the values than can be computed from figures 2.4 and 2.10 (as we can see later).

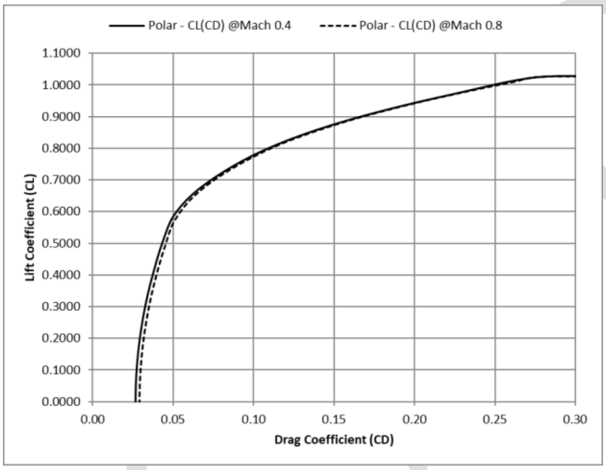
Wings swept at 16°

Figure 2.4 on page 25 and fig. 2.10 on page 30 allows to build:

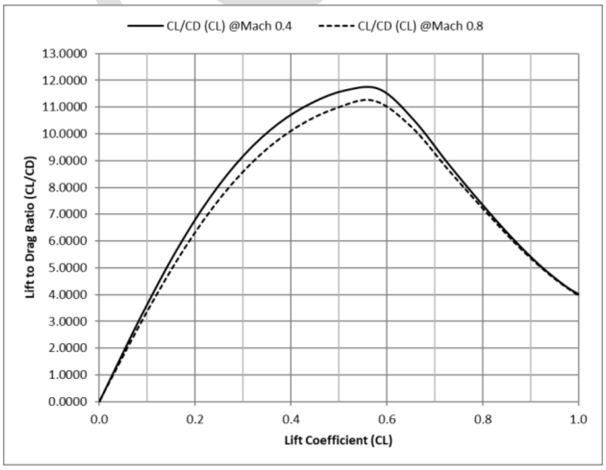
The zero lift drag (relevant in fact only when Mach < 0.8):



The polar curve for Mach number less than 0.6 and 0.8

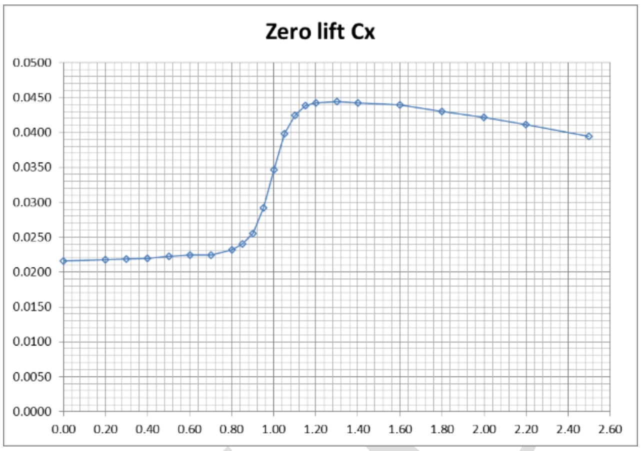


And the corresponding Lift to Drag ratio for same Mach values:

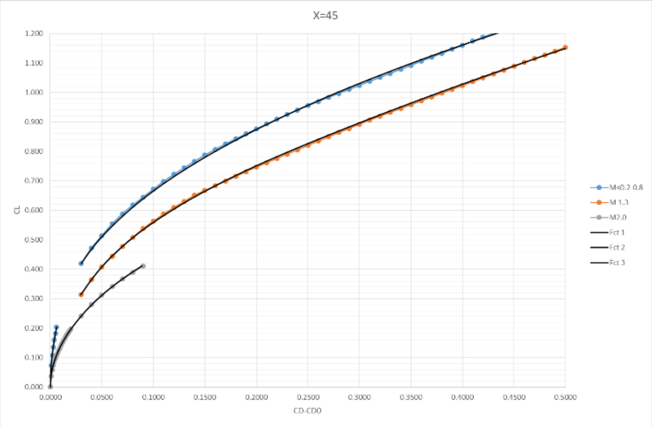


Wings swept at 45°

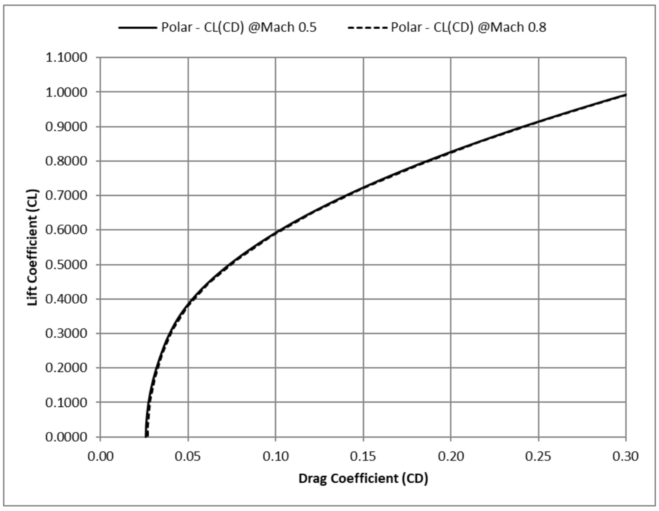
Figure 2.4 on page 25 and fig. 2.10 on page 30 allows to build the zero lift drag:

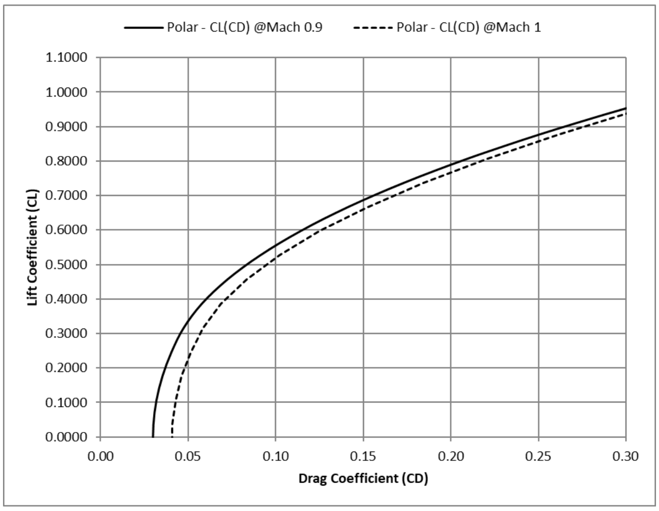


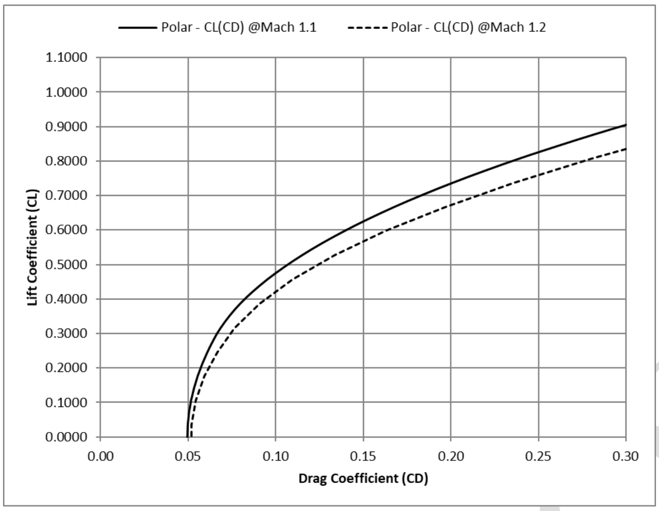
And the polar curve for different Mach numbers, first the one found in fig 2.10 (in color, points extracted from figure, in black interpolation function built to fit the points):

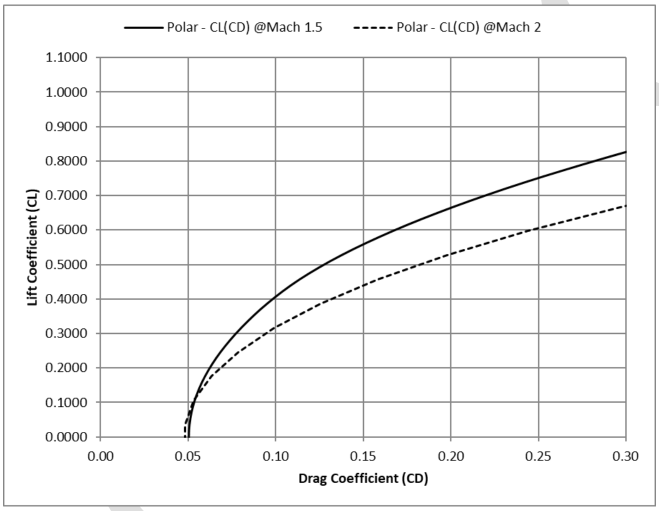


Then, by interpolation of driving parameters, for other values of Mach number.





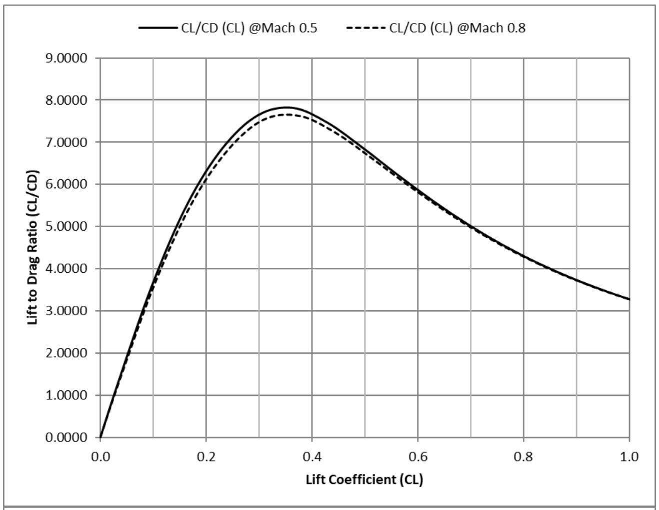


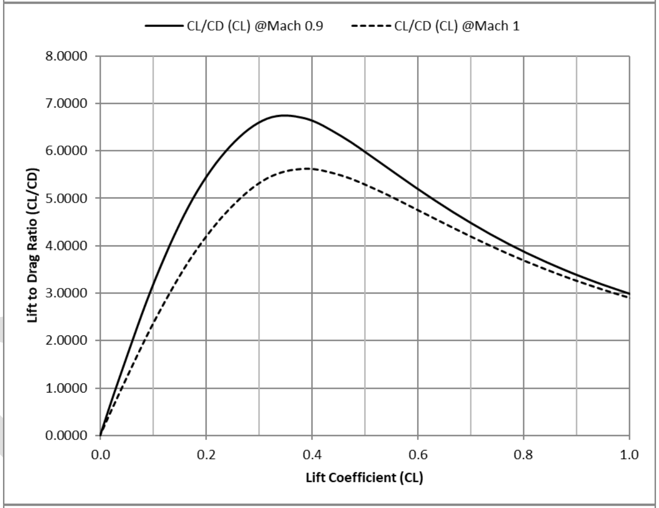


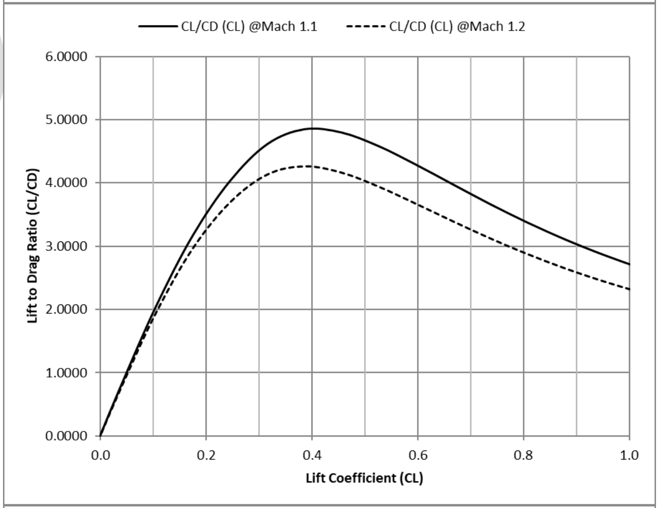
Those polar curves allows to compute Lift to Drag ratio that values is supposed to have been given in fig 2.14.

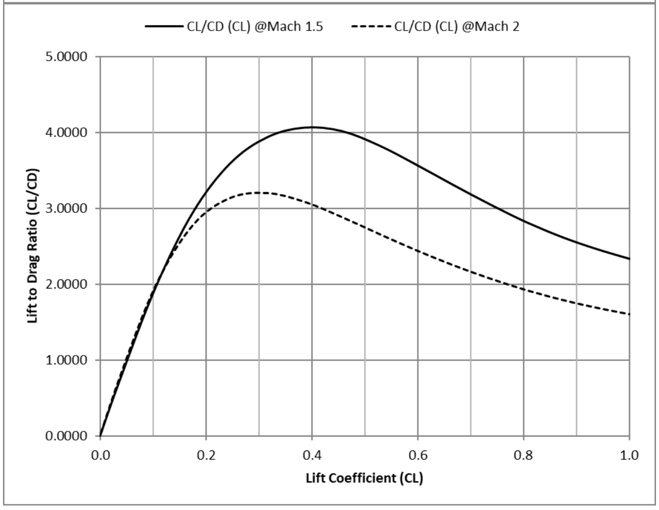
And the subsonic polar curves give a bit higher values (between 8.6 at very low Mach and 8.24 at Mach 0.8) that those of the figure 2.14

The figure below shows the values that will be used in the flight model studied here.

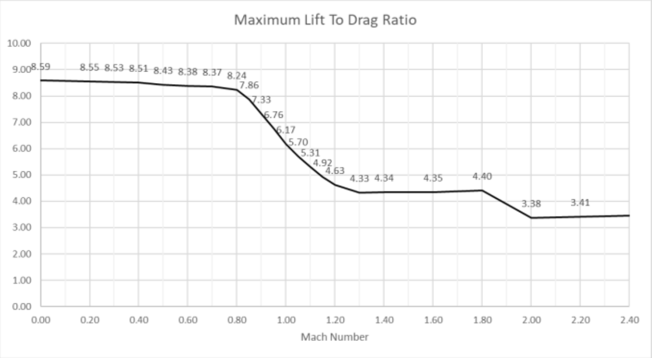






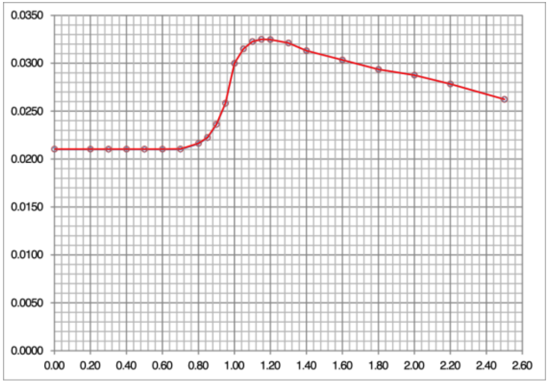


The figure below summarize Maximum lift to Drag ratio depending on Mach value for wing swept at 45°.

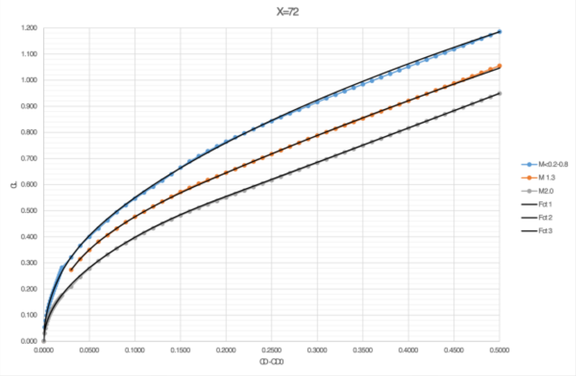


Wings swept at 72°

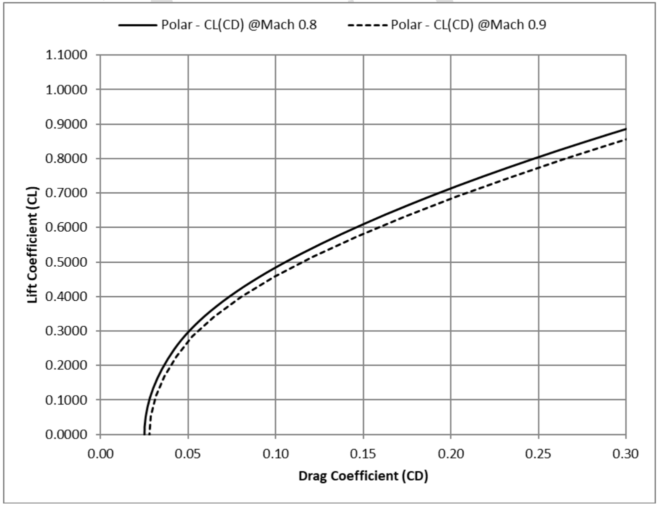
Here are Cx0 from figures 2.4 for a sweep angle of 72°.

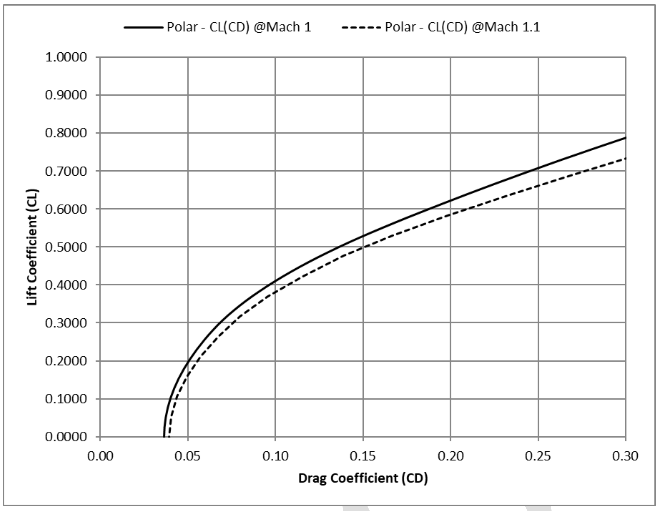


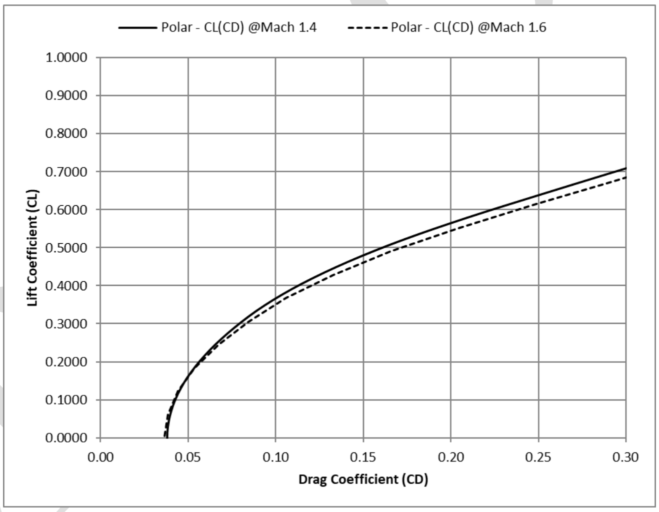
And ΔCx curves, in color are points extracted from figure 2.10, in black interpolation function built to fit the points:

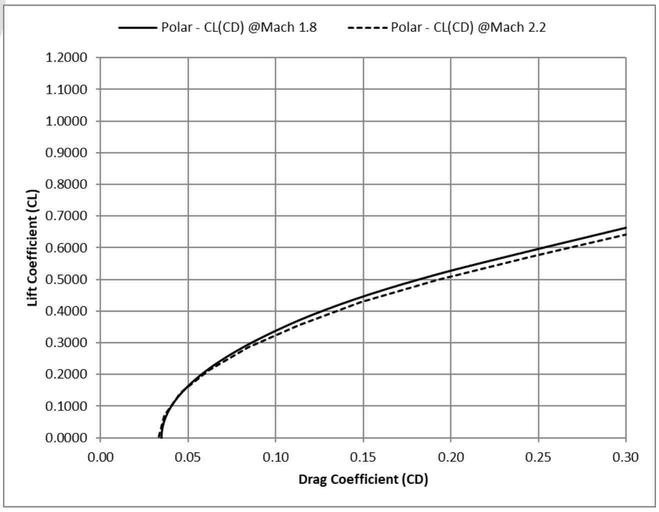


The interpolated Polar curves for different Mach numbers

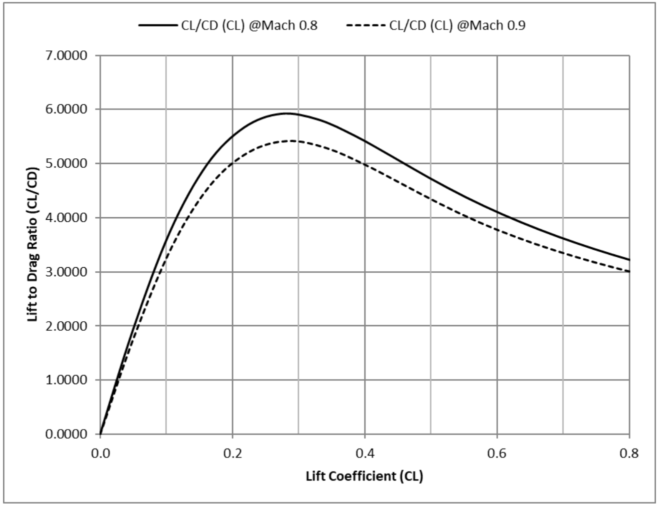


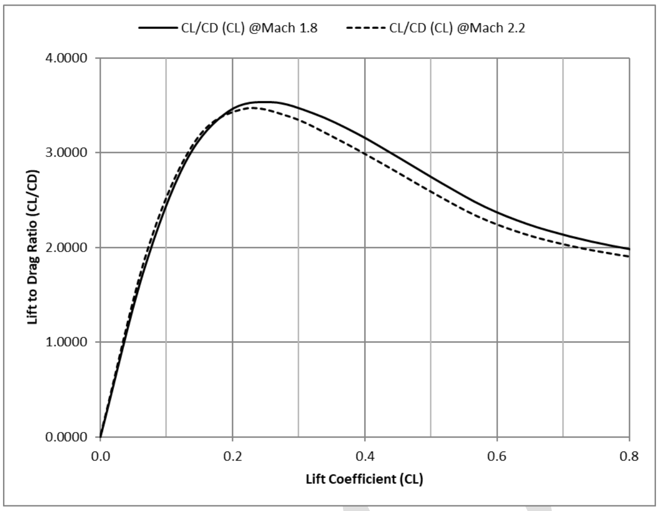


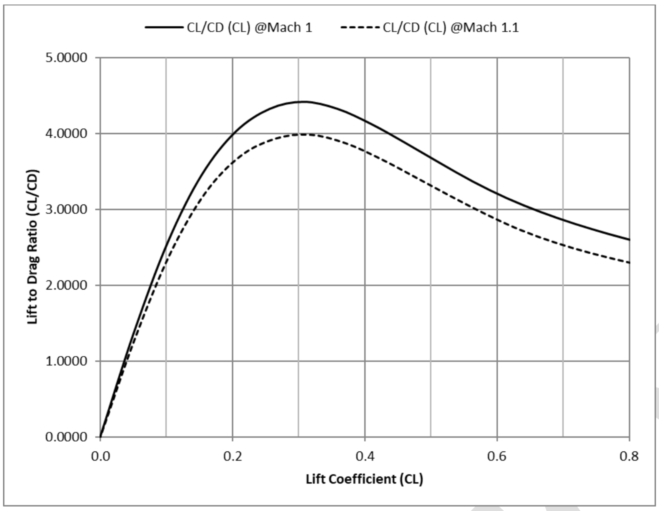


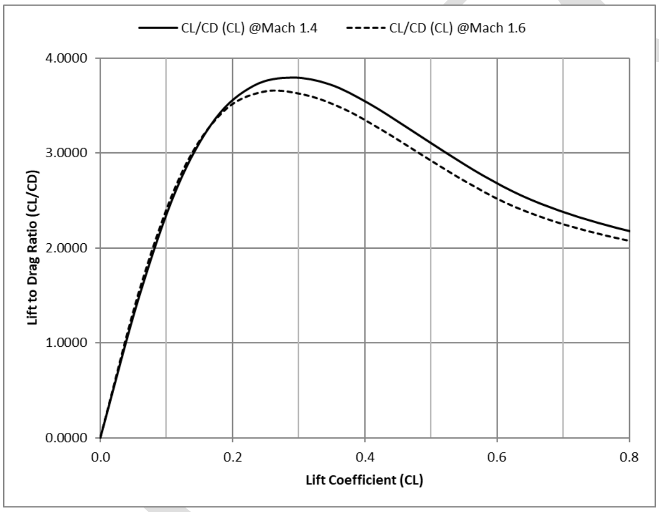


And the corresponding Lift to Drag ratio:









E. Performance with X=72°.

All performance data and figures reported in the following sections are computed for the identified combat configuration: GW=13T, 2xR-60M/MK, 2xR-23/R-24

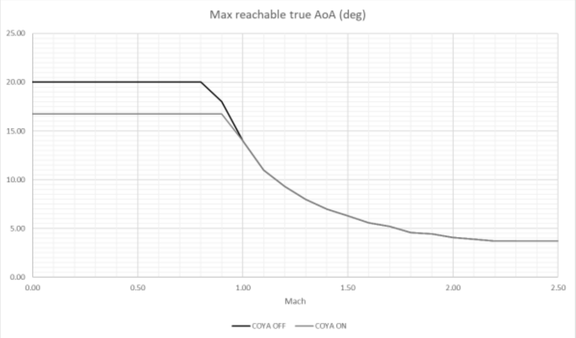
- Maximum Lift Turn

Maximum lift performances are not the most important ones when we want to evaluate close air combat capabilities. They can be maintained during a very small period (not more than 1 to 2s) before the energy and speed have been lost.

But they give an indication of what a pilot can do when it is just about: "do it or you're dead", or "do it or you'll miss". They are only showing the capability to avoid being shot (escape from the line of sight when being gun shot, or from an incoming missile) or to finalize the firing solution.

With such a sweep angle the structural limits in term of load factor are set to 8.5G in subsonic (M<=0.85) and 7.5G in supersonic, more than most of other planes of its generation (the 9G limit is a common characteristic of the next generation: F-15, F-16, MiG-29, Su-27, Mirage 2000…).

If we combine the Maximum lift described in fig.2.3 and the SOUA system (the angle of attack limiter), we can build a maximum reachable true angle of attack diagram.



That is deduced from the fig. 2.3 restricted to X=72°

- From Mach 0 to 0.8, maximum lift AoA can be theoretically reached (we choose 20° of true AoA) if SOUA/COYA is not engaged, then maximum reachable AoA decrease due to lack of pitch command efficiency.
- Lift (CL) at 20° of true AoA (yellow curve) and at 14.75° of true AoA /24 indicated (red curve), are read from fig. 2.2 up to Mach 0.8 and remain constant above.
- Max lift with SOUA/COYA (true AoA < 16.75°) is the green curve

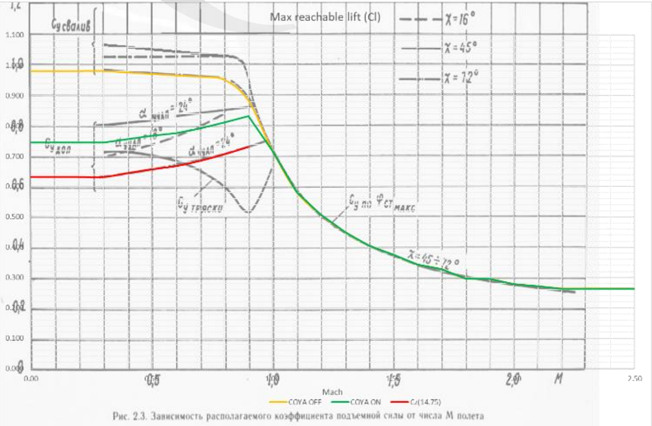


Рис. 2.3. Зависимость располагаемого коэффициента подъемной силы от числа M полета

Combined with load factor limitation (maximum Ngz) and the thrust at maximum after burner regime, it allows us to compute the following capabilities: maximum normal load factor and turn rate, minimum turn radius along Mach number at different altitudes, for the combat configuration with a gross weight of 13,000Kg, with and without SOUA system engaged.

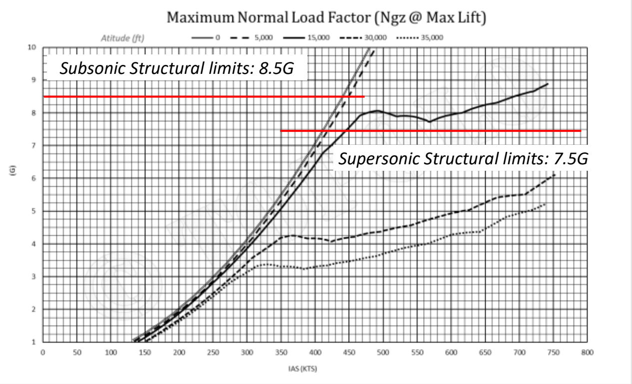
Maximum Load Factor is given by:

$$Ng.GW = Th(M,Z).sin(AoA_{max}) + \frac{1}{2}\rho(Z).Cl_{max}.S.M^2.a(Z)^2$$

with

- Cl_{max}: Maximum Lift coef at a given Mach number
- AoA_{max}: the true AoA angle (deg) giving Cl_{max}
- GW :the current weight (Newton)
- Ng :the normal load factor
- $\rho(Z)$: the volumetric mass of air (kg/m^3) at the altitude Z
- M: the true Mach number
- $a(Z)$ the speed of sound (m/s) at the altitude Z
- $Th(M,Z)$: theMaximum AB thrust (Newton)
- S: the reference area(m^2)

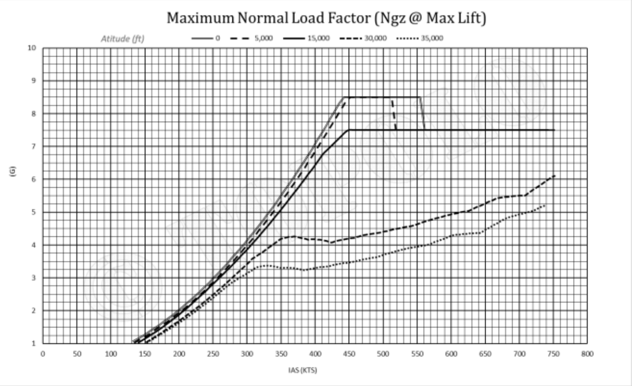
First, without SOUA engaged NgZ limits can be exceeded:



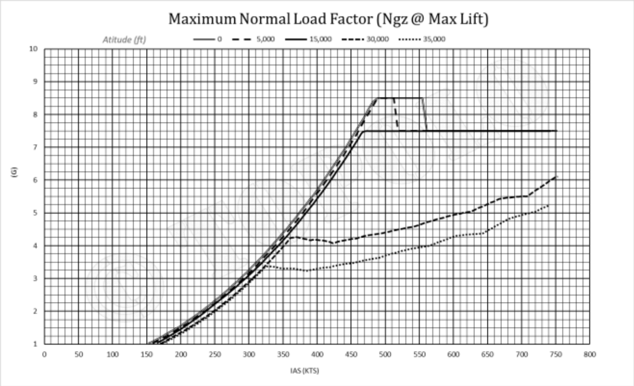
At low altitude, structural limit of 8.5G is exceeded above 440Kts; at 15,000ft the limit is also reached at around 440Kts (but above M0.85 the limit is only 7.5G).

If we just want to keep the load factor inside structural limits, but not engage the AoA limiter (SOUA), we can see that above 440 Kts, the pilot needs to manually reduce AoA to keep the plane inside the allowed load factor domain up to medium altitude (15,000ft). At higher altitudes there is no risk.

Stall speed (indicated) is around 130Kts (240 km/h) in that case.



Then with AoA limiter (SOUA) engaged:



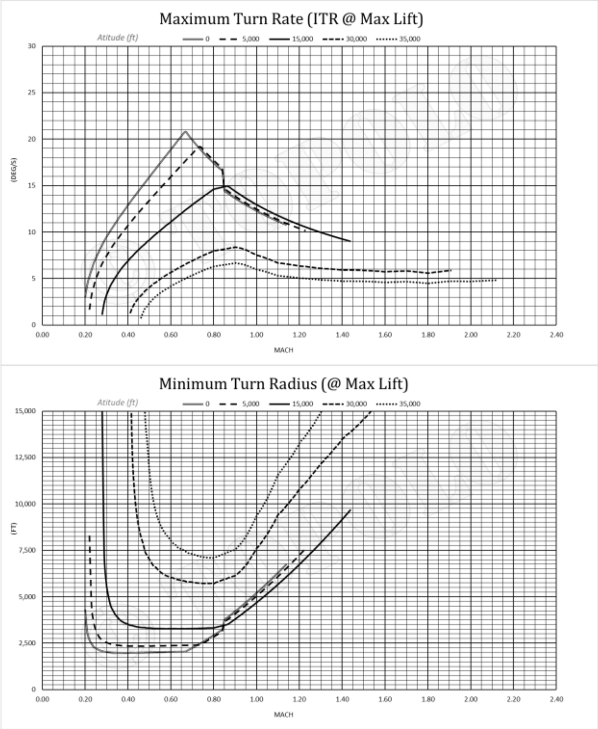
The AoA limiter does not prevent to hit the load factor limit (but it is not its purpose that is mainly to reduce departure risk). 30 additional Kts are required to reach the same load factor than witout AoA limiter.

With SOUA system engaged, stall speed (indicated) is around 150-170Kts (280-315km/h). This does not mean that the aircraft cannot be flown slower; this only means that 1G cannot be sustained at lower speed. In many air combat configurations maneuvers (yo-yo, vertical scissors…) are performed with lower load factor (between 0.0 and 1.0) allowing lower speed.

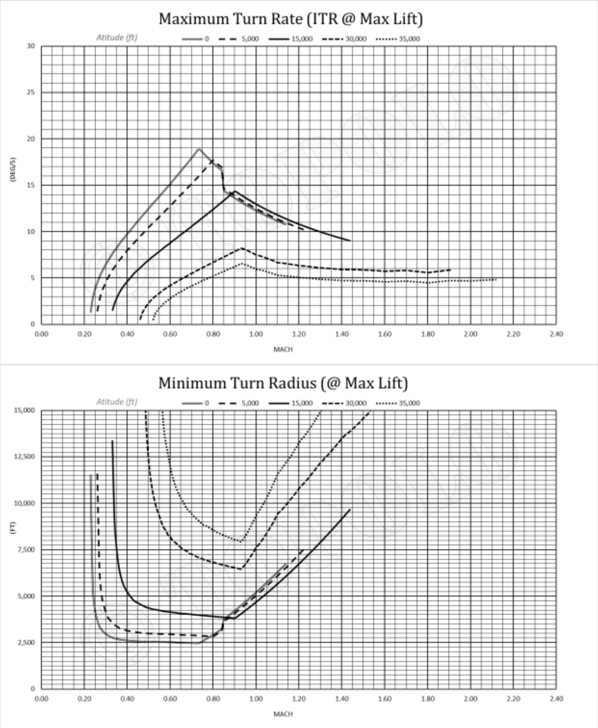
From load factor at a given Mach Number and altitude, we can compute the corresponding turn rate and turn radius by $R = \frac{V^2}{g.\sqrt{Ng^2-1}}$ and $\omega = \frac{g.\sqrt{Ng^2-1}}{V}$ with

- R: turn radius in m
- ω: the turn rate in °/s
- V: true air speed in m/s
- g :the gravity acceleration (9.81 m/s^2)
- Ng :the load factor

First with SOUA not engaged:



And then with SOUA (AoA limiter) engaged



With 18°/s of instantaneous turn rate at 5,000ft and a radius around 2,500ft at sea level, the MiG-23ML with its wings fully swept back, the SOUA engaged and its structural limits, without slats or flaps available, is a bit less agile then Mirage-III/5 (20°/s) or F-5E (22°/s) but more than the F-4E Blk50 (16.8°/s).

We can also notice the very little impact of the AoA limiter (the SOUA) on the instantaneous turn rate (-1°/s or -2°/s) and minimum turn radius (+250ft) up to 15,000ft

- Acceleration and Climb

In this category, we will find different performance indicators, dealing with several combat capabilities.

First one is the “instantaneous constant speed climb rate” and derivatives (climb angle, acceleration...), also called extra specific power (Ps). This one reflects the capability of the aircraft to keep its energy (speed) when maneuvering in the vertical plane. In such a combat tactics, the one having the highest Ps is highly advantaged.

The second is the distance covered in a certain amount of time, at constant altitude, starting from a given speed. They are deduced from the time required to go from one speed to a higher one, also called time-to-mach.

Starting from M0.9 (regular offensive CAP posture), it does measure aircraft’s capability to catch a target or the offensive capability to force opponent to stay in the fight.

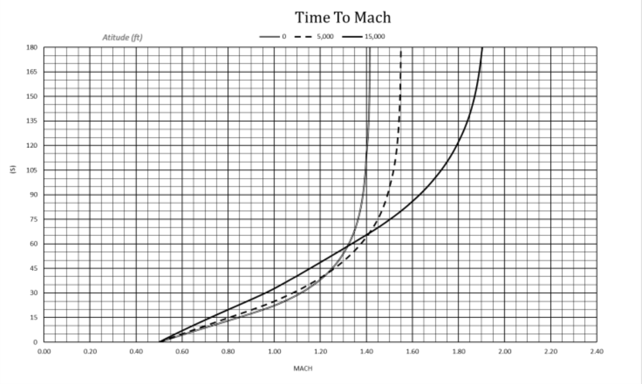
When started from much lower speed (near the end of a close air combat), it indicates a defensive capability to break the fight.

Last, it can be also measured the time required to climb to a given altitude, but if this is one of the main performance indicators for a pure interceptor, it has less importance in close air combat.

Based on lift, drag and thrust, we can compute 1G acceleration curves: time required to reach a Mach number value from a lower one at a given altitude.

This can be done by integrating the following set of equations:

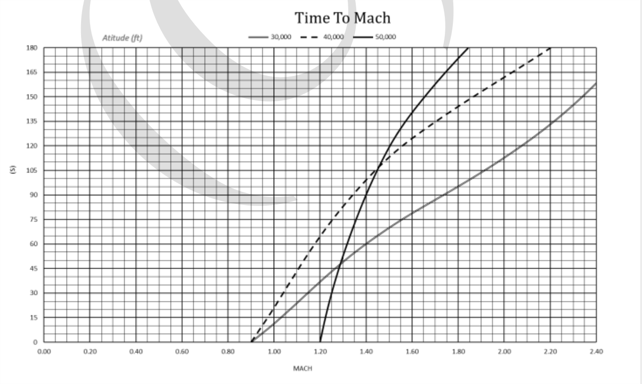
$$Cl(AoA,M): Liftcoeffunctionof Machand AoA$$
$$Cd(AoA,M): Dragcoeffunctionof Machand AoA$$
$$V: trueairspeed$$
$$\begin{cases} M = \dfrac{V}{a(Z)} \\ GW = Th(M,Z).sin(AoA) + \dfrac{1}{2}\rho(Z).Cl(AoA,M).S.V^2 \\ \dfrac{dV}{dt} = \dfrac{g}{GW}.\left[Th(M,Z).cos(AoA) - \dfrac{1}{2}\rho(Z).Cd(AoA,M).S.V^2\right] \end{cases}$$



With the VNE (1,400 Km/h or 756 Kts IAS) being equivalent to M1.14 at sea level, we can see it is exceeded in less than 30'' starting from M0.5

At 5,000ft, the VNE of M1.23 is reached in less than 35'', and at 15,000ft, the M1.44 limit is reached in 58''.

At least at low level the pilot needs to be really cautious to keep the speed within limits. In case VNE is exceeded, one of the reported "minor" consequences is the impossibility to move the wing forward, leading to a landing with the wings swept at 72deg and no flaps… In some cases it seems the wing sweep mechanism damage caused an asymmetrical wing movement. In both cases we can imagine a high probability of crash or an ejection.



Between 30,000 and 40,000ft (regular high altitudes) the limit Mach number (M2.34) is exceeded in 1'30'' or 2'30 from M0.9; at 36,000ft a clean MiG-23ML would, theoretically, accelerate past Mach 3.0 (well after its engine failed or its windscreen burnt)

If we compute the horizontal distance covered in 3' at different altitudes (indication of the capability to rejoin the target, or to outrun an opponent), we have the following values:

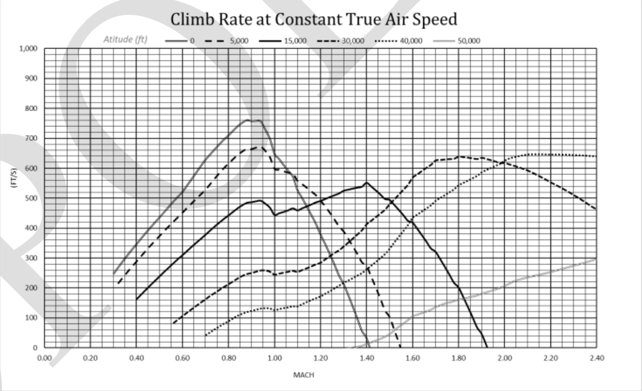
At 5,000ft, from M0.5: 43.9 Nm (only 37.63Nm for the F-4E Blk41, the best performer in the early 70s)

At 15,000ft, from M0.5: 46Nm (only 40.27 for the F-4E Blk41)

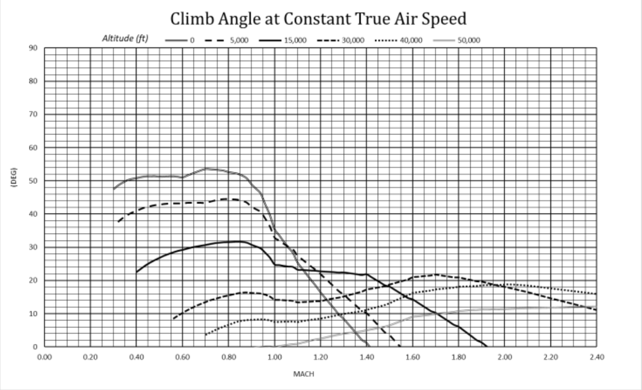
At 30,000ft from M0.9: 51.16Nm (only 44 for the F-4E Blk41)

That means that, with its wings folded, and if pilot does not stick to speed limitations, the MiG-23ML can outrun any fighter from the 70s (MiG-21, Mirage III, F-5E, F-4…), but can catch them all, even being 6Nm behind (and even 10Nm at 30,000ft).

And Excess Specific power at 1G that can be seen as the instantaneous climb capacity (theoretical instantaneous climb rate at constant true air speed):



And the equivalent climb angle.



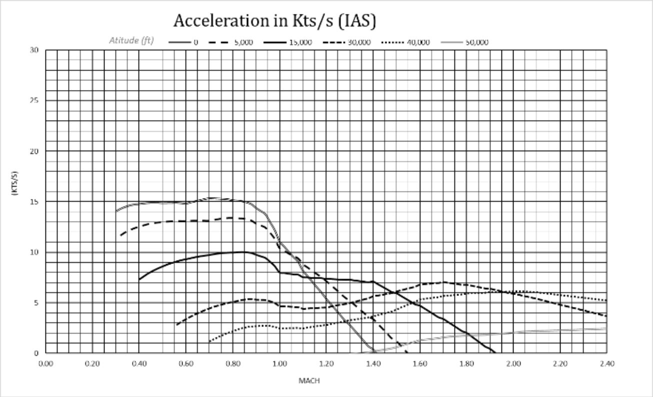
Or the 1G acceleration capability (indicated air speed gain in 1s)

The equivalence being given by:

$$m.g.z + \frac{1}{2}.m.V^2 = Cst$$

$$\frac{d}{dt}(m.g.z) + \frac{d}{dt}\left(\frac{1}{2}.m.V^2\right) = 0$$

$$\frac{dV}{dt} = \frac{g}{V}.\frac{dz}{dt}, Ps = \frac{dz}{dt}, \frac{dV}{dt} = \frac{g.Ps}{V}$$



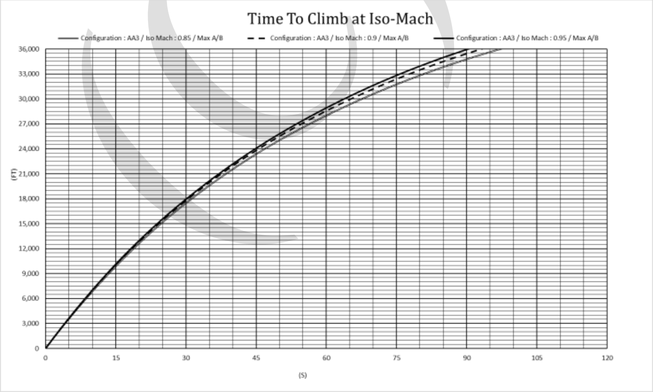
Such diagram clearly shows that M2.35 or 1,400Km/h speed limitations can be very easily overshot.

At 40,000ft and at its limit speed of M2.35 the MiG-23ML with its 4 AA missiles and its R35 engine still accelerates with more than 5 Kts per second when level, or is able to climb at 643 ft/s at 16.5 degrees pitch angle (close to the 683ft/s for the F-4E, the best performer at 5,000ft).

While the subsonic acceleration of the MiG-23ML with its wings swept fully backward is very close to F-4E Blk41, one of the best interceptors of its generation (670ft/s @ 5,000ft compared to the 680ft/s for the F-4E Blk41), the supersonic acceleration (or climb rate) outmatches it: at 30,000ft, the potential climb rate increases with the speed up to 650 ft/s at M2.00. In the same conditions the potential supersonic climb rate of the F-4E Blk41 reaches a maximum of 370 ft/s at M1.50 and then decreases slowly to 0 at M2.1

Based on the previous instantaneous climb rate values, we can now compute the time (and also fuel and distance) required to climb from a given altitude to another by following a defined climb schedule.

When it comes to fastest climb, the engine is set to maximum after burner and the fastest climb schedule is often an iso-mach one, with a Mach number value close to 0.9 (and lower when drag increases with external loadout). In the case of a clean MiG-23ML, the most efficient climb profile up to 36,000ft is the one with Mach number kept at 0.95.



Of course this figure does not mean that it takes 90” to reach 36,000ft from brake release. It means that if the plane is at sea level at a speed of M0.95 with a climb angle for a constant true air speed (around 55 deg nose up) and if the pilot adjusts climb angle to keep the Mach number constant and equal to M0.95 all the time, only then he will reach 36,000ft in 90”.

To have a comparison point, the F-4E Blk.41 (one of the fastest versions of the Phantom II) with 4 AIM-7 takes 75” to reach the same altitude, and to reach it in less than 60”, we will need to wait for Su-27SK or F-15.

The constant iso-mach climb is usually the fastest one up to 36,000ft, which can be seen from the Excess Specific power at 1G diagram, where the best value is reached at around M0.9. For altitudes above 36,000ft, best Ps may be at higher mach number, but this leads to different climb schedule pattern. For example, for the clean Mirage F1 the recommended climb schedule to reach 50,000ft is to:

1. climb at constant IAS 500Kts up to M0.9
2. climb at constant Mach 0.9 up to 30,000ft,
3. accelerate up to IAS 650Kts at constant altitude
4. climb at constant IAS 650Kts up to M1.8
5. climb at constant Mach 1.8 up to 50,000ft

With wings swept at 72deg, MiG-23ML maximum Ps is already reached at supersonic Mach number at 15,000ft.

To reach the same 36,000ft, instead of the constant Mach 0.95 climb, we can follow a schedule like:

1.	climb at constant Mach 0.95 up to 15,000ft	(24s)
2.	accelerate up M1.40 at constant altitude	(37s)
3.	climb at constant Mach 1.40 up to 36,000ft	(46s)

The total is 107s, a bit slower than for the 90s of the iso-mach climb schedule, but the advantage is that if you want to climb above 36,000ft you will do it faster at M1.4 that at M0.95.

Let’s try to find an efficient climb schedule up to 50,000ft.

With an iso-mach schedule at M0.95, 50,000ft is reached from SL in 250s (4’10’’)

The comparative F-4E Blk41 with 4-AIM-7 takes 198s (3’18’’) to reach the 50,000ft

Here is the M0.95/15,000ft/M1.40 example:

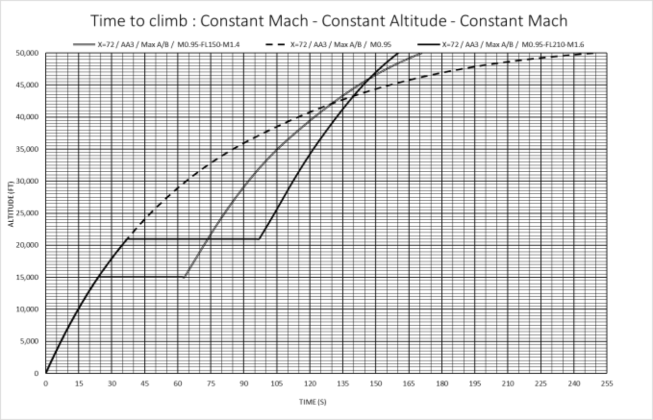
1.	climb at constant Mach 0.95 up to 15,000ft	(24s)
2.	accelerate up M1.40 at constant altitude	(37s)
3.	climb at constant Mach 1.40 up to 50,000ft	(108s)

The total is 169s (2’49’’)

Here is the M0.95/21,000ft/M1.60:

1.	climb at constant Mach 0.95 up to 21,000ft	(37s)
2.	accelerate up M1.60 at constant altitude	(58s)
3.	climb at constant Mach 1.60 up to 50,000ft	(64s)

The total is 159s (2’39’’)


Time to climb : Constant Mach - Constant Altitude - Constant Mach

Note 1: M1.6 cannot be reached before 21,000ft to respect the 756Kts VNE.

Note 2: All attempts to beat F-4E Blk41 time required to reach 50,000ft by adapting its climb schedule seems in vain: the better climb rate at M1.4 (only above 30,000ft) never compensates the time required to accelerate from 0.9 to 1.4. With what seems to be its best climb schedule (M0.90 / 30,000ft / M1.40), the F-4E Blk41 will reach 50,000ft with following schedule:

1. *climb at constant Mach 0.90 up to 30,000ft* *(56s)*
2. *accelerate up to M1.40 at constant altitude* *(48s)*
3. *climb at constant Mach 1.40 up to 50,000ft* *(102s)*

The total is 206s (3'26''), which is slower than the constant speed climb.

So, compared to one of the best interceptors of its time, the MiG-23ML will reach 50,000ft from sea level (starting from its optimal climb speed and attitude) in 2'39'' instead of 3'18'' !

- Sustained Turn

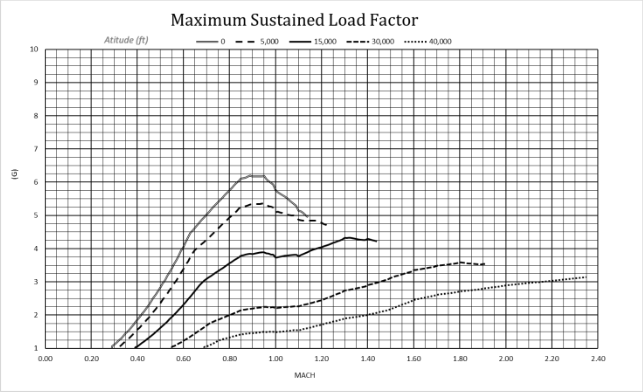
Next performance indicators are "Constant speed and altitude turn capability"

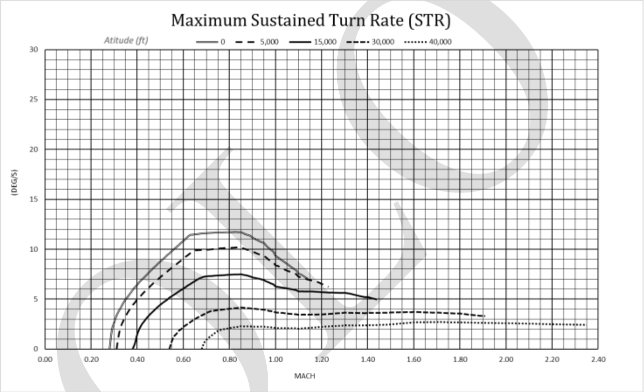
They can now be computed by solving:

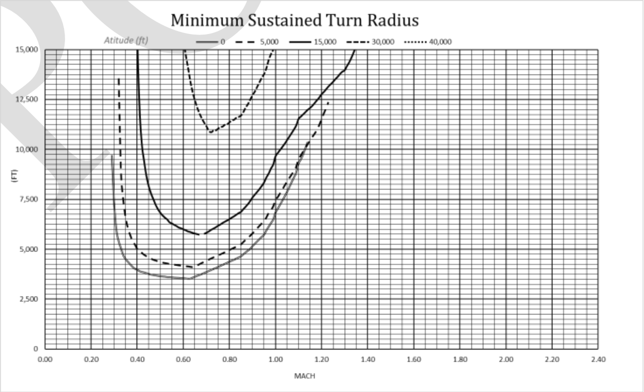
$$\begin{cases} Ng.GW = Th(M,Z).sin(AoA) + \frac{1}{2}\rho(Z).Cl(AoA,M).S.V^2 \\ Th(M,Z).cos(AoA) - \frac{1}{2}\rho(Z).Cd(AoA,M).S.V^2 = 0 \end{cases}$$

Maximum sustained turn rate at a given altitude is not negatively impacted by the SOUA limiter.

With wing fully swept back, maximum sustained turn rate is reached at M0.8 at all altitudes, with an angle of attack far below the SOUA limit.


Maximum Sustained Load Factor


Maximum Sustained Turn Rate (STR)


Minimum Sustained Turn Radius

When it comes to sustained turn capability, even if the sweep angle of 72deg is clearly not the one giving the best capabilities at medium or low Mach numbers, the MiG-23ML is below the standard values of this period

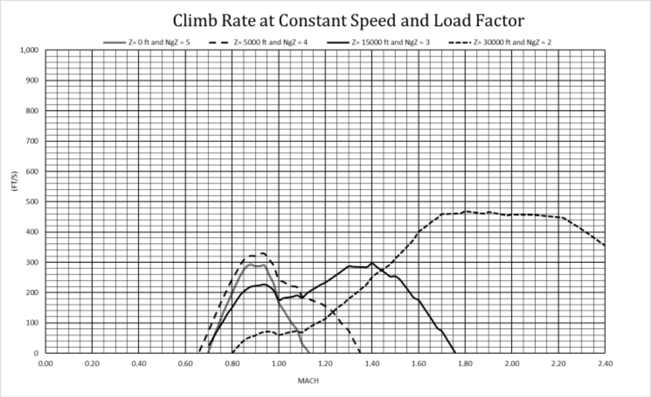
At 5,000ft: 10.2 d/s (13.3 d/s for the F-5E-3)

At 15,000ft: 7.5 d/s (10 d/s for the F-4E Blk 50)

At 30,000ft: 4.14 d/s (6.4 d/s for the F-4E Blk 50)

When turn rates are compared, it is usually considered that a difference of 3°/s is a significant advantage.

- Climbing Turn



The maximum climb rate (at constant speed) under a given load factor describes the capability of an aircraft in what is called the oblique plan (horizontal plan means turning at constant altitude, vertical plan means climb but do not turn).

It is usually performed as a defensive maneuver, with a medium load factor. Here I've chosen a 5G turn at sea level, 4G @ 5,000ft, 3G @ 15,000ft and 2G @ 30,000ft.

With wings fully swept back, the MiG-23ML shows average performance in this domain:

With 328 ft/s @ 5,000ft, it is on par with the 311 ft/s of the F-5E-3 and the 342 ft/s of the F-4E Blk50 (slated) but superior to the 280 ft/s of the Mirage 5, and inferior to the 461 ft/s of the F-4E Blk41 (non-slatted)

At 15,000ft, with 296 ft/s at Mach 1.4, it is clearly superior to Mirage III/5 (211 to 245 ft/s) or F-5E (260) and on pair with the F-4E (300 ft/s for Blk50, 360 ft/s for non-slatted blk41), but if we consider only the subsonic domain, with 220 ft/s, it's below average.

At 30,000ft, the supersonic turning climb rate of the MiG-23ML is 468ft/s while the second best (F-4E Blk41) can only climb at 205ft/s, but if we consider only the subsonic domain, with only less than 80 ft/s, the MiG-23ML climbs under 2G even slower than the Mirage IIIC.

- Quickest Half turn

This value measures the time required to perform a half turn at constant altitude with maximum allowed load factor and then maximum allowed angle of attack (when speed drops below the one required to reach maximum load factor).

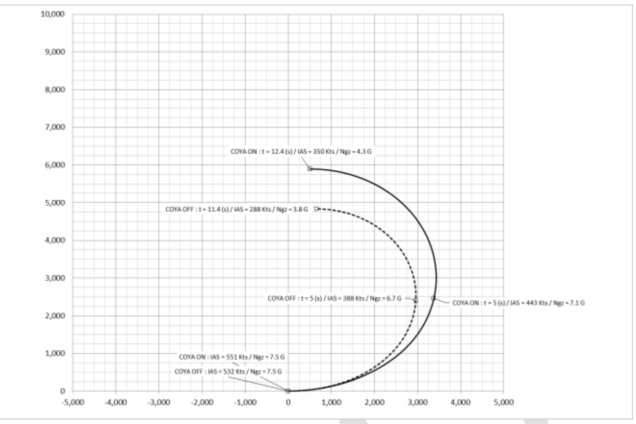
For every altitude (5,000, 15,000 and 30,000ft), the result highly depends on the initial speed, so the one giving the quickest half turn is maintained, with or without SOUA system engaged.

At 5,000ft

Result is or course better without SOUA engaged, and in that case, the half turn could theoretically be performed in 11.4s when started at 532Kts/M0.87 (10,6s for the F-5E)

With SOUA engaged, the quickest half turn is performed in 12.4s (+1s) starting faster (551 Kts / M0.90)

The figure below shows the plane trajectory and speed variation with and without SOUA engaged.



The two trajectories start diverging when speed decreases down to the value where it is no more possible to keep maximum allowed load factor, thus the AoA increases up to the maximum allowed, which differs with and without SOUA engaged.

The performance computed without SOUA engaged is to be considered as "theoretical", as it assumes the pilot being able to keep the angle of attack at a value giving the maximum lift, which is precisely on the edge of stall, without facing any departure. It, in fact, defines the performance that can never be exceeded, rather than the one actually achievable.

At 15,000ft

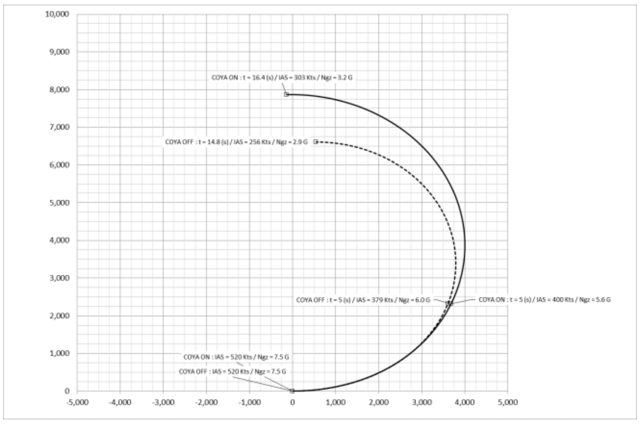
At this altitude, the time required to perform the turn decrease with the initial speed being close to VNE.

Quickest half turn with SOUA engaged is theoretically completed in 15,2s reached starting from M1.17/614Kts.

Without SOUA, it can be completed in 14.2s reached starting from M1.12/587Kts.

Even if, from a tactical point of view, it can be imagined to merge from supersonic speed (since a high G load turn will bleed your energy, the more you have at the beginning the better) the flight characteristics of a plane at high load factor in transonic regime is known to be all but easy to fly: when speed drops from supersonic to subsonic, pitch up is generally experienced, leading to over-G. I highly doubt computed performances can be achieved in actual flight.

For this reasons, I will only consider half turn started at a speed of M1.0/520Kts. Without SOUA, a half turn could theoretically be completed in 14.8s (11.8s for an F-5E).



With SOUA engaged and same initial conditions, the half turn is performed in 16.4s (+1.6s), like at lower altitude, the AoA limiter does not significantly (less than 10%) reduce the performance in this area.

At 30,000ft

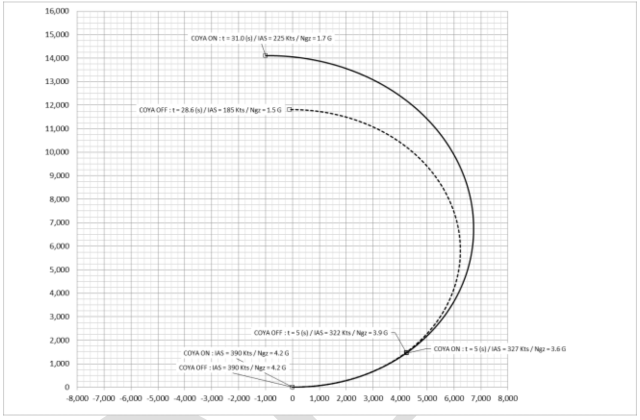
The situation is similar to the one described at 15,000ft: fastest half turn started from supersonic are:

- 25.4s from M1.21/484Kts without SOUA
- 26.8s from M1.27/510Kts with SOUA engaged

And for the same reason, we will keep only half turn started from M1.0/390Kts.

The figure below describes a half turn started at M1.0 / 520Kts (Mirage IIIC does the same in 22.20s)

- 28.6s without SOUA
- 31.0s with SOUA engaged



F. Performance with X=45°

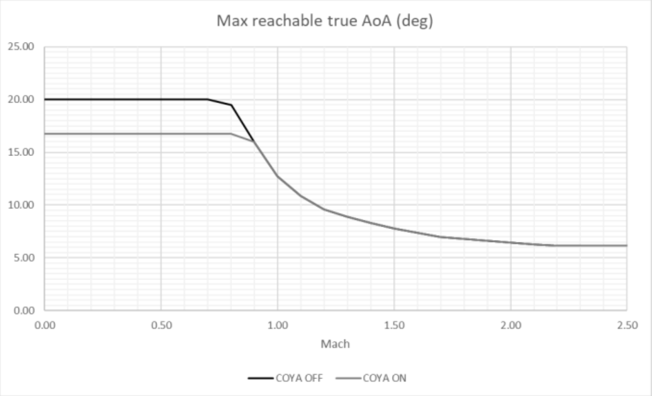
While the configuration with wings fully swept back is recommended for supersonic operations, the one with a sweep angle of 45 degrees is recommended for all combat operations (except against very slow moving target where fighting with wings swept fully forward is recommended).

So, a sweep angle of 45 degrees is to be considered as "the" close air combat configuration.

With this wing sweep angle, the reference area to be taken into account is 34.16 m2 (367.70 sqf)

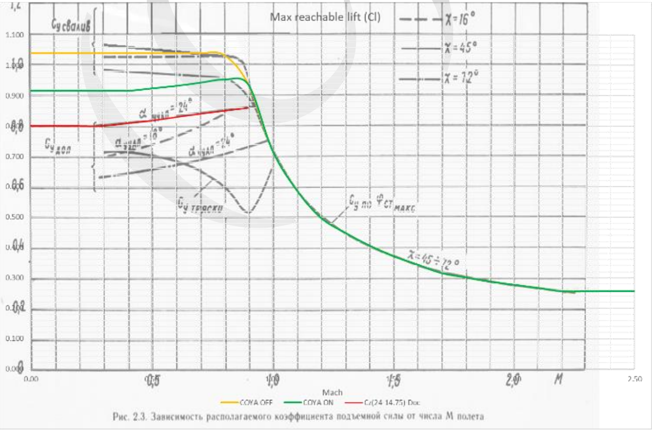
- Maximum Lift Turn

If we combine the Maximum lift described fig.2.3 and the SOUA system (the AoA limiter), we can build a maximum reachable true AoA diagram, and we can see it never exceed values allowed by SOUA/СОУА with SAU-23AM set to "Демпфер" mode (16.75° true AoA).

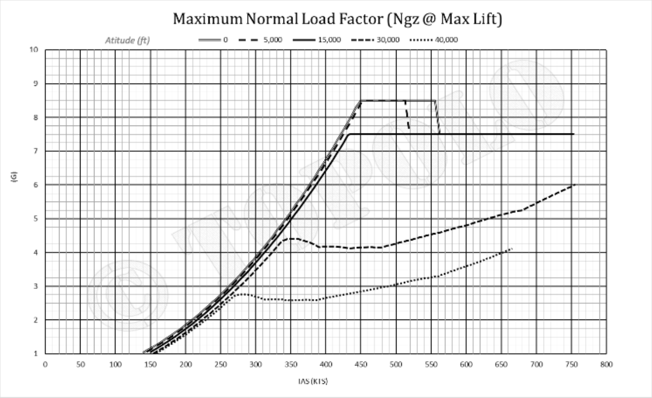


That is deduced from the fig. 2.3 restricted to X=45°

- From Mach 0 to 0.8, maximum lift AoA can be theoretically reached (we choose 20° of true AoA) if SOUA/СОУА is not engaged, then maximum reachable AoA decrease due to lack of pitch command efficiency.
- Lift (CL) at 20° of true AoA (orange curve) and at 14.75° of true AoA /24 indicated (red curve), are read from fig. 2.2 up to Mach 0.8 and remain constant above.
- Max lift with SOUA/СОУА (true AoA < 16.75°) is the green curve

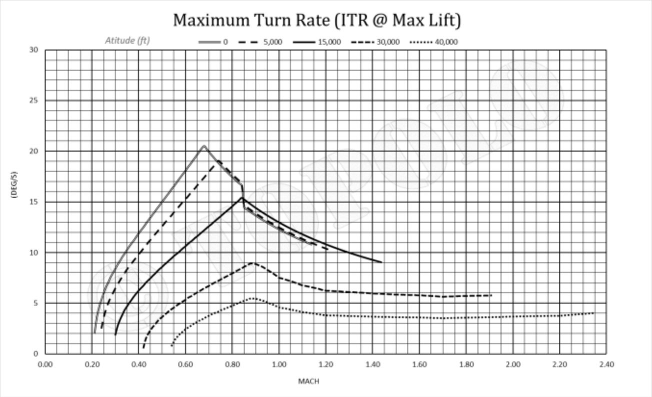


With SOUA/СОУА activated, the maximum lift coefficient (CL) with wing swept at 45° (0.953 at Mach 0.8) is higher than the one provided with wing swept at 72° (0.833 at Mach 0.90). As they also share the same load factor limitations, we can forecast better performances in term of stall speed, maximum instantaneous load factor, turn rate and turn radius.



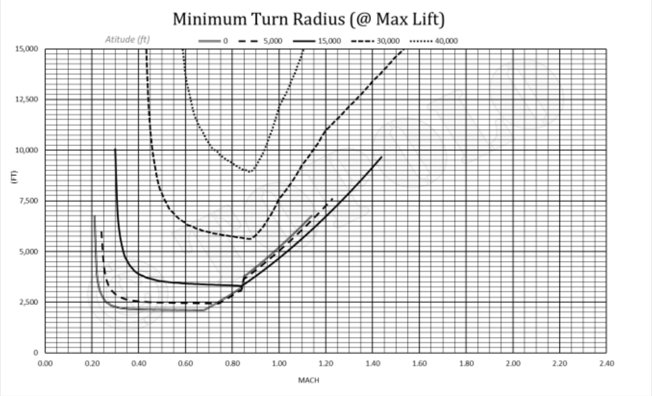
Stall speed at 1G is around 140-160 KCAS (260-300 km/h). At low altitude 8.5G can be reached (speed required to reach it is lower than M0.85) around 450 KCAS (835 km/h). At 15,000ft, maximum possible load factor (7.5G) is reached at 430 KCAS (800 km/h or Mach 0.84).

When we look at turn rate (instead of load factor), we get, with: 20.5°/s at SL, 19°/s at 5,000ft, 15.4°/s at 15,000ft



Therefore, we can already state that these maximum values are a bit below the "light" fighters of this period: F-5E, Mirage-III, MiG-21 (20-22 °/s at 5,000ft) and a bit better than the F-4E-Blk50 (17°/s).

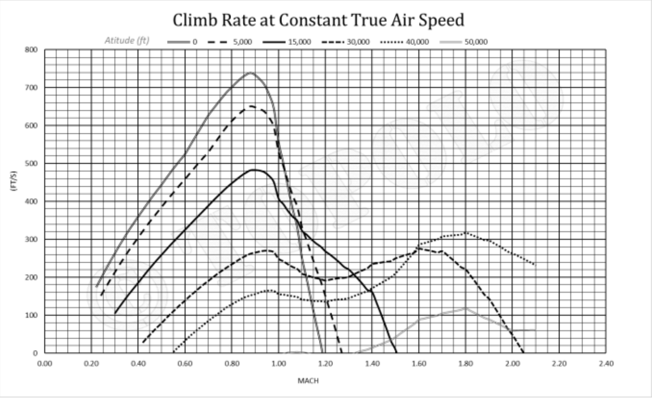
The minimum turn radius is always greater than 2,300ft at sea level.



- Acceleration and Climb

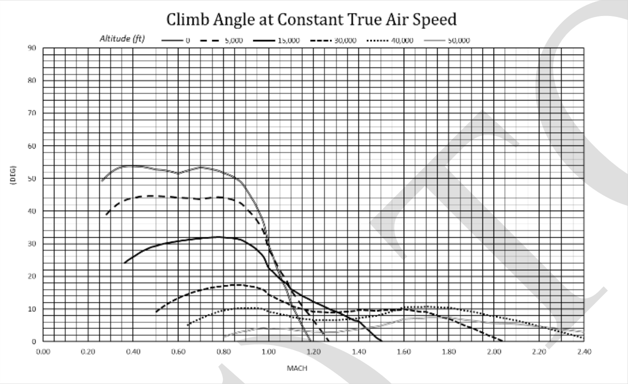
The instantaneous climb rate (Excess Specific Power) at 1G with wing swept to 45° shows values very similar to those with wing fully swept back until speed remain subsonic.

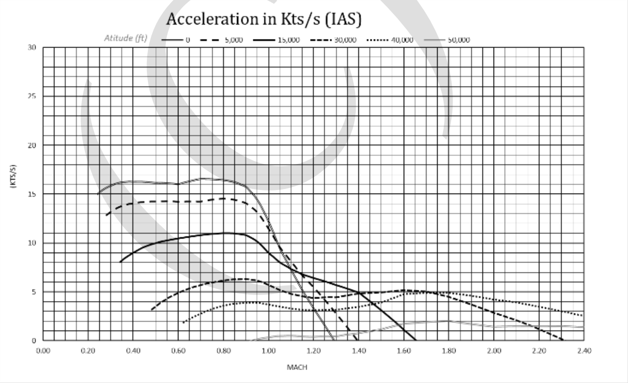
Here is the figure computed with the SOUA engaged and the regular combat configuration (but the SOUA system has no influence at all on climb or acceleration performances as they are reached at very low angle of attack)



This climb rate of the MiG-23ML being on par with the best performer (F-4E Blk41) in the vertical plane.

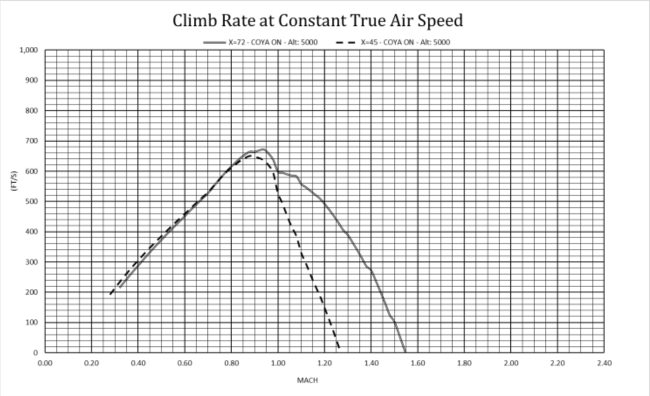
Then we can deduce the corresponding constant speed climb angle and the level flight instantaneous acceleration:

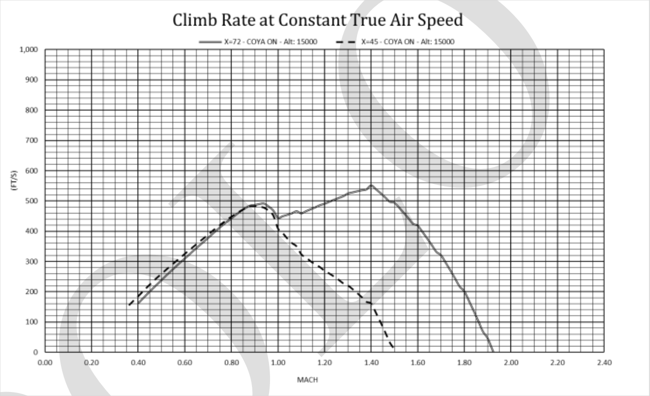


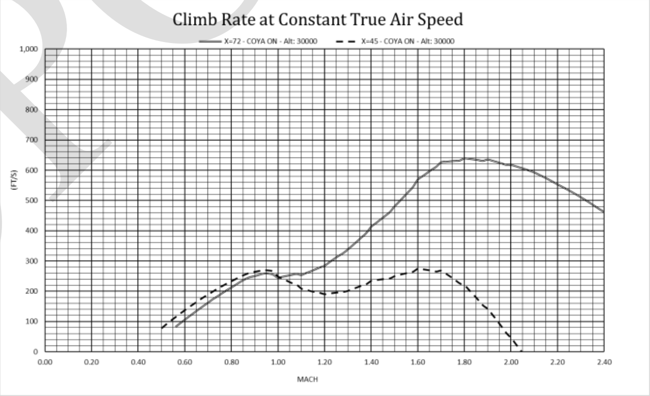


If we compare the Excess Specific Power with wing swept at 45 and 72°, we can see that the difference occurs only in supersonic speed range, and consequently has no importance in close air combat (Ps is the key factor when close air combat is performed in the vertical plane)

Compared values are displayed in the figures below:

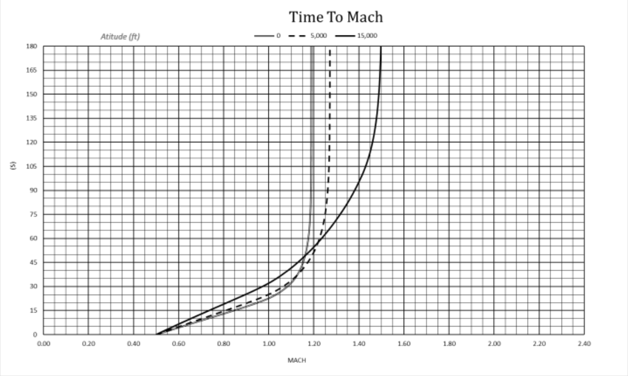


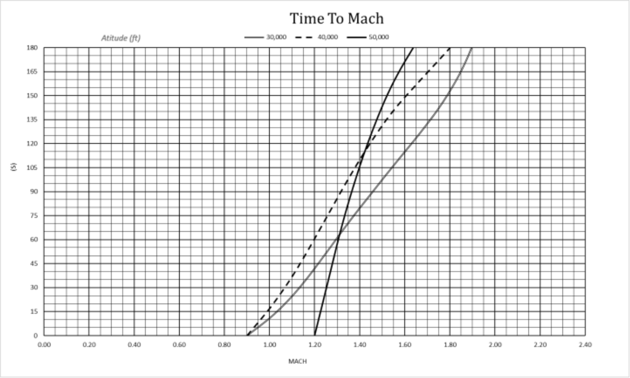




Now, we can compute the time to accelerate from a given Mach number to a greater one keeping the constant altitude.

In this context Excess Specific Power in supersonic regime become dimensioning and the computed performances with a sweep angle of 45° are significantly lower than with the wings fully swept backward.

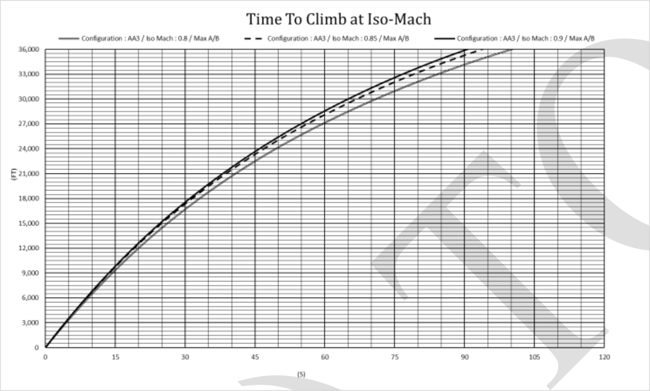




At sea level, starting from M0.5, VNE is reached in 41s (compared to the 30s with wings swept fully back), it take more than a minute at 5,000ft, a bit less than 1’40’’ at 15,000ft, and does not happen after 3’ at 30,000ft and higher.

MiG-23ML can go vertical in close air combat against any opponent of the 70s in keeping his wing swept at 45°, but as soon as it needs to break the fight or to catch a target, the best solution is clearly to set wings level and sweep them back to 72° to go supersonic.

When it comes to time required to climb to a given altitude bellow 36,000ft, performance with wing swept at 45° or 72° are not very different:

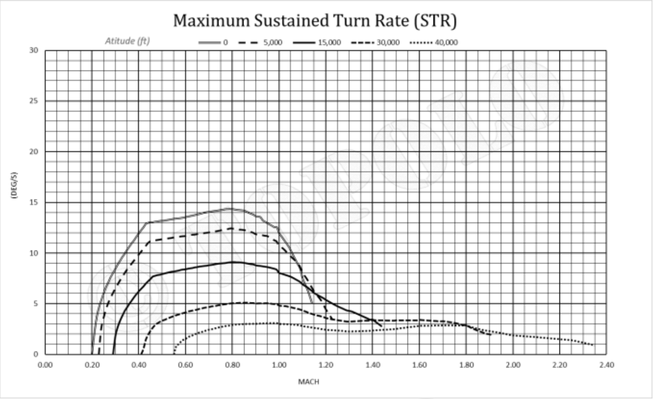


With wing swept at 45°, the best climb is achieved at Mach 0.9 and 36,000ft is reached in 91s (90s wings swept fully back), so if the target altitude is bellow tropopause, there is no need to change, wing sweep angle.

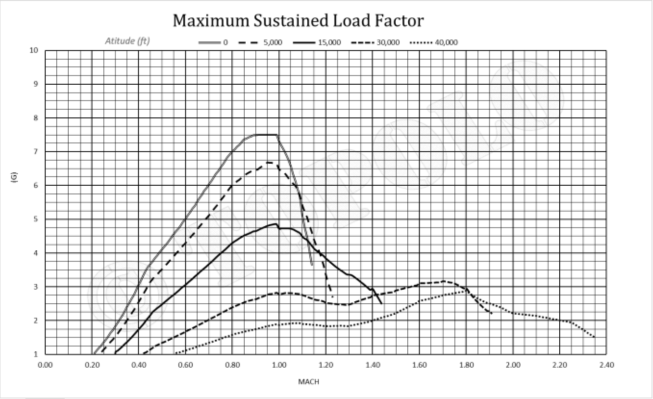
As soon as higher altitude is targeted, a supersonic climb is required, and in that case, sweeping the wings fully back is a must.

- Sustained Turn rate

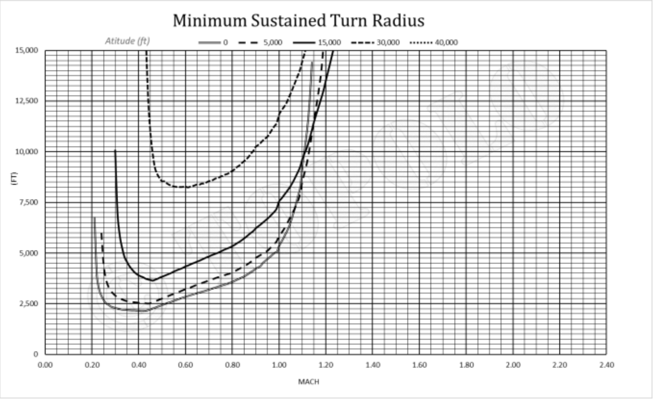
As expected, MiG-23ML sustained turn rate is close to the average value of the fighters of the 70s: 14.3°/s at sea level, 12.4°/s at 5,000ft and 9°/s at 15,000ft.



Maximum sustained load factor also shows that the load factor limitation has no impact above 5,000ft (performance at sea level not being really representative of actual combat).

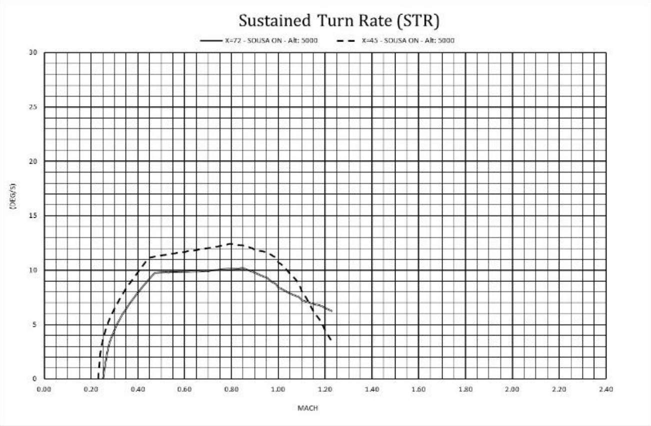


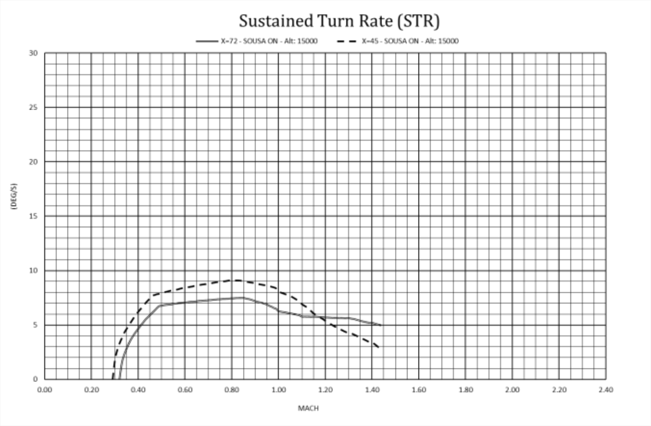
But as maximum sustained turn rate is reached at quite high speed (close to M0.8), this gives a quite poor minimum sustained turn radius:

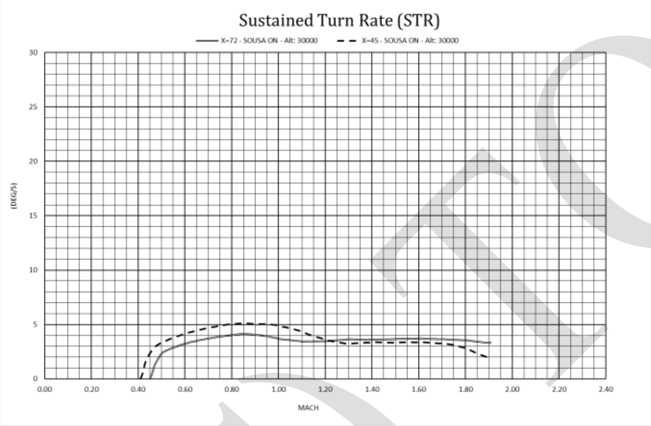


With more than 2,500ft at an altitude of 5,000ft, MiG-23ML is equivalent to the best F-4 (between 2,500ft and 3,000ft), and worse than all lighter planes (all able to sustain turn radius of 2,000ft or less at this altitude).

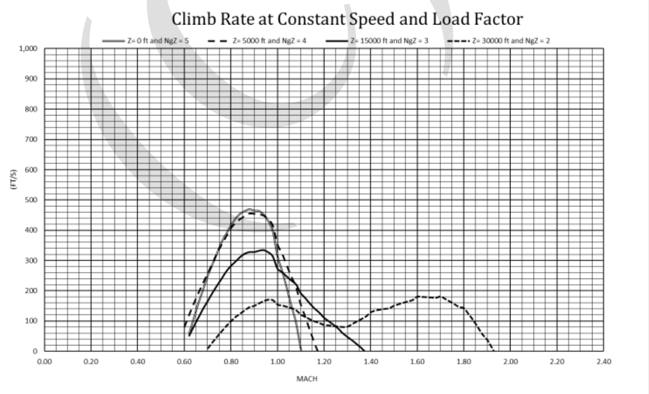
When it comes to comparison of the sustained turn rate with sweep angle of 45° and with wings fully swept, the above figure clearly shows that 45° is the best choice over the entire subsonic domain at all altitude:







- Climbing Turn



At low altitude (5,000ft) and turning at 4G, the MiG-23ML can still climb at 460 ft/s, on par with the F-4E blk41 (non-slatted) and far above all others 280ft/s for Mirage 5, 311 ft/s for the F-5E and 342ft/s for the slatted F-4E blk50.

Situation is similar at 15,000ft and 3G, the MiG-23ML can climb at 335 ft/s (a bit slower than the 361 ft/s of the F-4E blk41) but faster than the F-4E blk50 (301 ft/s) or Mirage III/5 (200-211 ft/s).

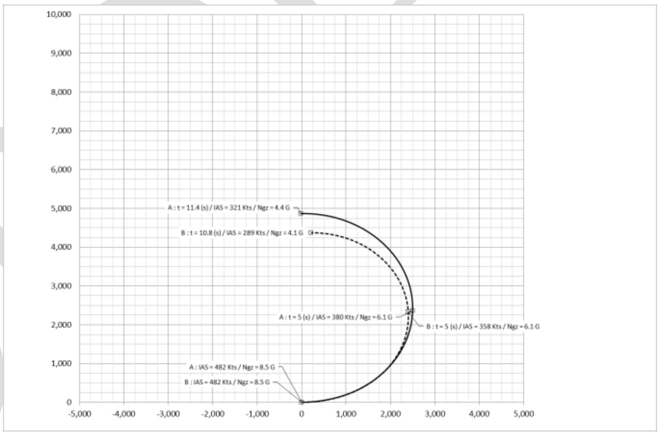
At 30,000ft, with 175-180 ft/s under 2G (at M0.9 or M1.7) the MiG-23ML is also close to the top: the F-4E blk41 is the best with 205 ft/s but the MiG-23ML is above all others.

In such a configuration, the MiG-23ML is clearly one of the best in the oblique plan (compared to the other fighters of the 70s)

- Quickest Half Turn

At 5,000ft

At this altitude, without overshooting the SOUA/СОУА AoA limiter (A), the quickest half turn is performed with an initial speed of M0.79/478Kts IAS in 11.4s. One can imagine win 0.6s in flying above maximum enforced AoA (B) with a high risk of departure.



This is better than the F-4E (between 13 and 13.8s), and close to the Mirage III and MiG-21 (around 12s).

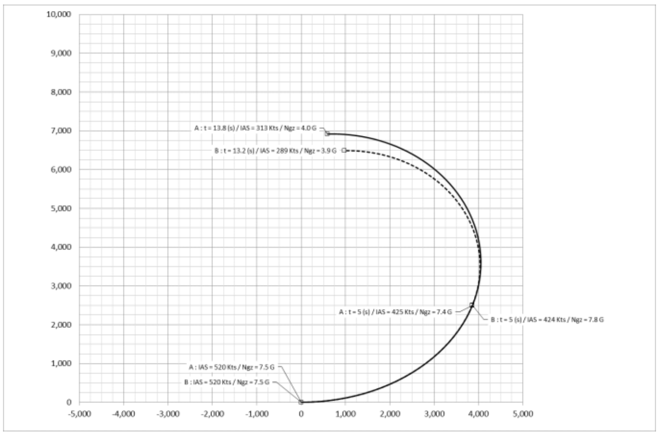
We also can see that these performances are not better that the 11.30s reached with wing swept at 72°.

But, if the half turn is performed at the merge of the dogfight, where sustained turn rate will become the most significant performance, knowing that the wing sweep angle cannot be changed once the turn is started, pilot, in fact, has no real choice, and needs to position his wing to 45°.

At 15,000ft

At 15,000ft, like with wing swept at 72°, computations give a quickest half turn with initial speed far above M1.0, which is quite irrelevant as the computation method is not able to handle the particular plane behavior of a high-G transonic turn (hard to control pitch up or wing drop).

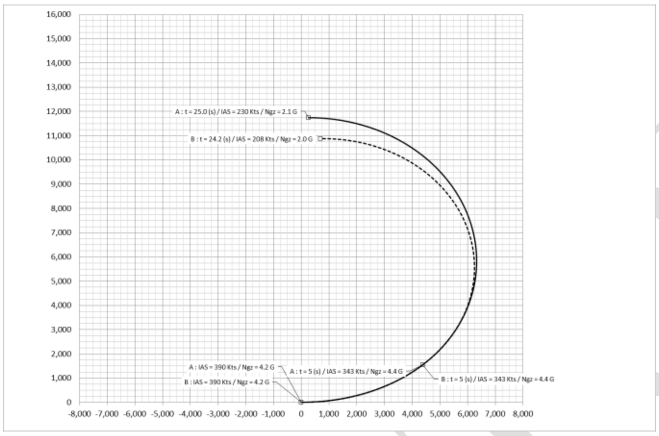
To stay inside relevant domain, we will consider half turn started at M1.0/520Kts IAS. In that case, half turn is completed in 13.8s with SOUA/СОУА (A) or 13.2s without. Which is better than the F-4E, non-slatted (16.6s), or even with leading edge slats (15.4s), but slower than the Mirage III (between 12.4 and 13s), the MiG-21 (between 13.2 and 14.2s) and the F-5E-3 (11.80s).



If this hard turn has been performed with then wings swept at 72°, it would have taken half a 1.4s more (15.2s instead of 13.8s, not really significant), and would have let the pilot in a much less comfortable situation for the dogfight to follow.

At 30,000ft

Of course, the problem of the initial speed giving the quickest turn is the same as that at 15,000ft and for the same reason, we will stick to initial speed of M1.0



The half turn is completed in 25s, similar to those of the F-4E (between 26.2 and 30.0s), faster than the F-4D (32s), but much slower than the MiG-21MF (22.6s) or the Mirage IIIC (22.2s).

At this altitude, there is not a large difference (< 2s or 8%) for the time required with wings fully swept back (26.8s).

G. Performance with X=16°.

This configuration, with wings fully swept forward is not the one recommended for air combat, but against very slow targets.

But, due to a very high Lift to Drag ratio, this configuration provides the MiG-23ML with very high performances, especially when it comes to sustained turn rate, the well-known key capability for close air combat.

- Maximum Lift Turn

The fig.2.2 gives the lift coefficient (CL) law for Mach numbers between 0.3 and 0.6, the fig.2.3 for the SOUA system (AoA limiter) gives the maximum reachable CL, so we can build a maximum reachable lift.
See above Fig. 2.3 restricted to X=16° and Mach >=0.8

- Maximum lift AoA can be theoretically reached (we choose 17° of true AoA) if SOUA/СОУА is not engaged.
- Lift (CL) at 17° of true AoA (orange curve) and at 11.75° of true AoA /18 indicated (red curve).
- Max lift with SOUA/СОУА (true AoA < 12.75°) is the green curve

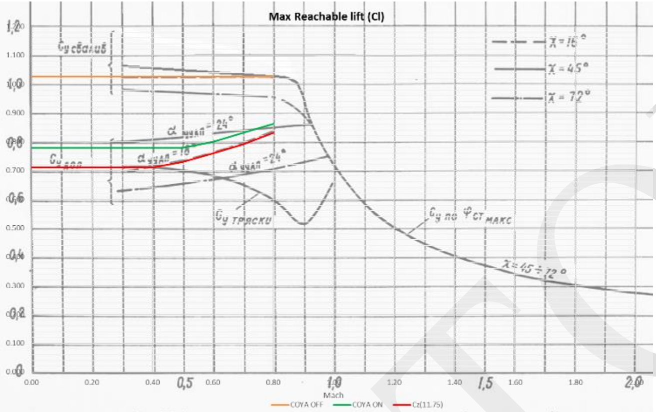
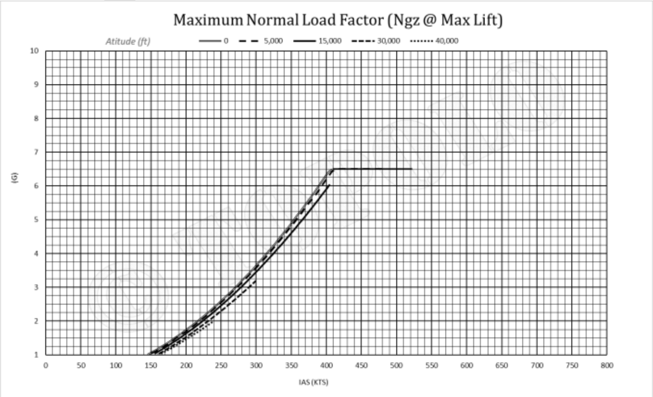


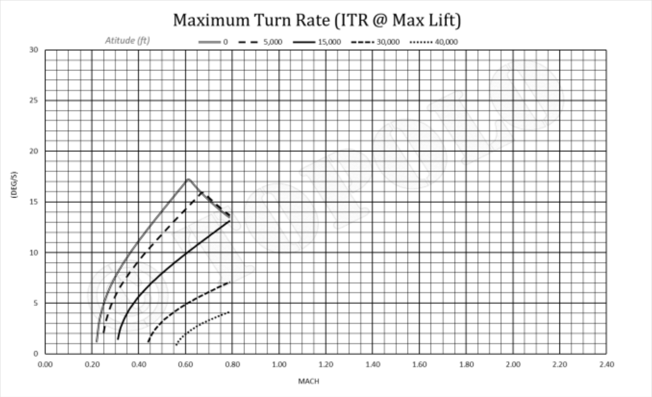
Рис. 2.3. Зависимость располагаемого коэффициента подъемной силы от числа M полета

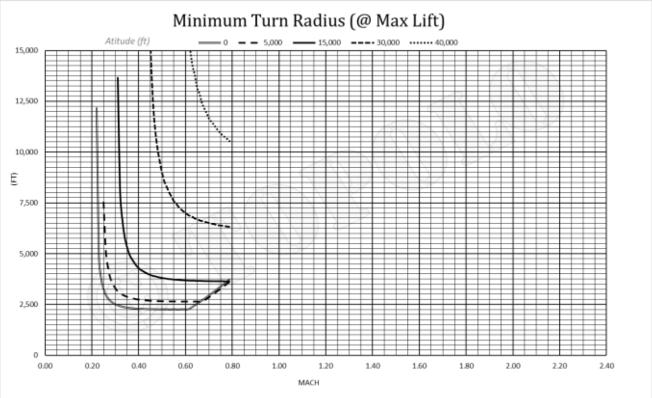
We can see that the SOUA limitation of 12.75 degrees AoA has a significant lift impact (0.86 instead of more than 1.02). But we have to keep in mind that, with wing swept full forward, the MiG-23ML has a sever yaw instability at high AoA, and thus is prone to departure, so lift with SOUA not engaged cannot be actually reached or at least kept when maneuvering.

The Normal Load factor is also very limited: 6.5g.



The stall speed (indicated) is between 140Kts (260km/h) and 160Kts (300km/h) depending on altitude. But with such a wing sweep angle, it is possible to use the flaps and so to significantly decrease stall speed.





So, at 5,000ft with a maximum turn rate of 17°/s and more than 2,500ft of radius, the MiG-23ML is worse than the F-5E by 4°/s and just equal to the slatted F-4E.

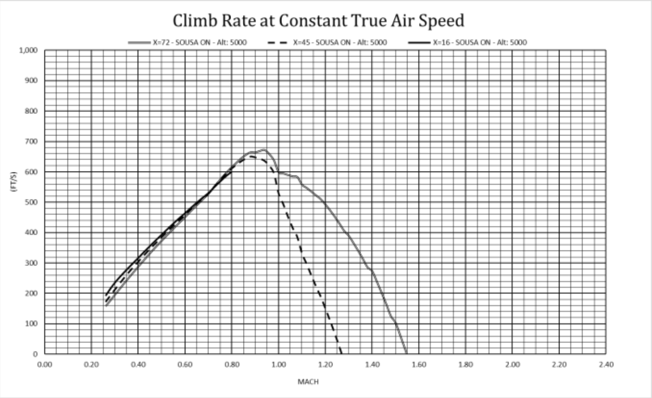
At higher level (30,000ft), with only 7°/s, the Mig-23ML is worse by 7°/s compared to the F-5E and 4°/s to the slatted F-4E.

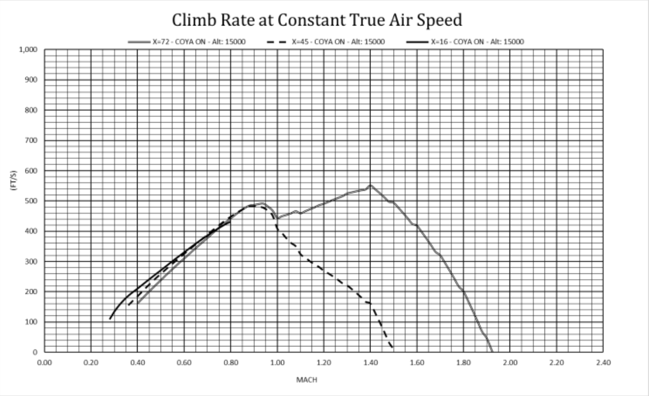
The reason for these poor values is not only linked to the lack of lift (consequence of very limited AoA to avoid yaw instability), even but more to the load factor limitation of 6.5G and the Mach limitation (at least at high altitude). The load factor limitation impact even more the F-4E turning capability when loaded with AIM-9, but in case of the MiG, it does not depend on the loaded weapon, but on the main wing box rigidity. Overshooting this limit may lead to wing sweep device failure, so at best, you have a slow subsonic fighter, or worse, you may have only one wing swept back, leading to a very unsafe situation.

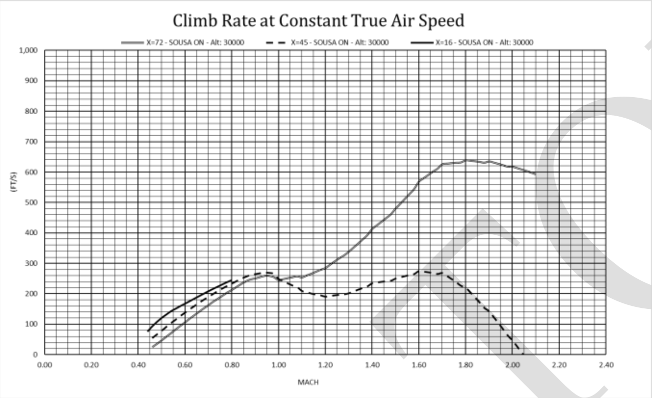
That means that the better lift capabilities provided by sweeping the wing forward gives the advantage only when load factor limit is not reached, or in other words, below 320 knots indicated. As soon as you exceed this speed you should sweep the wings a bit back, allowing you to pull more Gs.

- Acceleration and Climb

If we look at constant speed climb rate (excess specific power) with wing swept at 16° compared to those with wings partially or fully swept back, we can see that, even in that domain, there is no benefit (or a small one) compared to wings swept back below Mach 0.8.





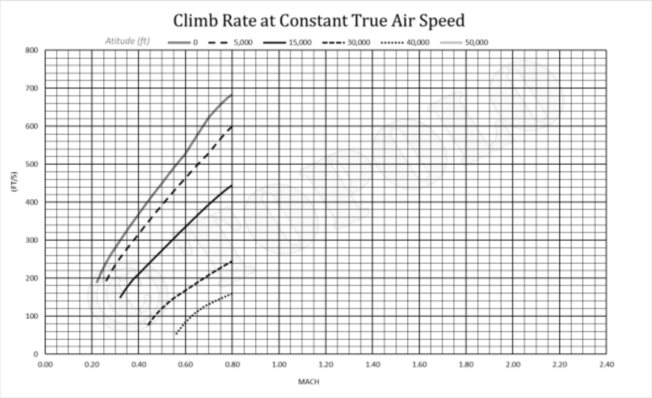


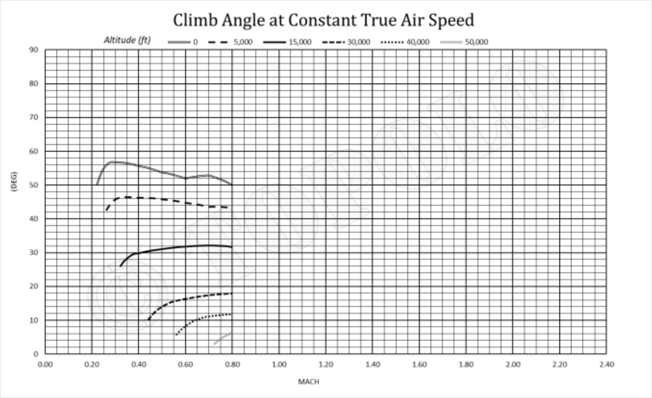
But what we can also see is that then optimum climb speed is always above M0.8.

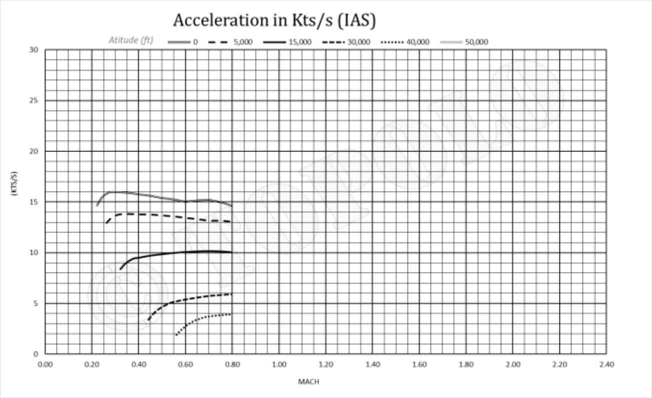
So, in terms of maneuvering capabilities in the vertical plane at speeds below M0.8, there is no advantage in sweeping the wing back… but, if you want to reach a higher flight level, it is always better to sweep the wings back to 45 or 72, accelerate to M0.9 and then climb.

The following figures are only to be considered to reflect acceleration and vertical maneuvering capabilities that are still very high compared to other fighters.

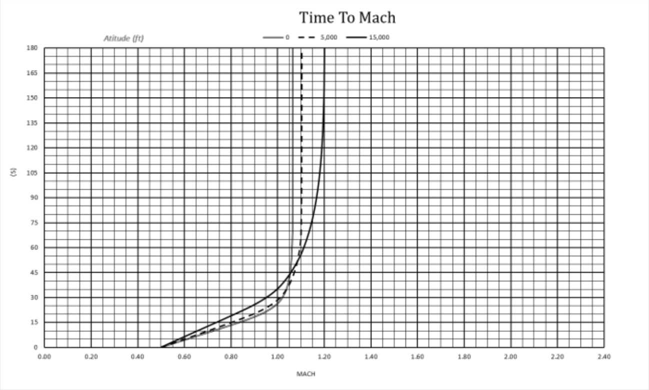
From 5,000ft to 30,000ft, no one but the F-4 has a better climb rate or acceleration. In the vertical plane at low speed the MiG-23ML with wings swept at 16° outclasses any Mirage III/5, F-5 or MiG-21.







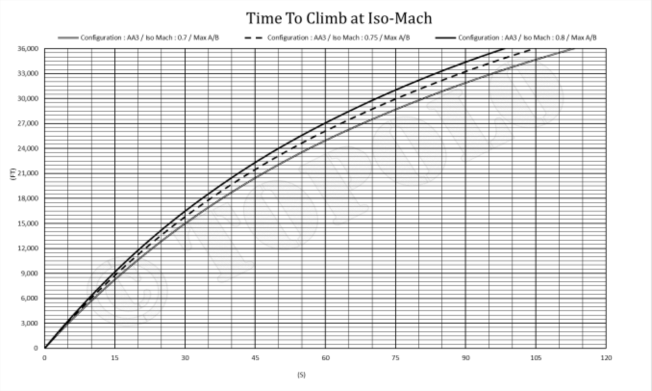
Since keeping wings swept to 16° is never the best solution to accelerate, the following figures are in fact only useful to understand how much time it takes to overshoot speed limitations if pilot keeps after burner on.



At low level, starting from M0.5, it takes less than 15s to reach M0.8 (at 1G level flight). At 30,000ft, it takes 33s.

This clearly indicates how difficult it would have been to stay in a dogfight with wings swept forward and after-burner engaged: up to 15,000ft, you need to keep nose up more than 30° or pull high G not to damage the plane.

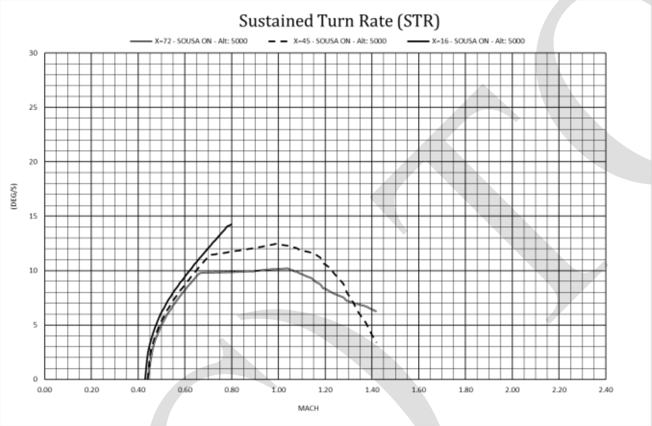
On the other hand, the figure below also shows that time required to climb is not significantly higher than with wings swept back.

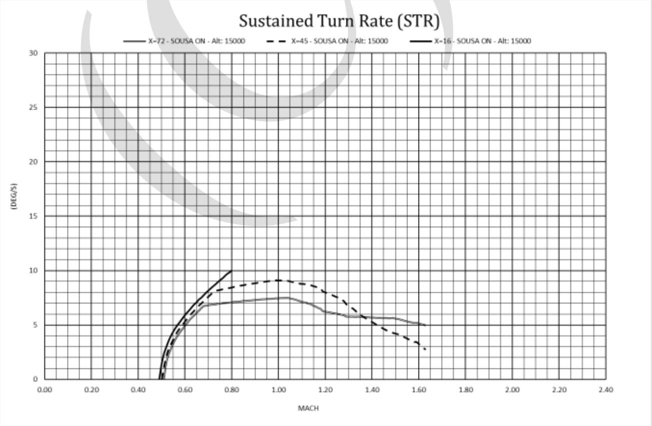


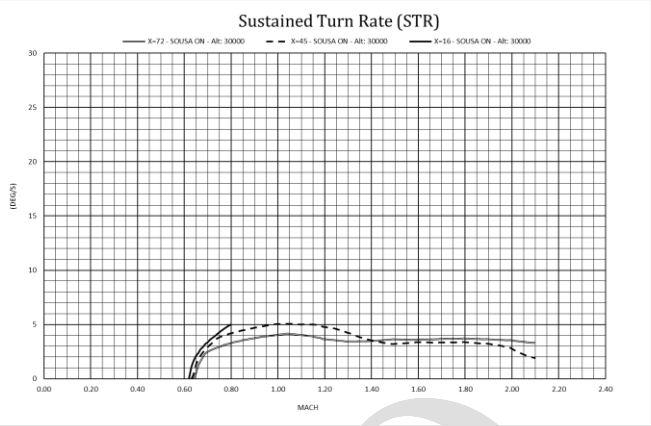
- Sustained Turn

When it comes to sustained turn rate, the figures below show that, at all altitudes, the MiG-23ML turns much faster with wings swept forward than in any other configuration.

The 3 figures below compare maximum sustained turn rate with the different wing sweep angles (16, 45 and 72°) at low, medium and high flight level (respectively 5,000ft, 15,000ft and 30,000ft).

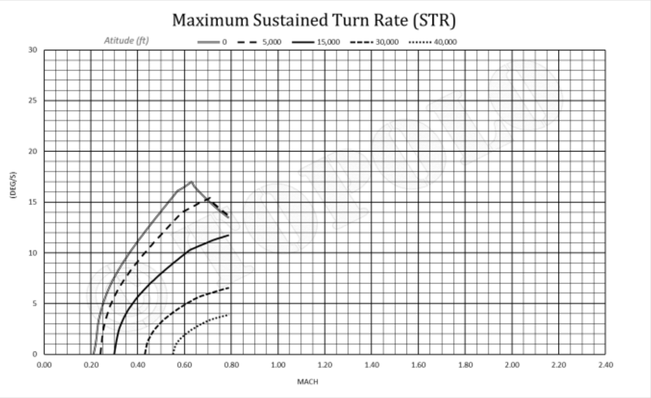






Maximum values achieved with wing swept at 16° are 1° (high altitude) to 2.5° (low altitude) higher (value considered as a significant advantage in combat) than with the X=45° (recommended configuration for air combat) and most significant benefit is obtained between M0.7 and M0.8 at low or medium altitude (+1.5-2.5 °/s)

Max sustained turn rate at all altitudes with wing swept at 16° and AoA limiter (СОУА/SOUA) engaged are described in the figured below:



If we compare maximum values with other fighters of the same era (late 60s up to mid 70s), they are at least 1°/s higher (better) than for the F-5E-3, F-4EBlk50, MiG-21 or Mirage III/5.

Maximum (17°/s at SL, 15.5°/s at 5,000ft, 12°/s at 15,000ft) are close to those of F-14A and 3 or 5°/s lower than for a clean F-15A, F-16A or MiG-29A (iz.9.12).

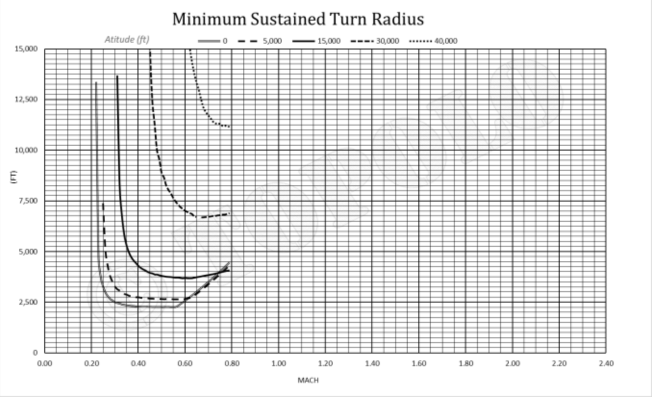
This would have make the MiG-23ML with wing swept at 16° a bit ahead of other fighter of its generation even if significantly below the next one (F-15/F-16/MiG-29…).

The problem is that superior sustained turn rate is available only in a plane configuration that limit the speed to M0.8, so engaging a turn fight in these condition may allow to turn faster than the opponent, but only if he does not accelerate.

That is the main concern of the military value of the full forward wing (16°) configuration: even if it provide the best climb rate and the best sustained turn rate, it will not allow to keep the contact (and the firing range) with the target because you will always be 60Kts-100km/h slower (at least).

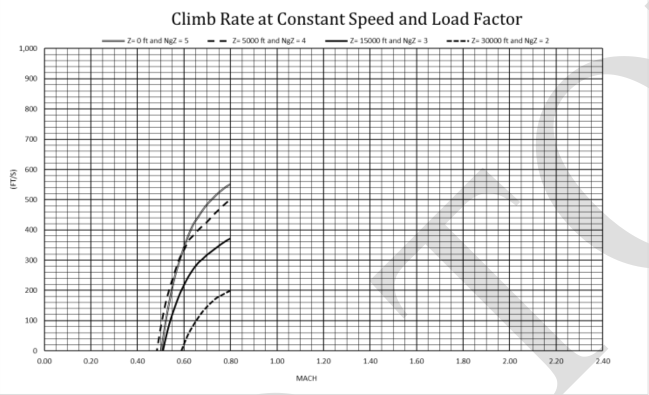
In addition, the fact is that above 350/370Kts with A/B engaged, pilot cannot stay inside load factor and speed limits, even at max load factor (+5.5), plane still accelerates and will exceed M0.8 very soon (if not climbing of course).

With 2,500ft of minimum sustained turn radius at 5,000ft (see figure below), the MiG-23ML with wings fully forward is behind Mirage III/5, F-5E or MiG-21 (all between 1,900 and 2,100ft), but better than any F-4 (between 2,600 and 3,000ft). The relative position of all aircrafts remains the same at 15,000ft and 30,000ft.



- Climbing Turn

At all altitudes, the MiG-23ML is superior to any of its opponents in the oblique plan.



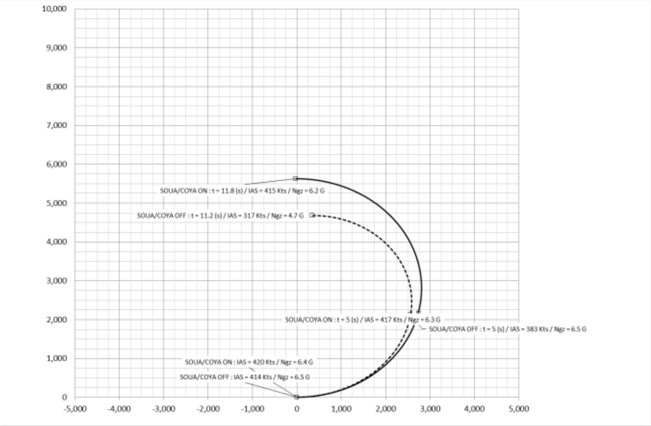
At 5,000ft/4G, all of them have a possible climb rate between 1/2 and 2/3 of the 500ft/s of the MiG-23. Under 4G, the MiG-23ML climbs almost twice faster than the Mirage III/5 or the MiG-21 in a straight forward climb….

Situation is the same at medium altitude (15,000ft) and becomes a bit more balanced (with the F-4 at least) at 30,000ft.

Turning climb is the domain where the superiority of the MiG-23ML with wings swept fully forward is the most obvious (and also the only way to keep the plane inside its flight domain : climb and turn hard, if you relax one of the two you will have to cut off after burner thrust not to damage the structure).

- Quickest half turn

At 5,000ft



In low level flight, with a quickest half turn in 11.8s, the MiG-23ML with wings swept forward is a faster than the 13s of the slatted F-4E Blk50 with AIM-9 (also limited to 5.5G) but slower than the 9.5-10.5s of the F-5E-3, MiG-21 and Mirage III/5.

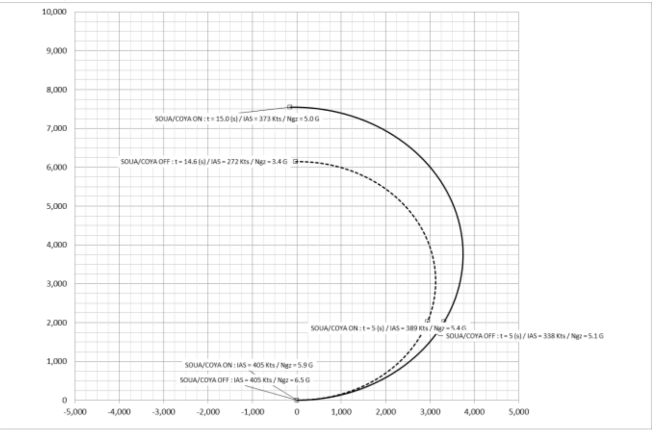
There are several explanations: first, the MIG-23 is limited to 6.5G, then it is limited in AoA (thus in lift) due to its yam instability, and finally it is limited in speed (M0.8).

For these reasons, the quickest half turn is completed in at slow speed compared to other planes (420Kts / M0.69).

We can also see that overshooting AoA limitation of the COYA/SOUA (pulling more than 18kg on the stick) does not allow to gain more than 0.6s, and even more lead to a half turn end at much lower speed and load factor, not a good idea to go on. And remind that due to yaw instability at high AoA, overshooting COYA/SOUA limits will probably lead to a departure more than to a sharper turn…

That also means that, even if the raw value is "average", in fact this performance is far from describing the MiG-23ML capability in a low level head-on merge: if your opponent sees you at such a low speed, he will never chose a high-G horizontal turn solution but will keep its energy and speed or will go into the vertical.

At 15,000ft



At medium altitude, the "over powered" behavior of the MiG-23ML with un-swept wings is less important, and the quickest half turn is performed from M0.79 (405 Kts IAS).

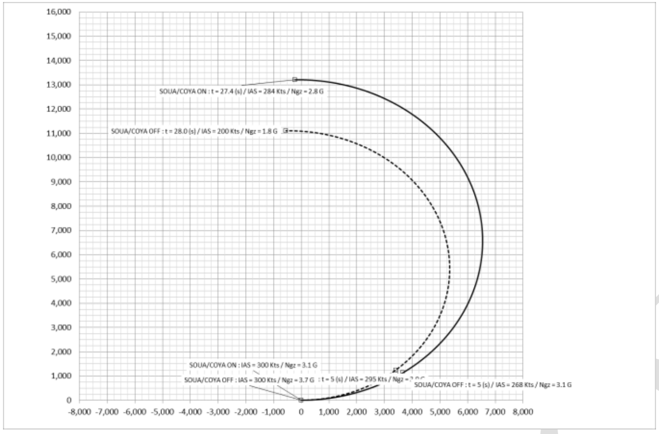
This is still slower than other aircraft, but not that far from a regular merge speed.

The SOUA/COУA impact is also low in time (+0.4s) and in addition to avoid departure, provide better end speed and load factor.

The time required (15s) is also closer, even if not on par, to the light fighters (11.8 for then F-5E, from 13.2 to 14.2 for then MiG-21, and from 12.5 to 13 for then Mirage III/5) and faster than the F-4 that is between 15.4 and 16.2s.

At this flight level, a low speed merge may be a good tactical solution, even if very easy to counter, as most opponents will usually try to keep the speed within diving to lower level during or just after the merge, what the MiG-23ML will not be able to follow due to its speed limitation (M0.8).

At 30,000ft



At high altitude, there is no more “over powered” situation but the MiG-23ML faces its Mach limitation.

Even if the 27.4s required to perform the 180deg turn are close to average between 22.2 for the Mirage IIIC and 32.0s for the F-4D, it must be said that at these flight levels, a speed limitation of M0.8 may prevent any pilot to engage a fight with wings swept forward.

- General comments on X=16° configuration.

There is no doubt that in such a configuration, the MiG-23ML performances in vertical, oblique and horizontal plan place it ahead of the other fighters of the late 60s – early 70s, but mainly (if not only) at low speed.

The two problems with this statement is that no air combat starts at low speed (or even at speed allowing the wings to be swept fully forward), and even if you can reach this portion of the flight domain, it is very difficult to stay inside as soon as you engage the after-burner (and a turn fight with only dry thrust is not an option).

For these two reasons, I believe that no MiG-23ML pilot would choose to sweep its wings fully forward to engage a visual range air combat against any high performance fighter. But he may choose to do that at high altitude when facing a low speed (subsonic) target.

H. Combat Performance charts

- CLIMB

INSTANTANEOUS CLIMB AT CONSTANT TRUE AIR SPEED

For each identified configuration, two main climb performances are detailed: Constant true air speed climb rate and angle.

The first one is the virtual vertical velocity (in ft/s), of the aircraft when load factor is 1G and true air speed (TAS) is constant, it is called the Specific Excess Power (Ps).

The second one describes the pitch angle (position of the FPM on the HUD ladder) corresponding to the vertical velocity from the first diagram.

Note that these values are lower than for Constant Mach Number Climb rate and angle below 36,000ft, because, as sound speed decreases with altitude, keep the Mach number constant during climb means the True air speed will decrease, consequently allowing for higher climb rates and angles.

Constant Indicated Air Speed (IAS) climb provides lower climb rate and angle as it requires an increase of the True during climb.

Figures are computed for the three wing sweep angles (16, 45 and 72°)

SUBSONIC ISO-MACH CLIMB SCHEDULE

This kind of diagram describes the time, distance and fuel required to climb to a given altitude, using maximum A/B thrust and an Iso-Mach flight profile.

This flight profile assumes the climb angle of the flight path is continuously adapted to keep the Mach number constant over time.

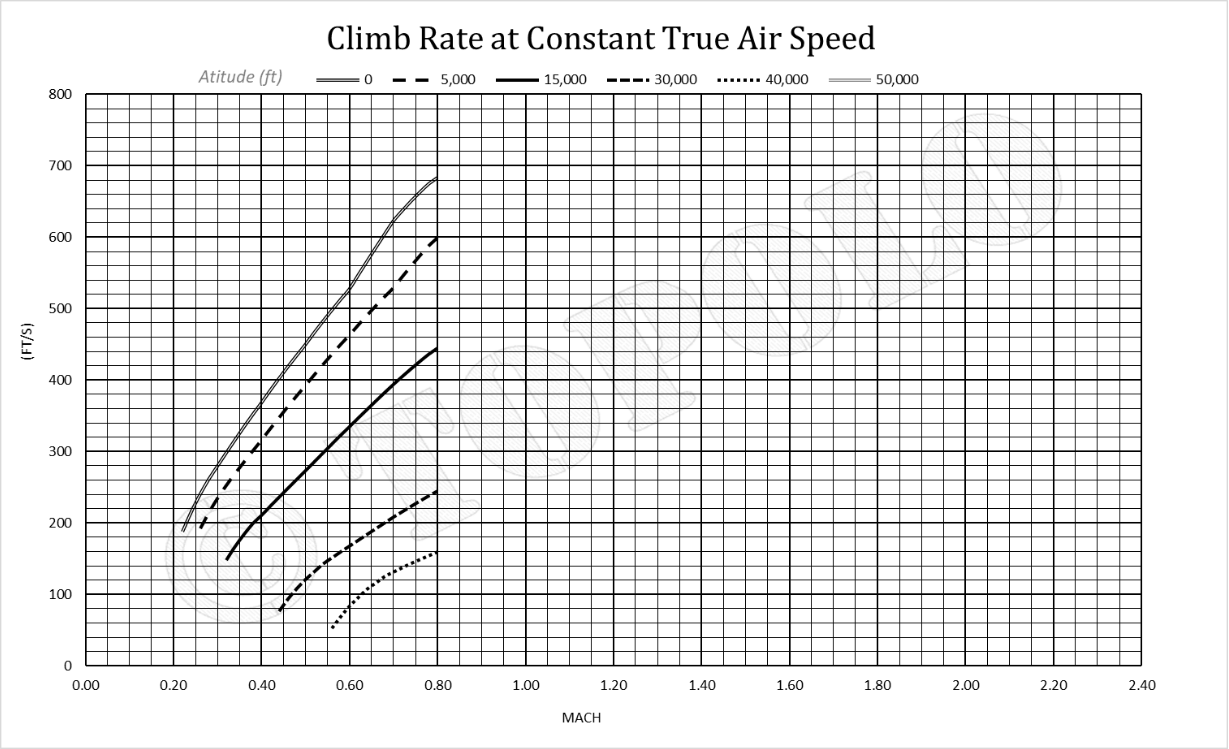
The values displayed in these diagrams do not take into account time, distance and fuel required to accelerate to the desired Mach number, nor to rotate from level flight to climb attitude.

Figures are computed for the three wing sweep angles (16, 45 and 72°).

Figure 1.1

Climb rate at constant True Air Speed

DATA BASIS : COMPUTED CONDITIONS: – Atmosphere : Standard Day / ISA – Engine regime: Max A/B – SOUA System : Engaged	AIRCRAFT : MiG-23ML izd.23-12A ENGINE: R35 Wing Swept Angle : 16° Loads : 2xR-60M/MK + 2xR-24R/T Gross Weight : 13,000 Kg / 28,697 lbs



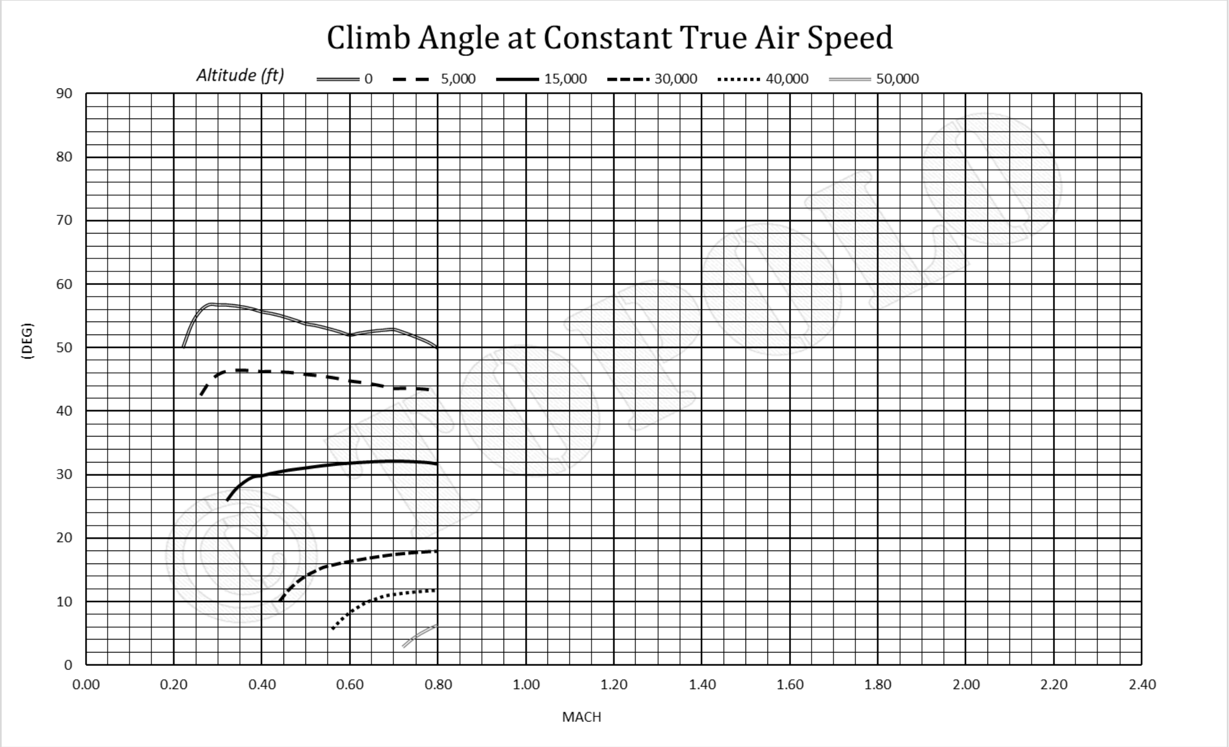


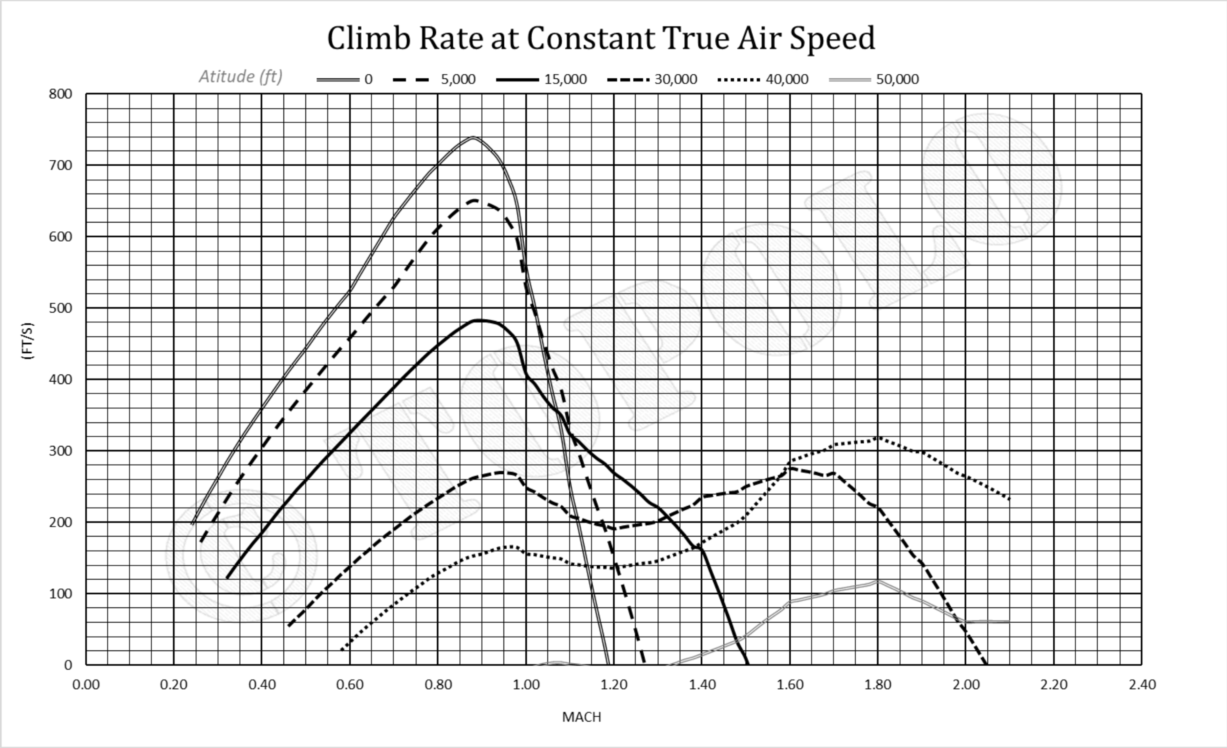
Figure 1.2

Climb rate at constant True Air Speed

DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs



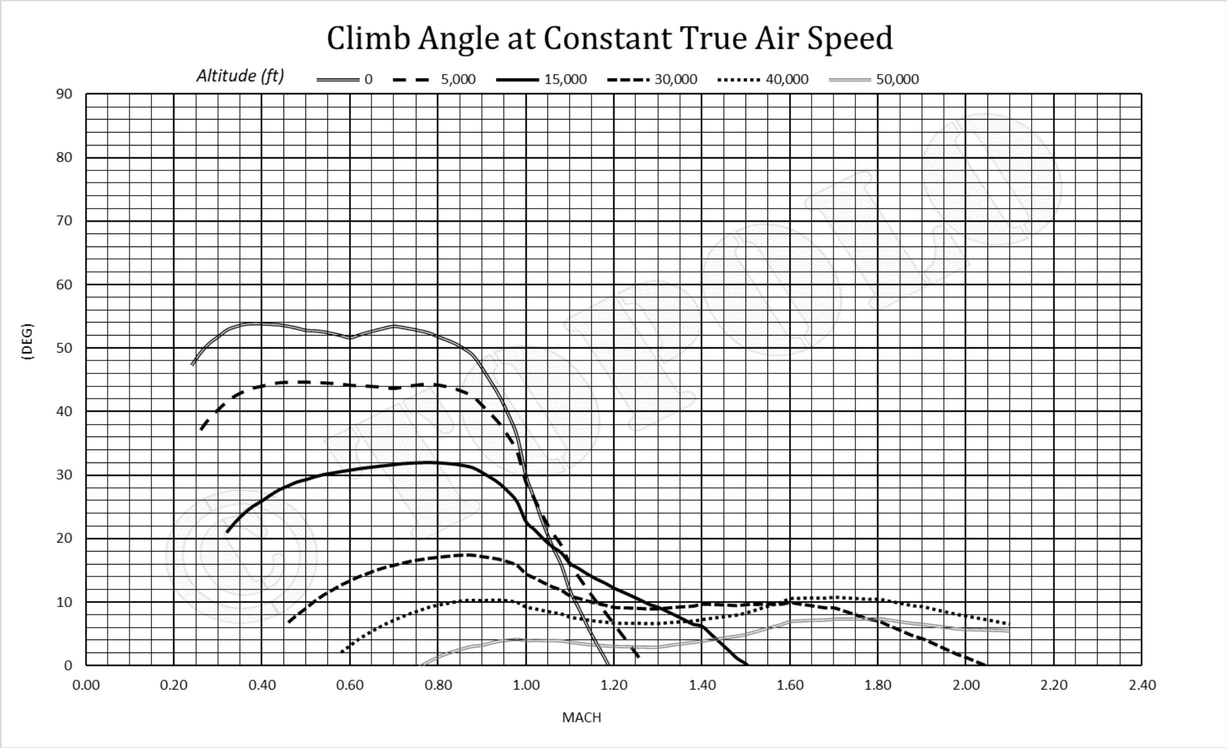
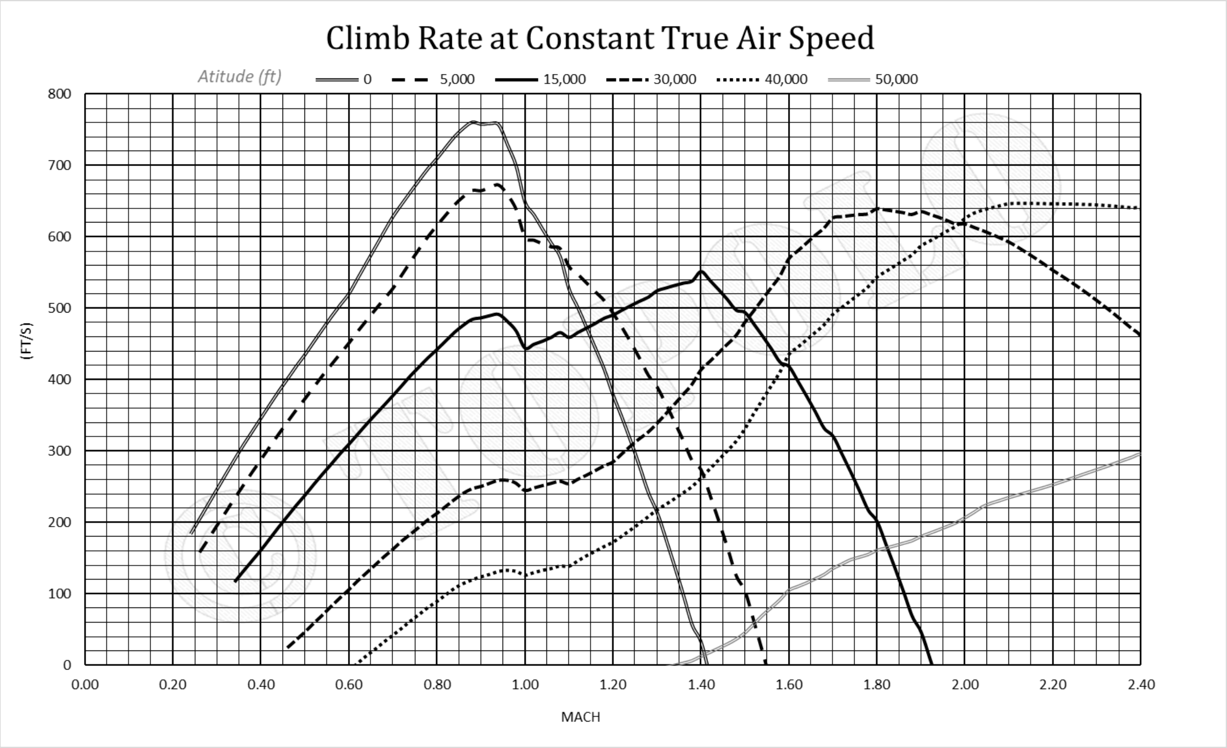


Figure 1.3

Climb rate at constant True Air Speed

DATA BASIS : COMPUTED CONDITIONS: – Atmosphere : Standard Day / ISA – Engine regime: Max A/B – SOUA System : Engaged	AIRCRAFT : MiG-23ML izd.23-12A ENGINE: R35 Wing Swept Angle : 72° Loads : 2xR-60M/MK + 2xR-24R/T Gross Weight : 13,000 Kg / 28,697 lbs



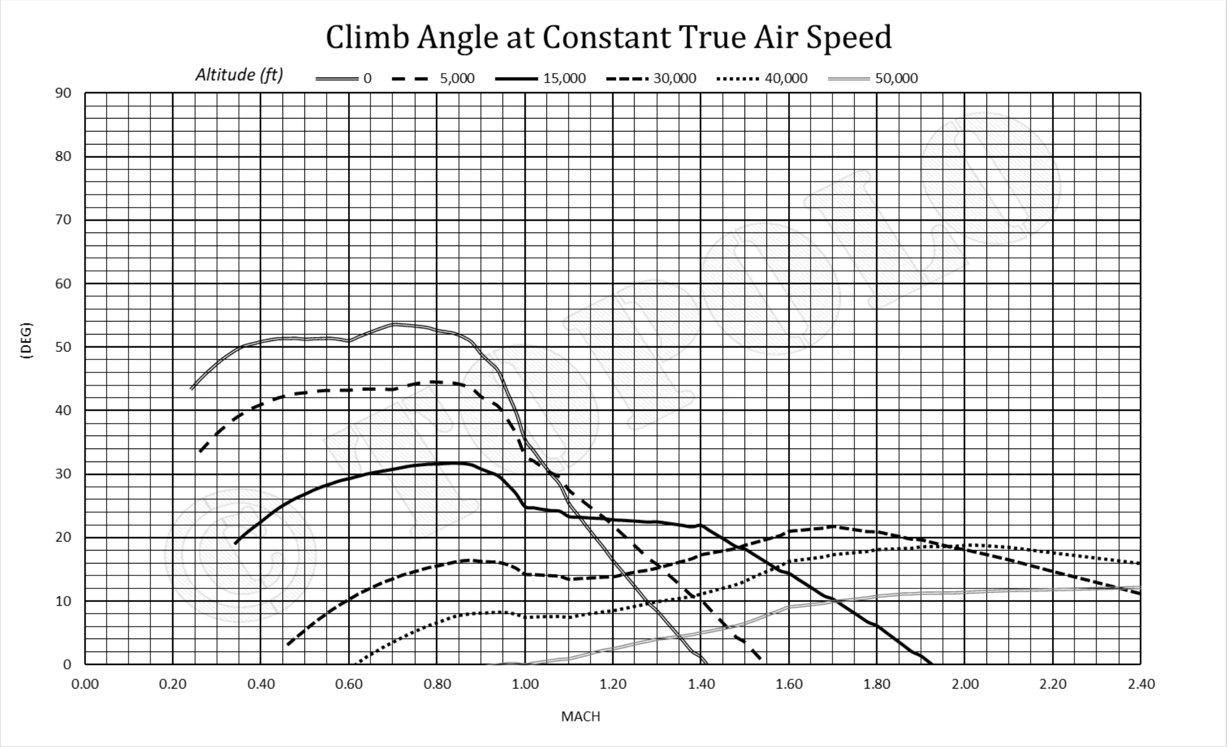


Figure 1.4

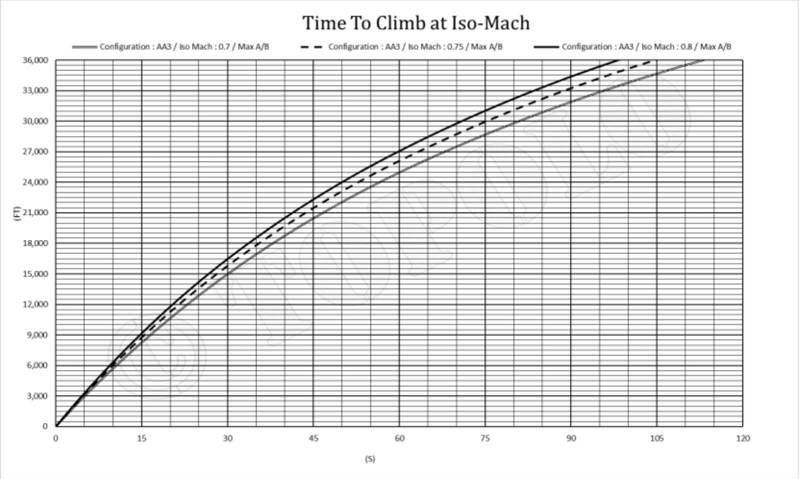
Climb Schedule at Iso Mach Number

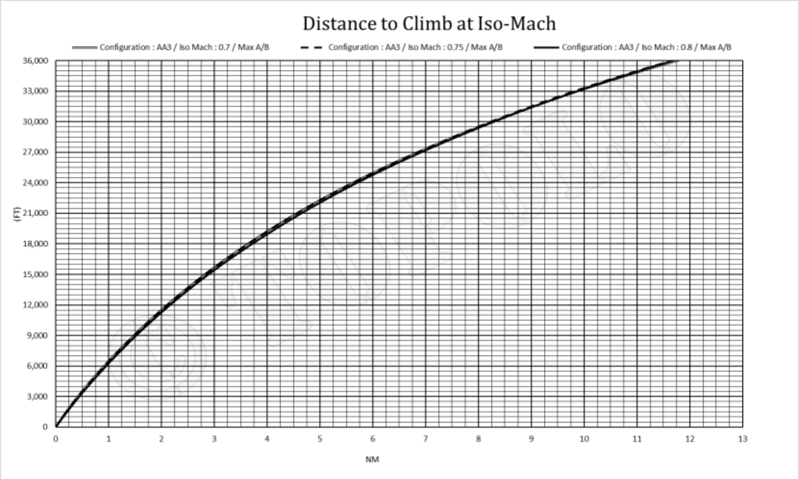
DATA BASIS : COMPUTED

CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 16°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs





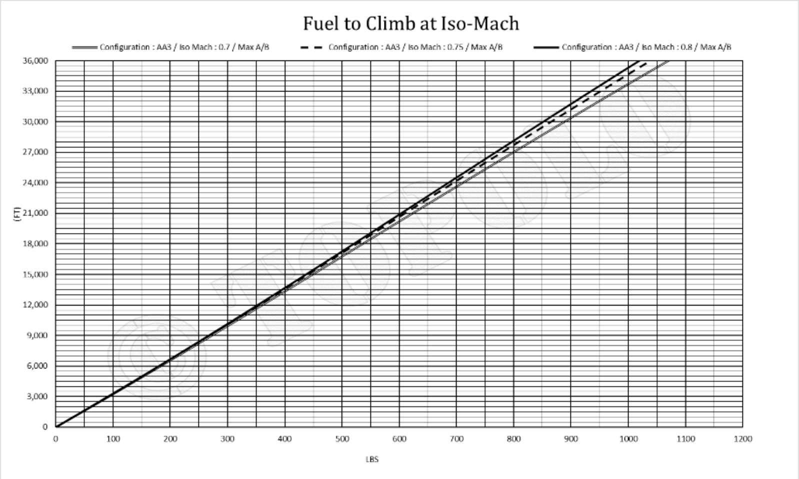
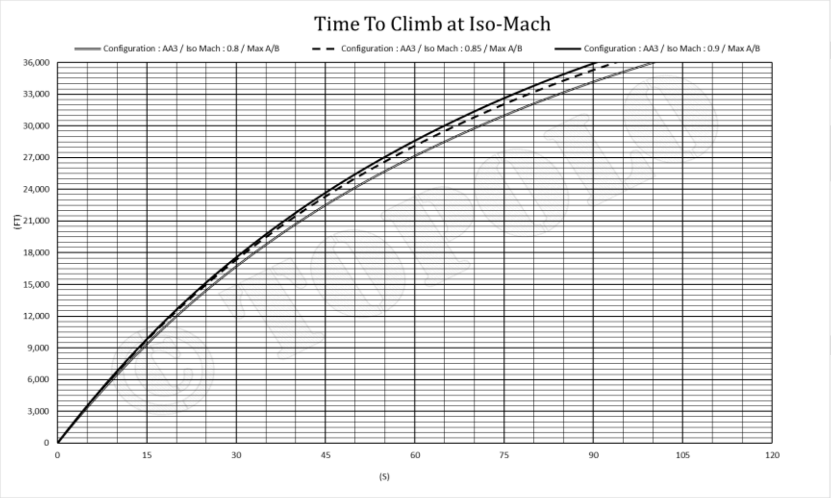
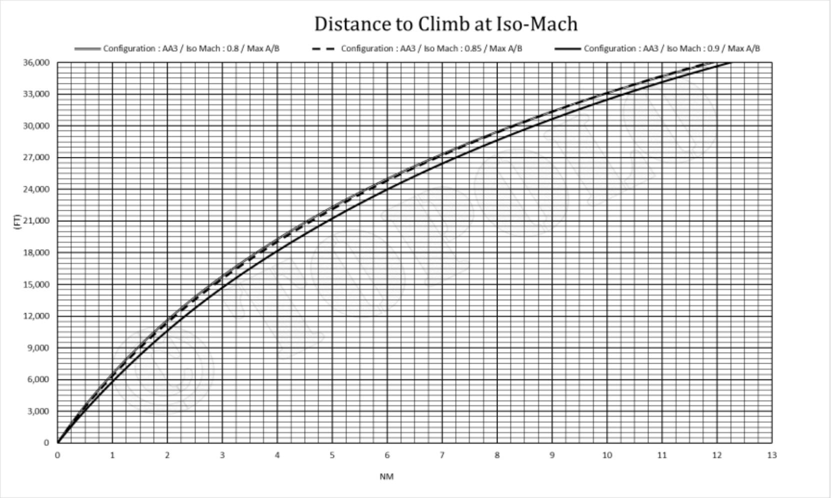


Figure 1.5

Climb Schedule at Iso Mach Number

DATA BASIS : COMPUTED CONDITIONS: – Atmosphere : Standard Day / ISA – Engine regime: Max A/B – SOUA System : Engaged	AIRCRAFT : MiG-23ML izd.23-12A ENGINE: R35 Wing Swept Angle : 45° Loads : 2xR-60M/MK + 2xR-24R/T Gross Weight : 13,000 Kg / 28,697 lbs





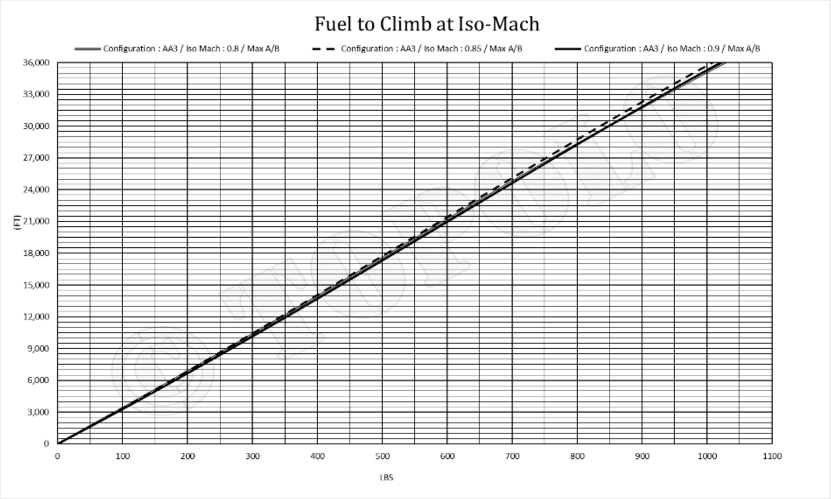
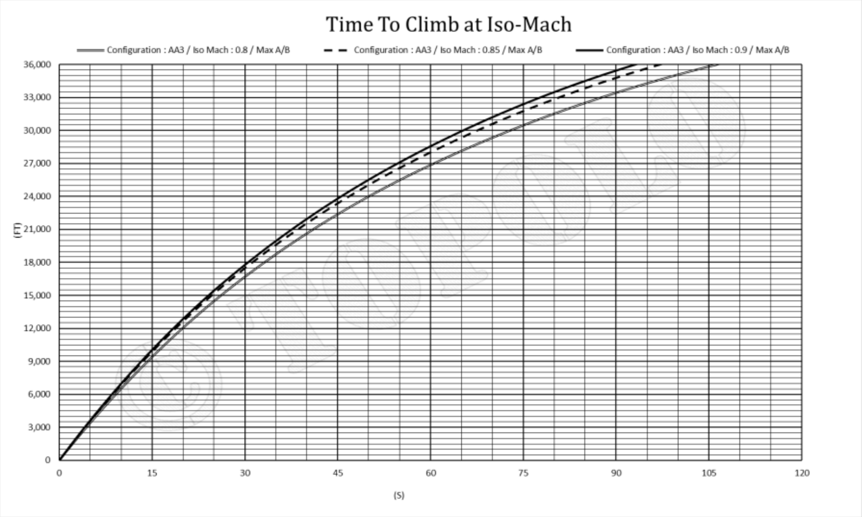


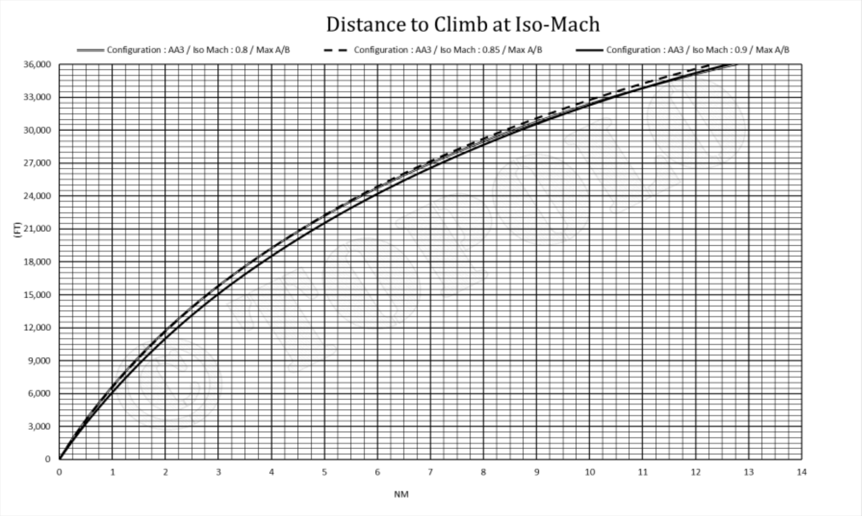
Figure 1.6

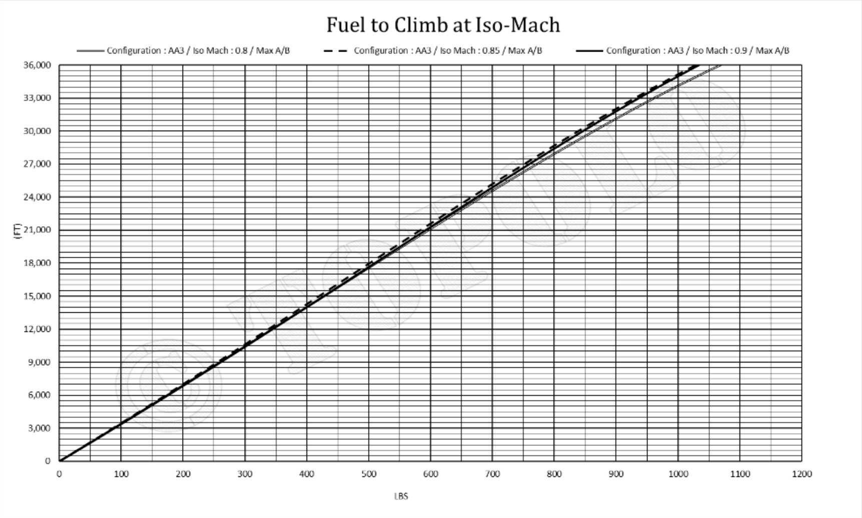
Climb Schedule at Iso Mach Number

DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 72°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs







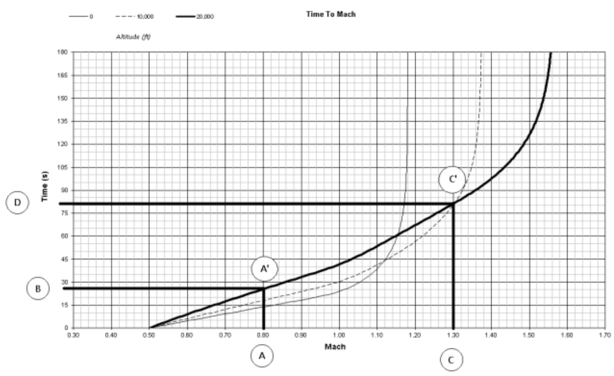
- ACCELERATION

This section present two acceleration figures:

- The first is the instantaneous acceleration (velocity increase in IAS Knots per second) in a 1G level flight.
- The second describes what happen during a 1G level acceleration run started at a given altitude, Mach number and gross weight: how much time, fuel and horizontal distance is required to reach a higher Mach number.

SAMPLE PROBLEM

Calculate time/distance to accelerate from M0.8 to M1.3 at 20,000ft ?



Step1 : enter the chart with initial Mach number (0.8) on horizontal axis (A), proceed vertically up to the curve related to desired altitude: 20,000ft (A’), then go horizontally to the vertical axis and read the start time (B) : 25s

Step 2: enter the chart with final Mach number (1.3) on horizontal axis (C), proceed vertically up to the curve related to the desired altitude: 20,000ft (C’), then go horizontally to the vertical axis and read the finish time (D): 80s.

Step 3: Compute then difference between then finish and start values; the time required to accelerate from M0.8 to M1.3 at 20,000 in this configuration is 80 – 25 = 55s.

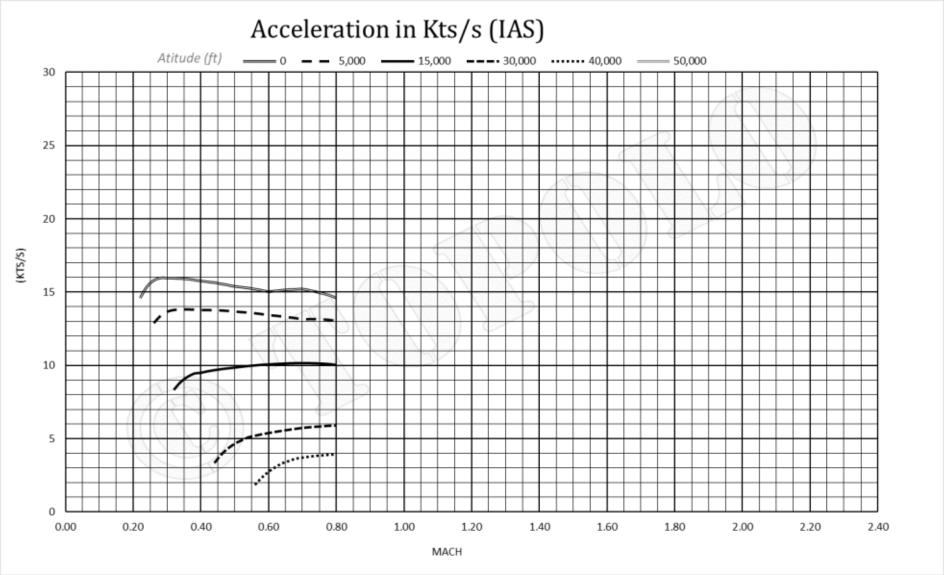
Same method is to be used to find the horizontal distance (in Nm) and the fuel used (in lbs) to perform the same acceleration.

Figure 2.1

Instantaneous Acceleration

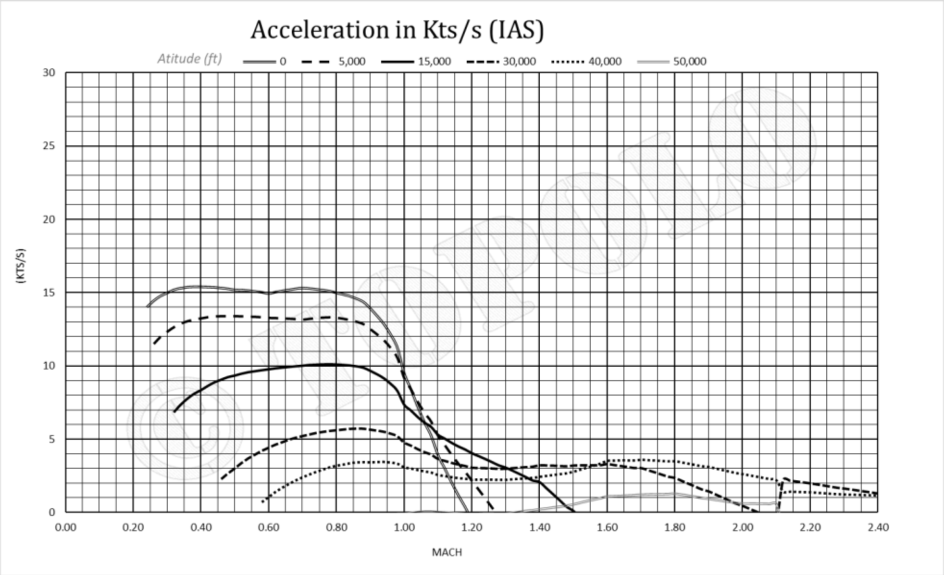
DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 16°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs



DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs



DATA BASIS : COMPUTED CONDITIONS: – Atmosphere : Standard Day / ISA – Engine regime: Max A/B – SOUA System : Engaged	AIRCRAFT : MiG-23ML izd.23-12A ENGINE: R35 Wing Swept Angle : 72° Loads : 2xR-60M/MK + 2xR-24R/T Gross Weight : 13,000 Kg / 28,697 lbs

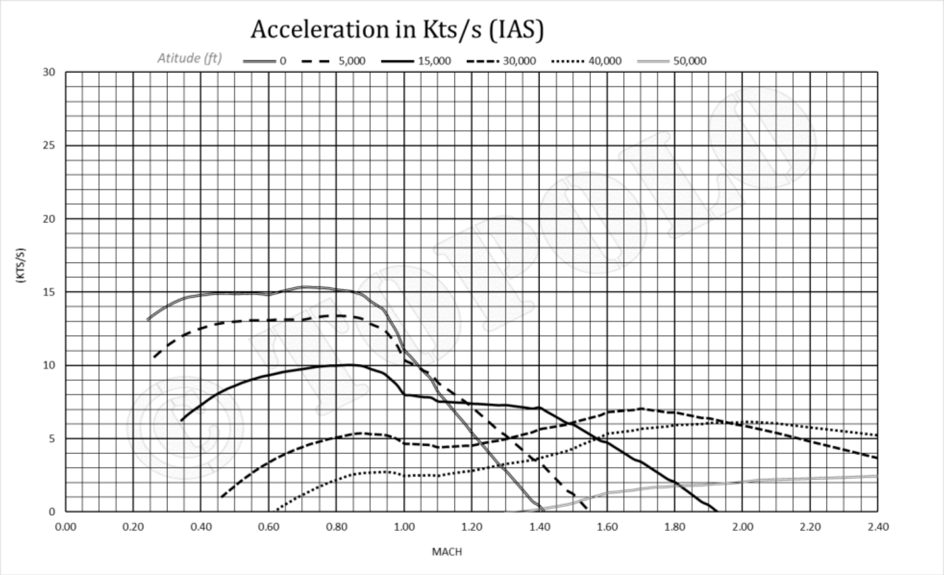


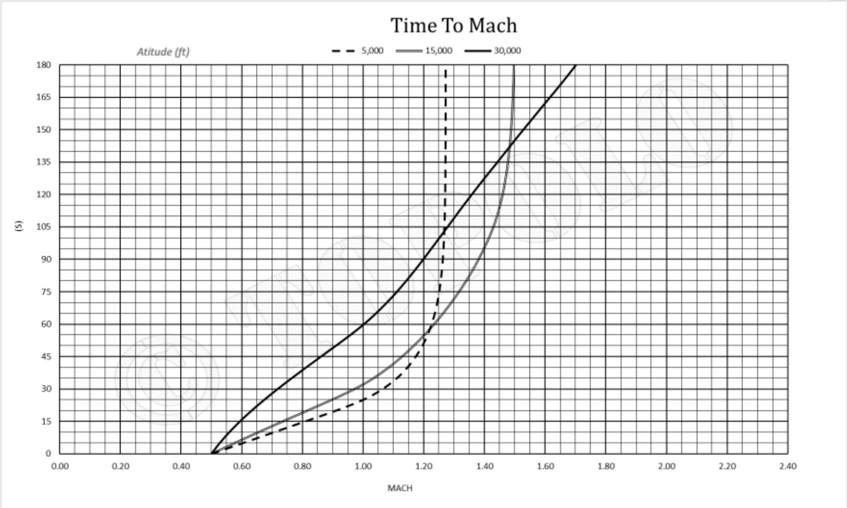
Figure 2.2

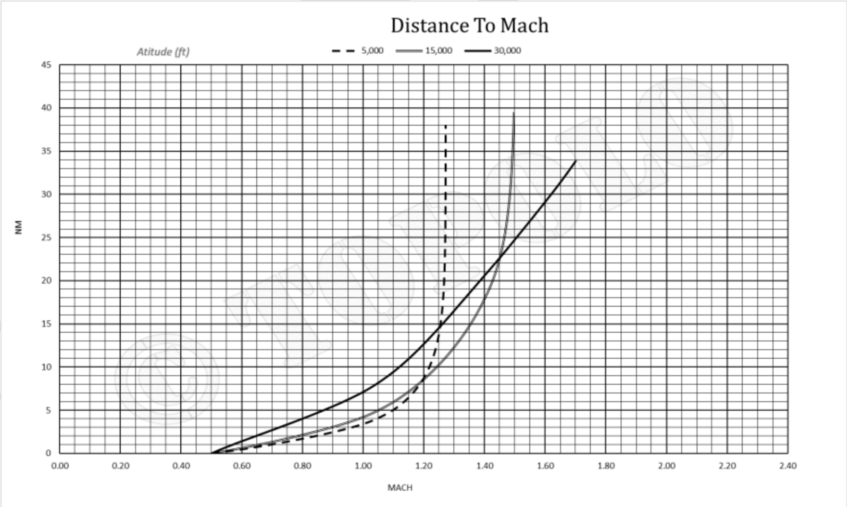
Acceleration Schedule at constant altitude

DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs


Time To Mach


Distance To Mach

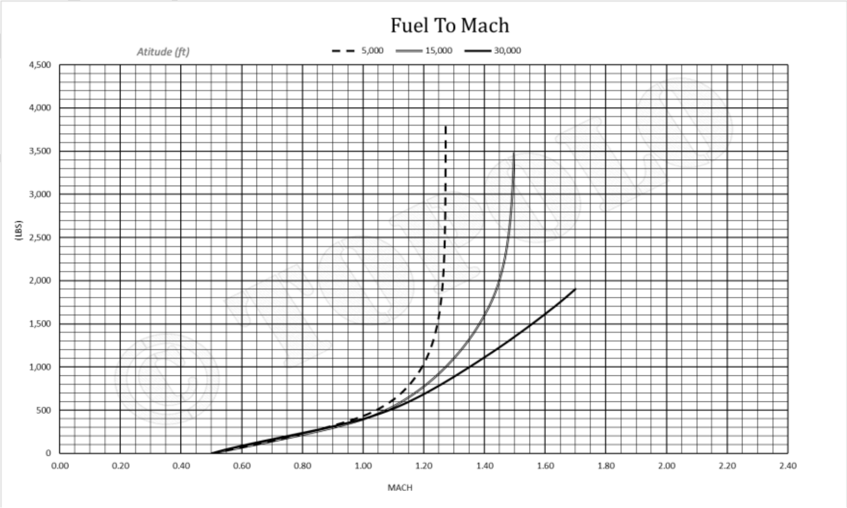
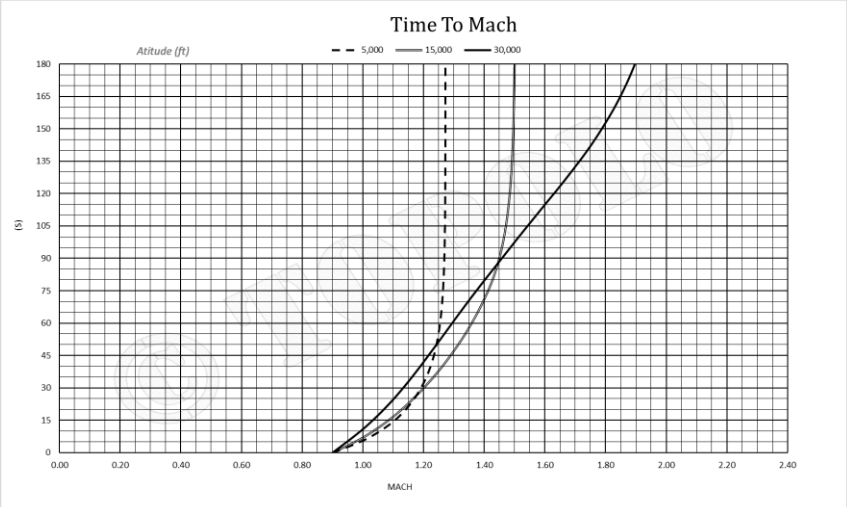
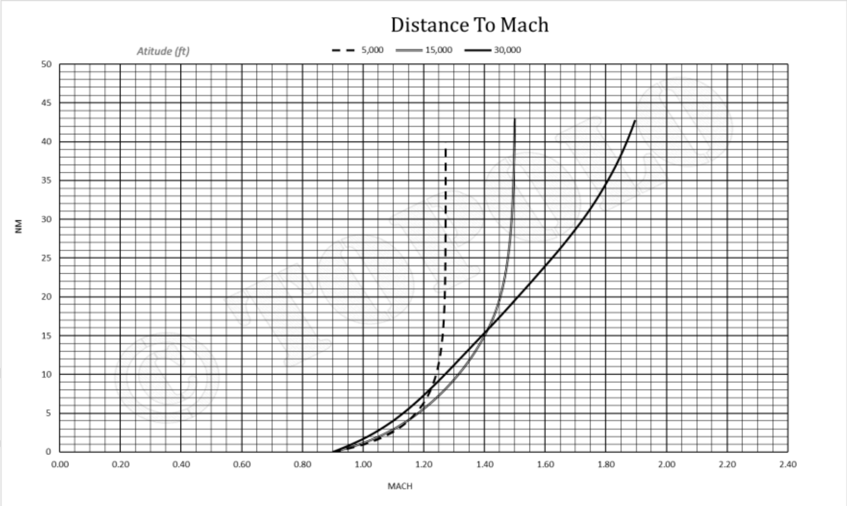

Fuel To Mach

Figure 2.3

Acceleration Schedule at constant altitude

DATA BASIS : COMPUTED CONDITIONS: – Atmosphere : Standard Day / ISA – Engine regime: Max A/B – SOUA System : Engaged	AIRCRAFT : MiG-23ML izd.23-12A ENGINE: R35 Wing Swept Angle : 45° Loads : 2xR-60M/MK + 2xR-24R/T Gross Weight : 13,000 Kg / 28,697 lbs





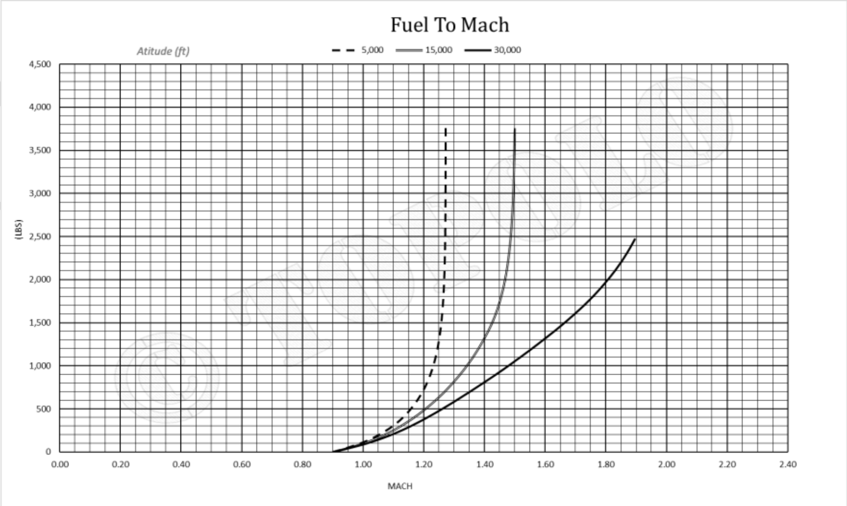


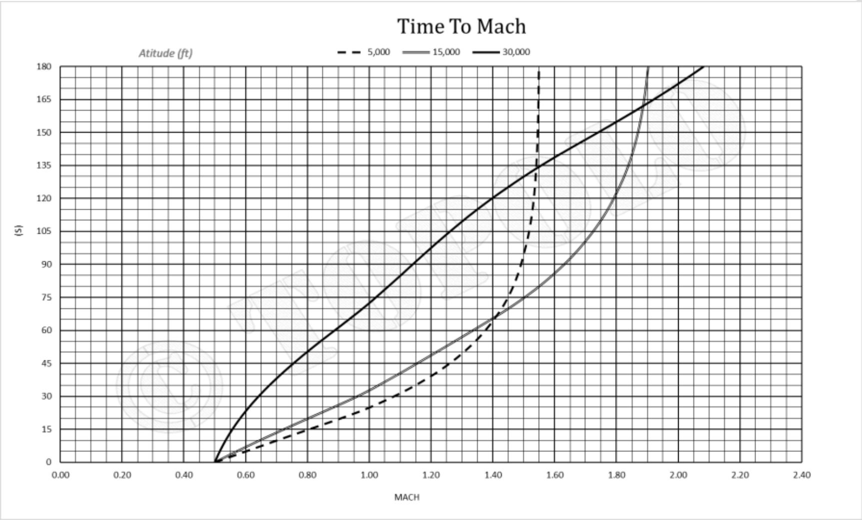
Figure 2.4

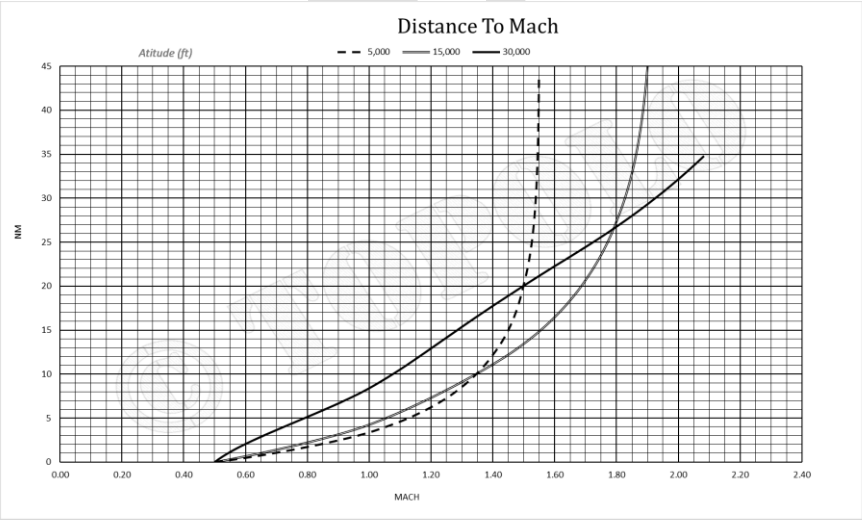
Acceleration Schedule at constant altitude

DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 72°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs





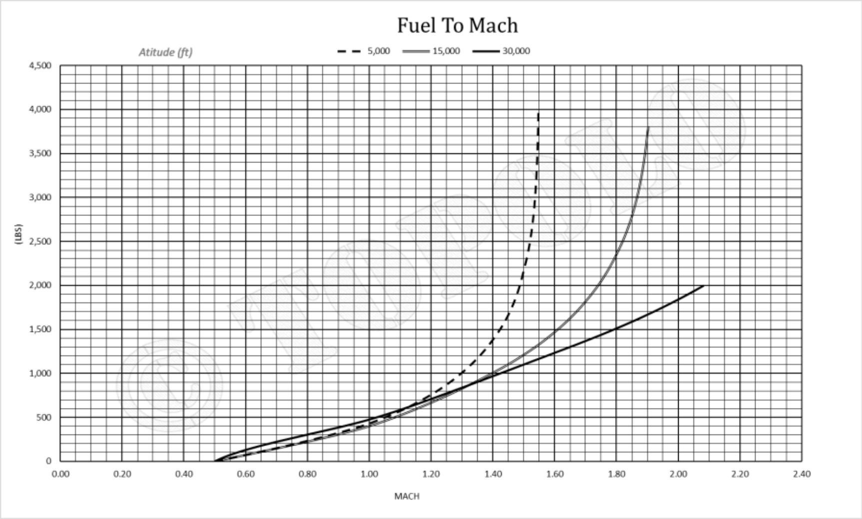


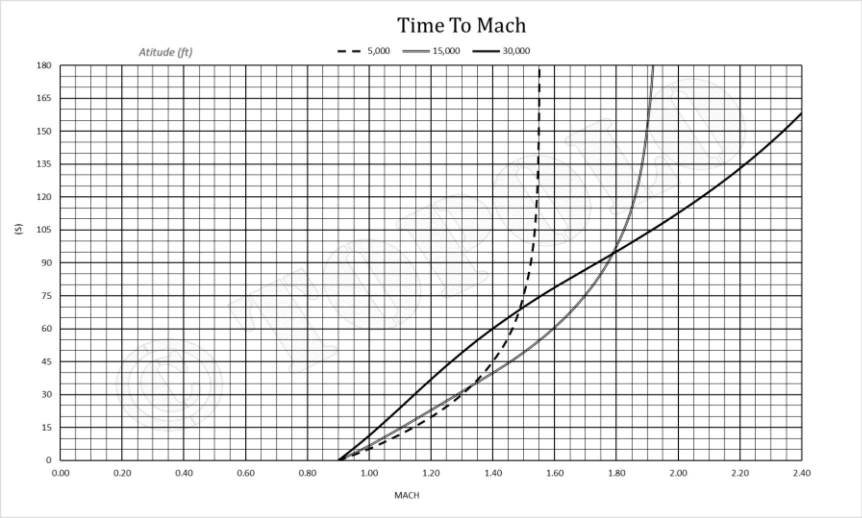
Figure 2.5

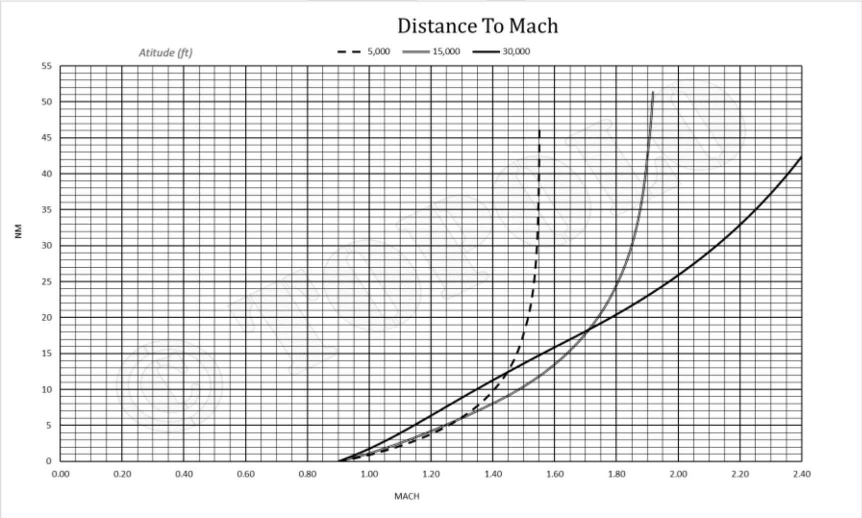
Acceleration Schedule at constant altitude

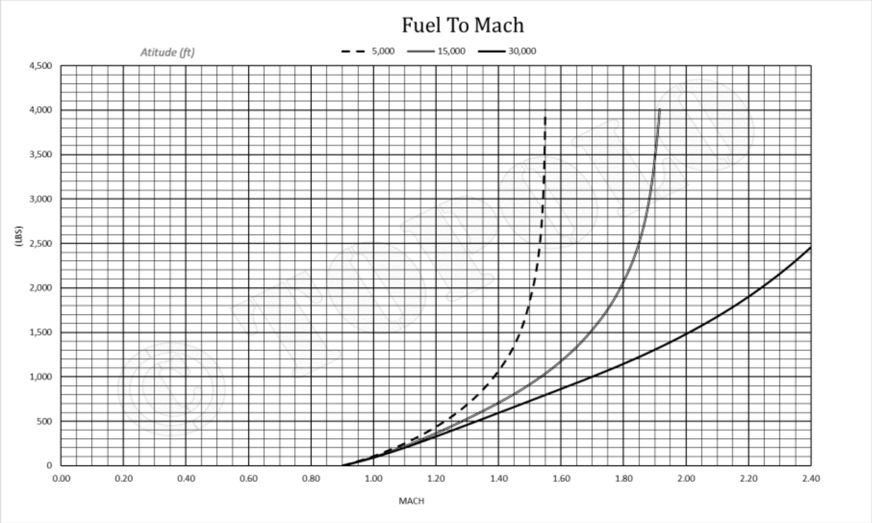
DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 72°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs







- CRUISE, RANGE and ENDURANCE

This section presents the fuel management data during cruise flight (constant speed and altitude in Military Thrust). For each aircraft configuration, you will find the instantaneous fuel flow (in lbs/h) required to sustain a given Mach number at a given altitude, the autonomy at a given Mach number and altitude (distance, in Nm that can be covered with a unit amount of fuel: 1,000lbs), and the endurance at a given Mach number and altitude (time in minutes that can be flown with a unit amount of fuel: 1,000lbs)

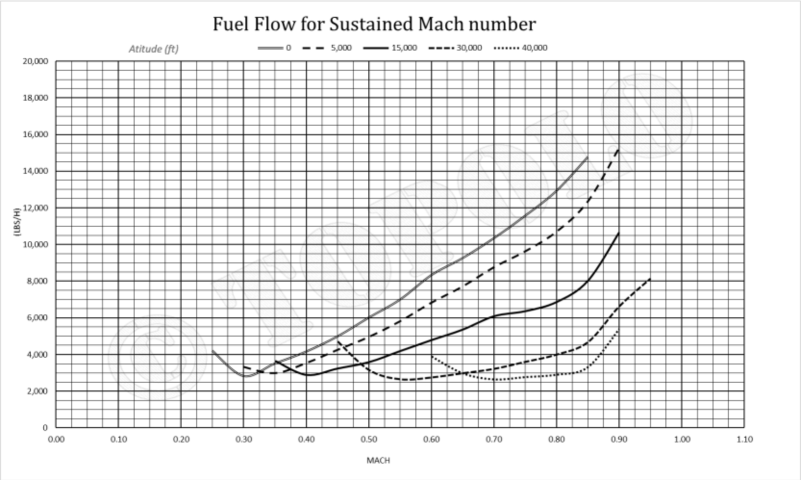
Figures are computed for the three wing sweep angles (16, 45 and 72°)

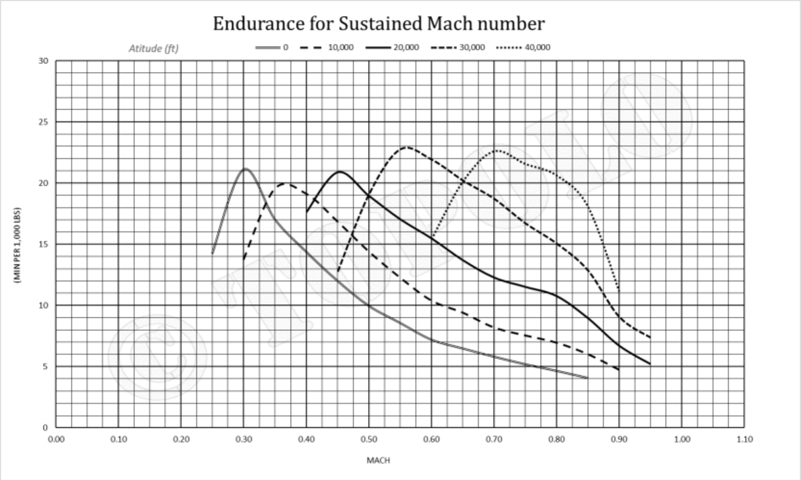
Figure 3.1

Fuel Flow – Endurance - Range

DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: MIL Power
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 16°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs





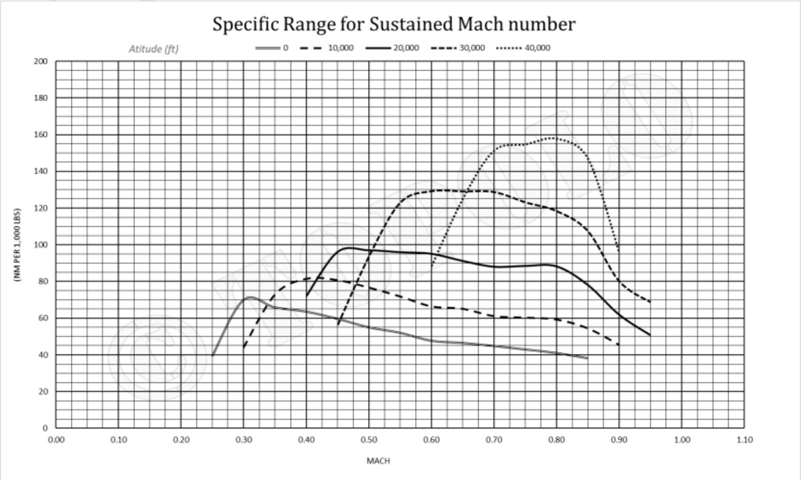
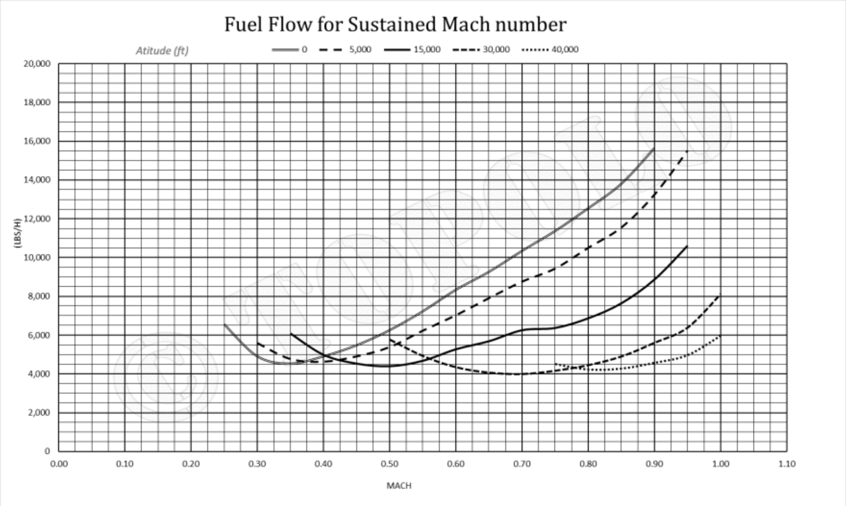


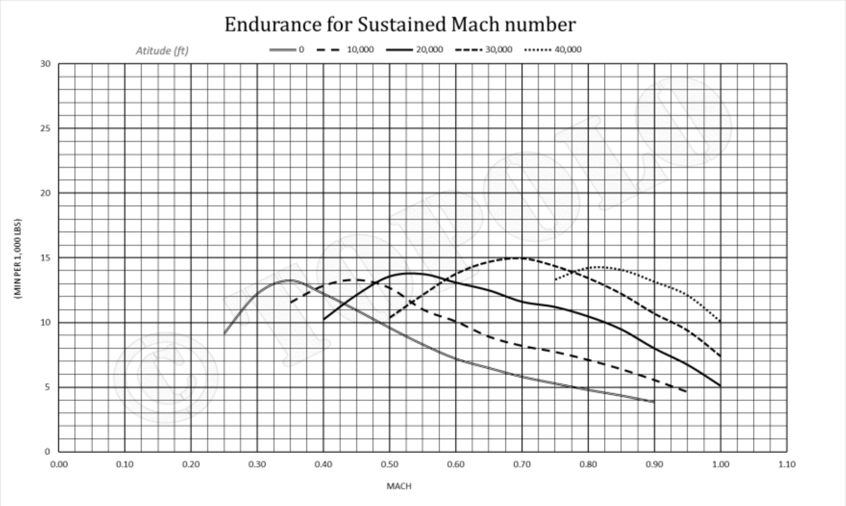
Figure 3.2

Fuel Flow – Endurance - Range

DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: MIL Power
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs





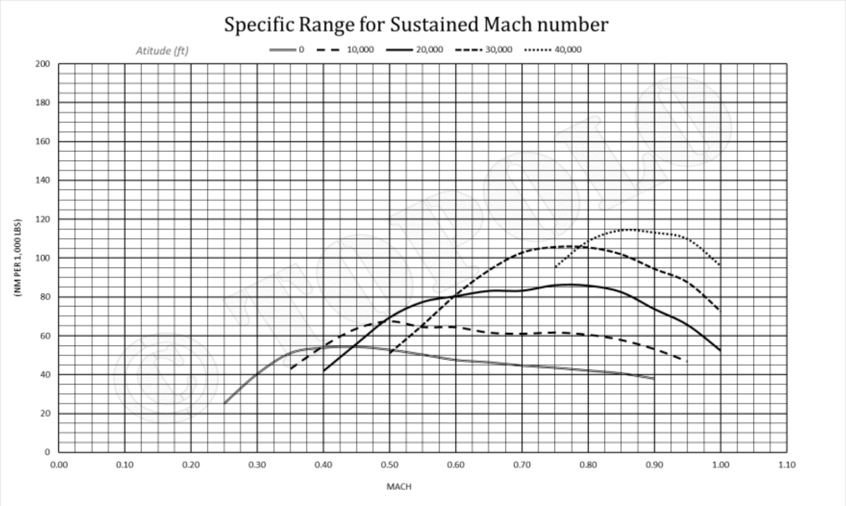


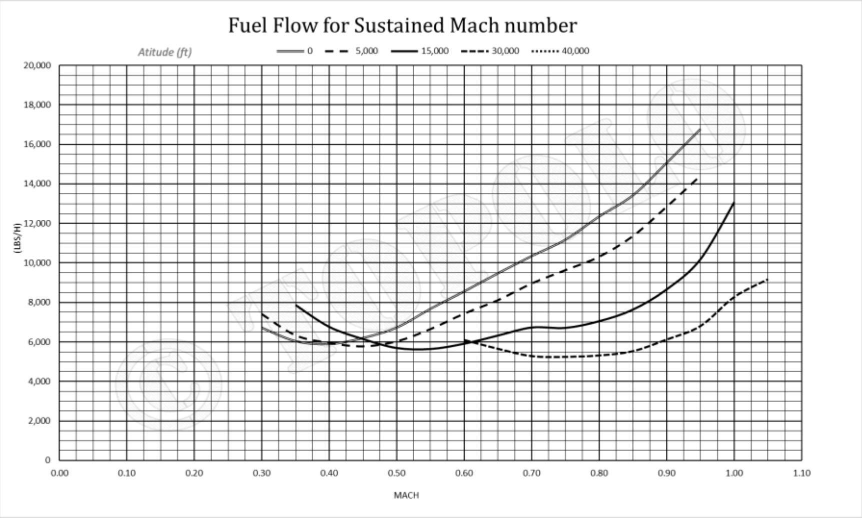
Figure 3.3

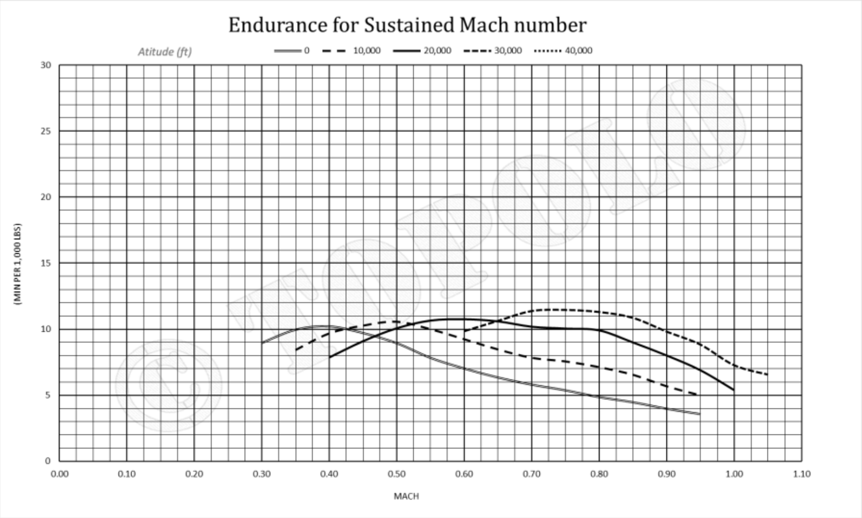
Fuel Flow – Endurance - Range

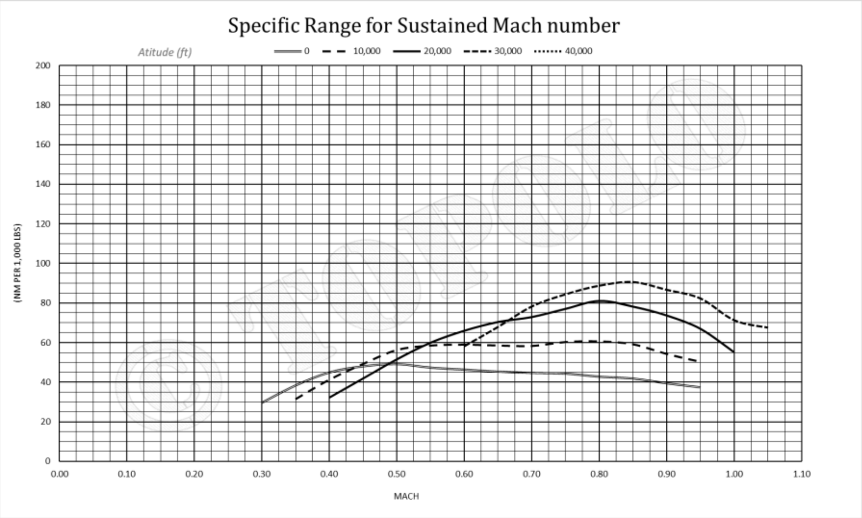
DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: MIL Power
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 72°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs







- TURNING

This section is organized by aircraft configurations. For each of them, you will find the following set of figures:

TURN PERFORMANCE SUMMARY

Sustained Turn Rate summary: three figures giving for different altitudes, showing the maximum sustainable (constant true air speed and altitude) turn rate (deg./s), normal load factor (Ng) and minimum turn radius.

Maximum Turn Rate summary: three figures for different altitudes, showing the maximum reachable (at maximum possible lift) turn rate (d/s), normal load factor (Ng) and minimum turn radius.

ENERGY MACH DIAGRAM

An Energy Mach Diagram is given for different altitudes (Turn Rate vs Calibrated Air Speed), with Iso-Ps (Extra Specific Power) curves set, and graphical indication of specific performances: maximum reachable (maximum lift and load factor) turn rate, maximum sustainable (Ps=0) turn rate, minimum instantaneous and minimum sustainable (Ps=0) turn radius.

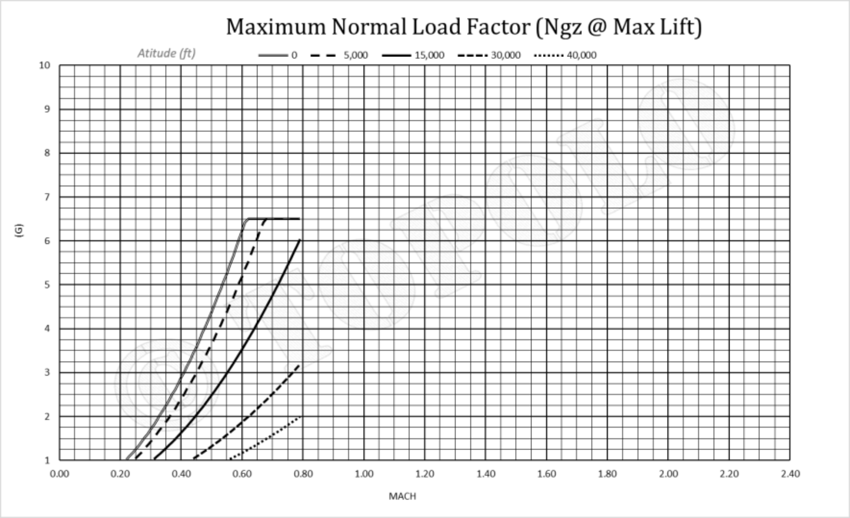
Figure 4.1

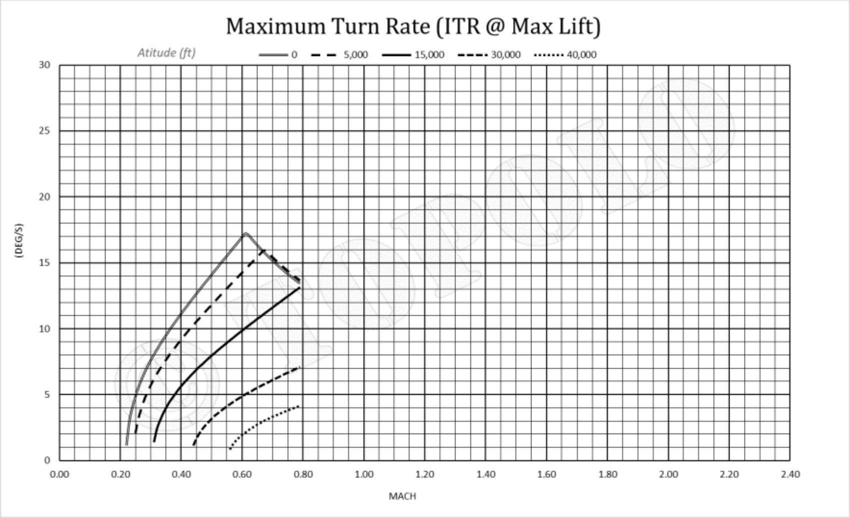
Maximum Lift Turn Capabilities

DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 16°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs





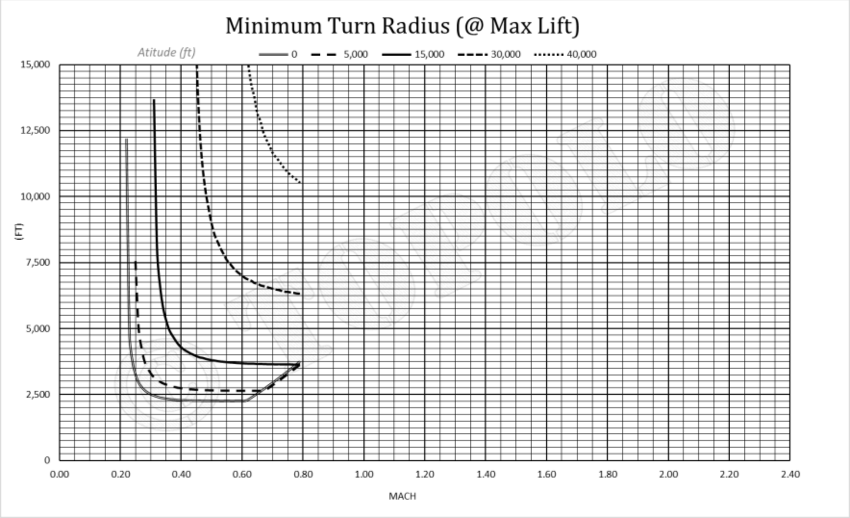
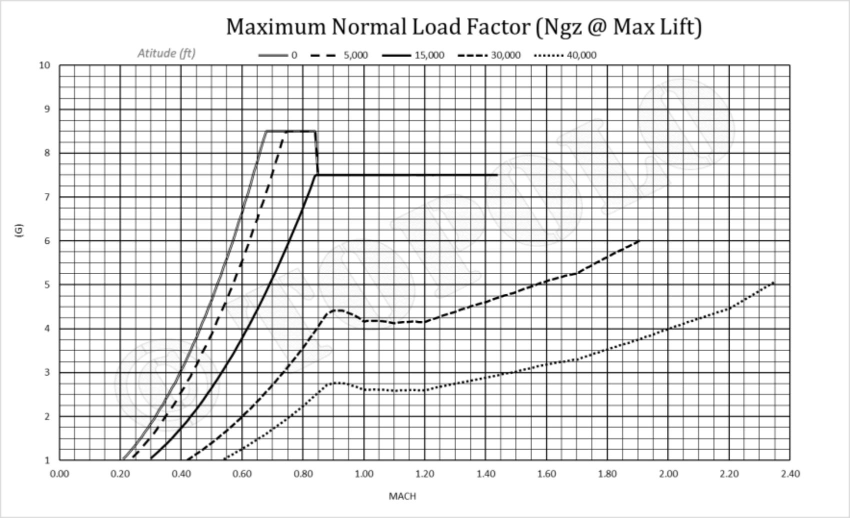


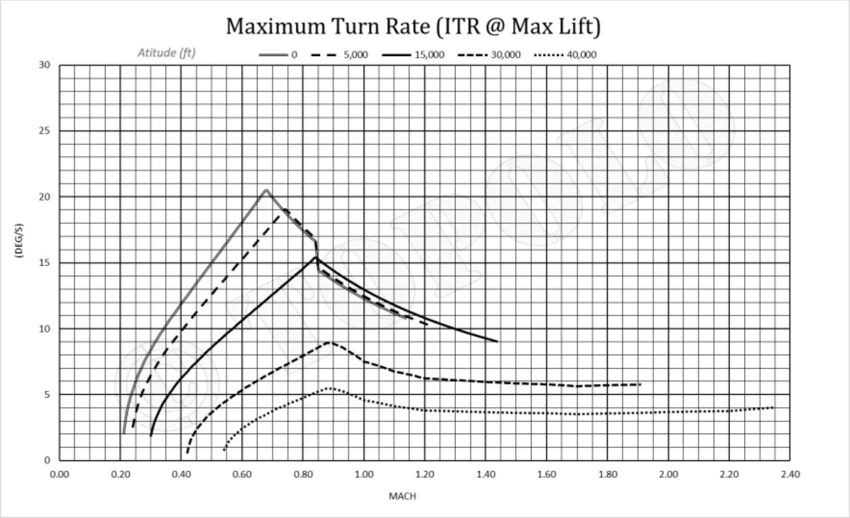
Figure 4.2

Maximum Lift Turn Capabilities

DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs





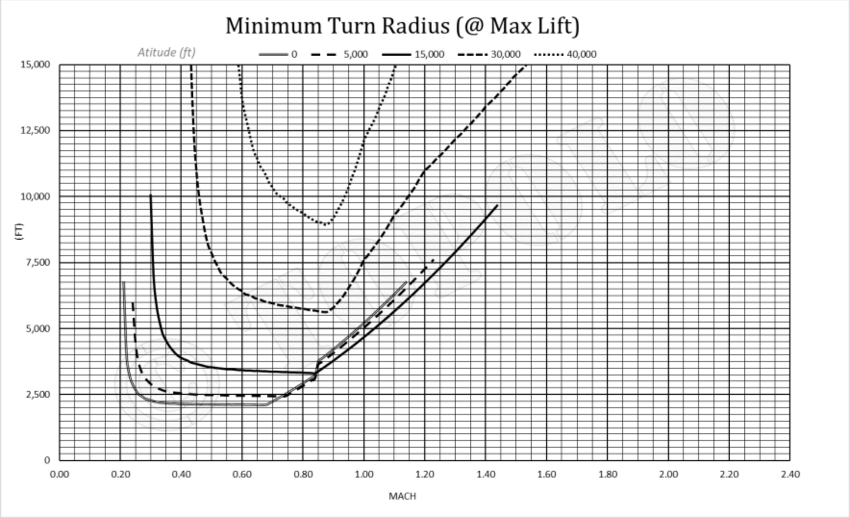
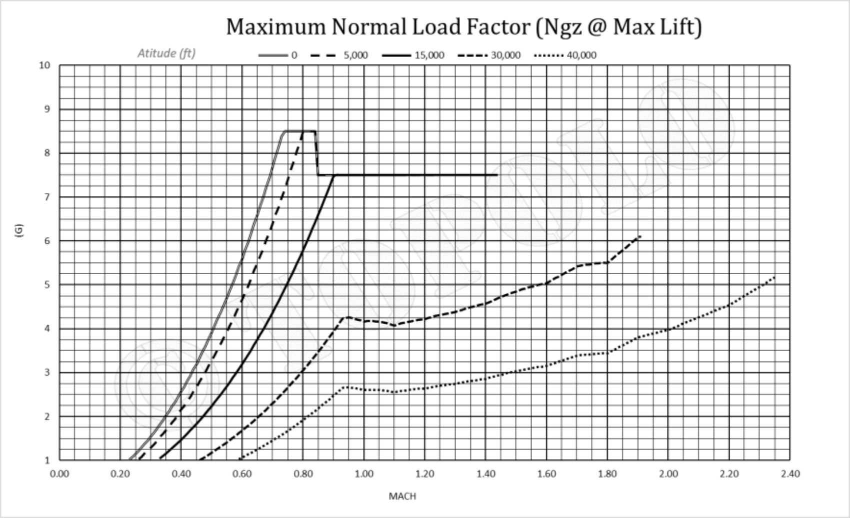
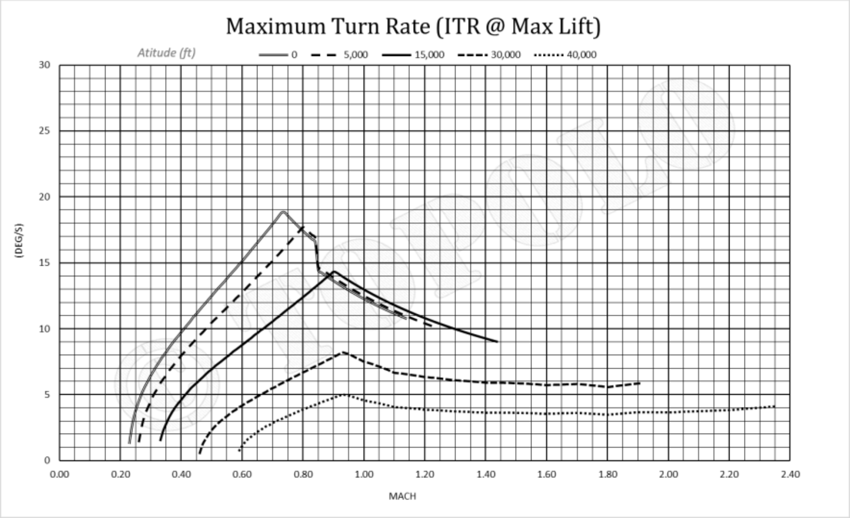


Figure 4.3

Maximum Lift Turn Capabilities

DATA BASIS : COMPUTED CONDITIONS: – Atmosphere : Standard Day / ISA – Engine regime: Max A/B – SOUA System : Engaged	AIRCRAFT : MiG-23ML izd.23-12A ENGINE: R35 Wing Swept Angle : 72° Loads : 2xR-60M/MK + 2xR-24R/T Gross Weight : 13,000 Kg / 28,697 lbs





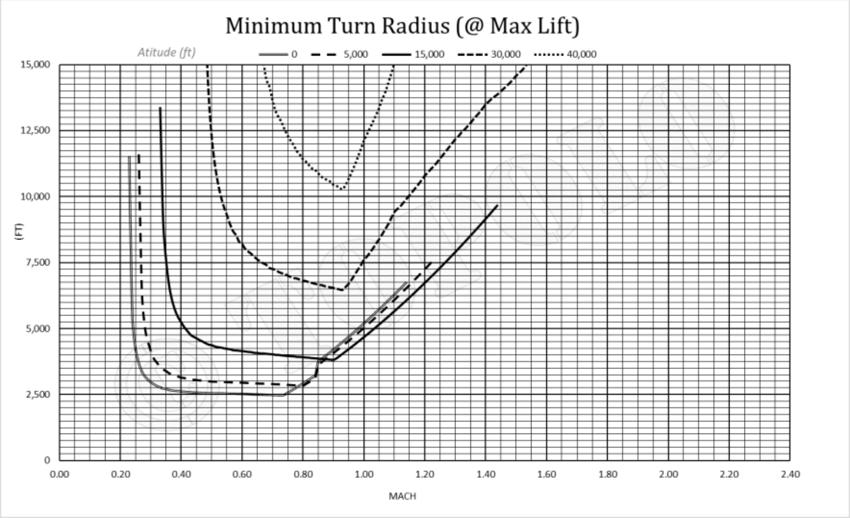
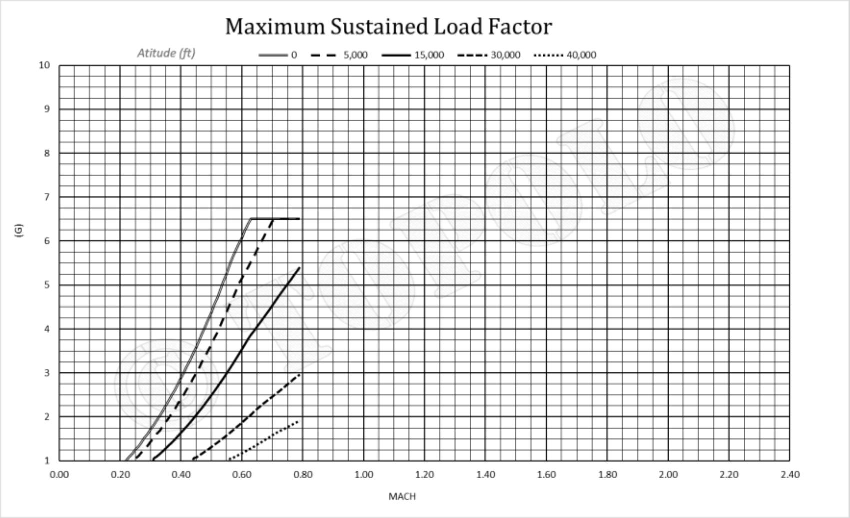
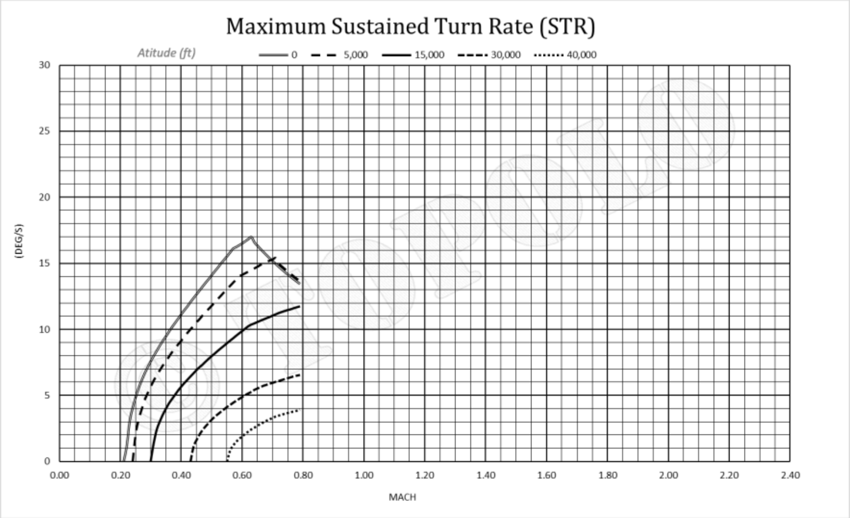


Figure 4.4

Sustained Turn Capabilities

DATA BASIS : COMPUTED CONDITIONS: – Atmosphere : Standard Day / ISA – Engine regime: Max A/B – SOUA System : Engaged	AIRCRAFT : MiG-23ML izd.23-12A ENGINE: R35 Wing Swept Angle : 16° Loads : 2xR-60M/MK + 2xR-24R/T Gross Weight : 13,000 Kg / 28,697 lbs





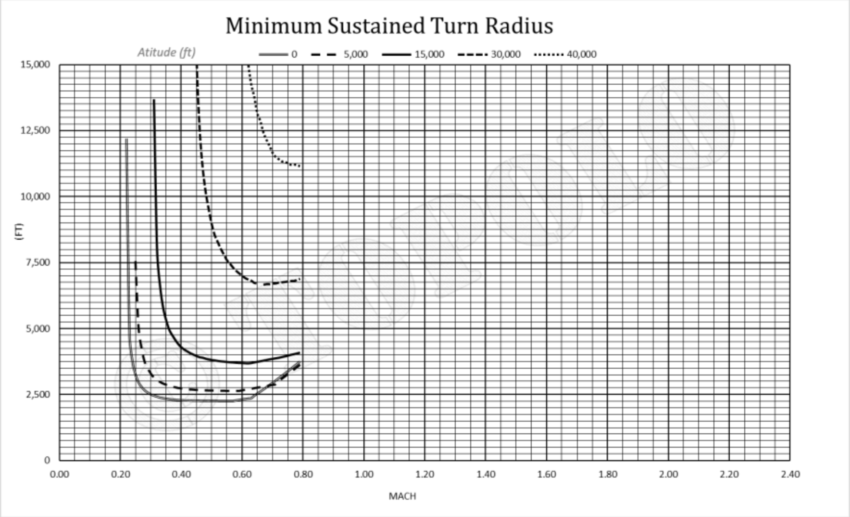
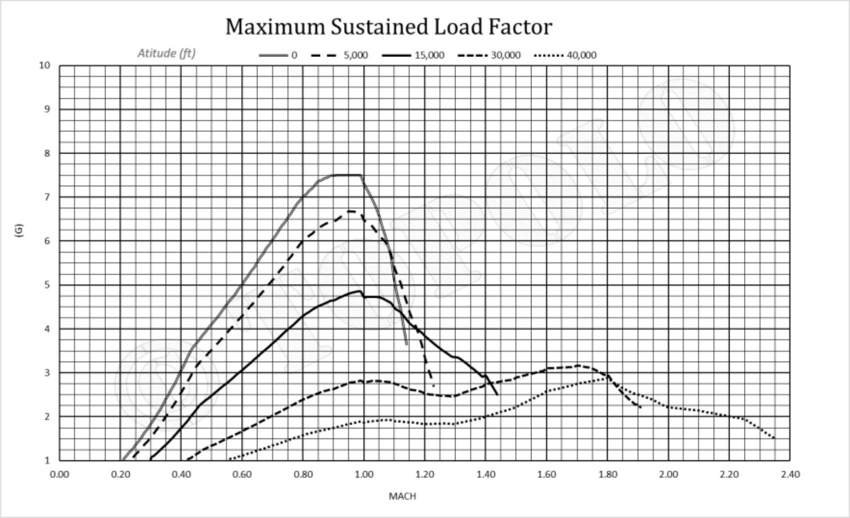


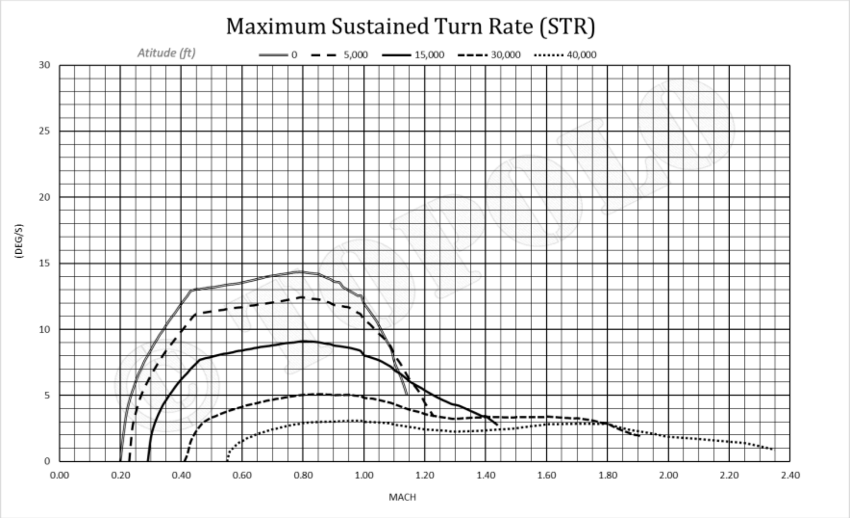
Figure 4.5

Sustained Turn Capabilities

DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs





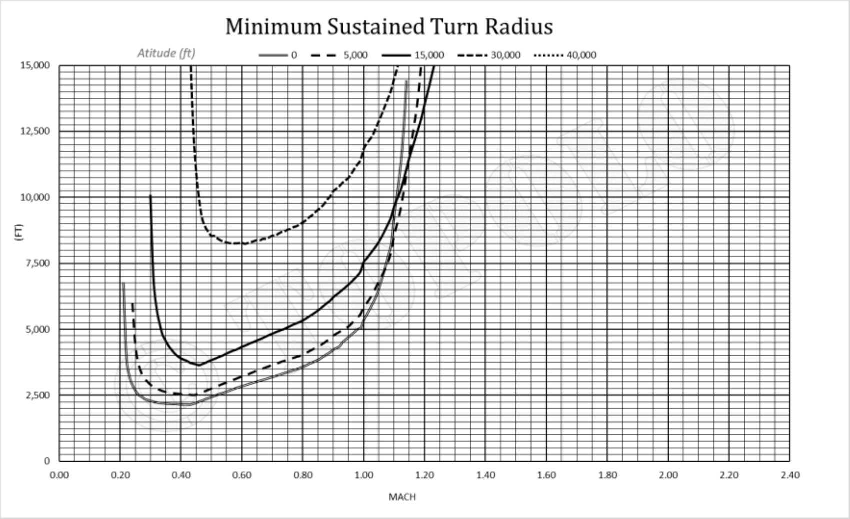
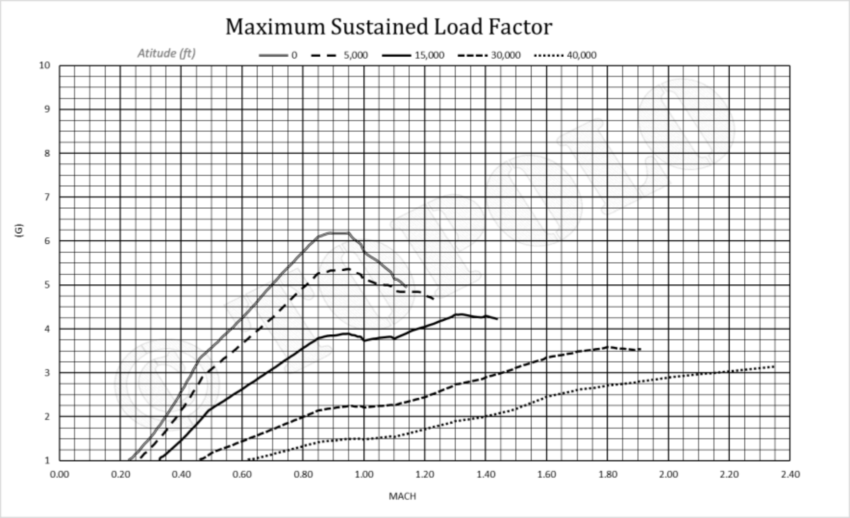
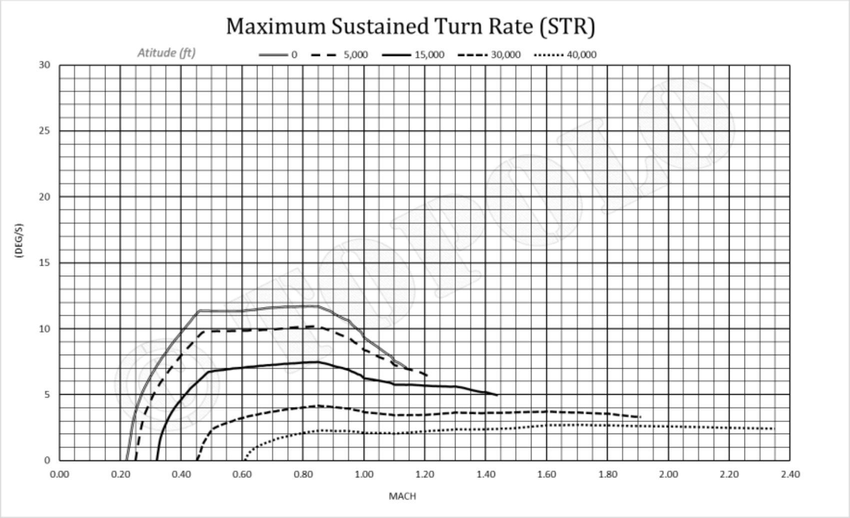


Figure 4.6

Sustained Turn Capabilities

DATA BASIS : COMPUTED CONDITIONS: – Atmosphere : Standard Day / ISA – Engine regime: Max A/B – SOUA System : Engaged	AIRCRAFT : MiG-23ML izd.23-12A ENGINE: R35 Wing Swept Angle : 72° Loads : 2xR-60M/MK + 2xR-24R/T Gross Weight : 13,000 Kg / 28,697 lbs





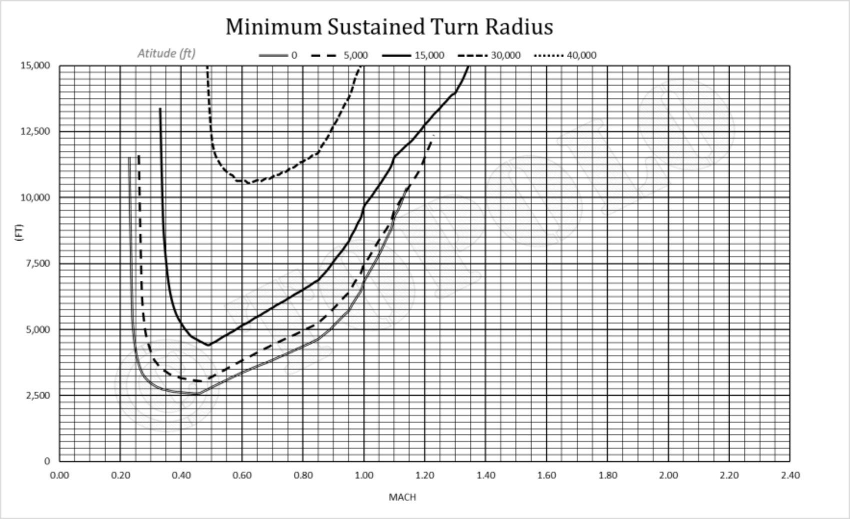


Figure 5.1

Energy-Mach Diagram at Sea Level

DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs

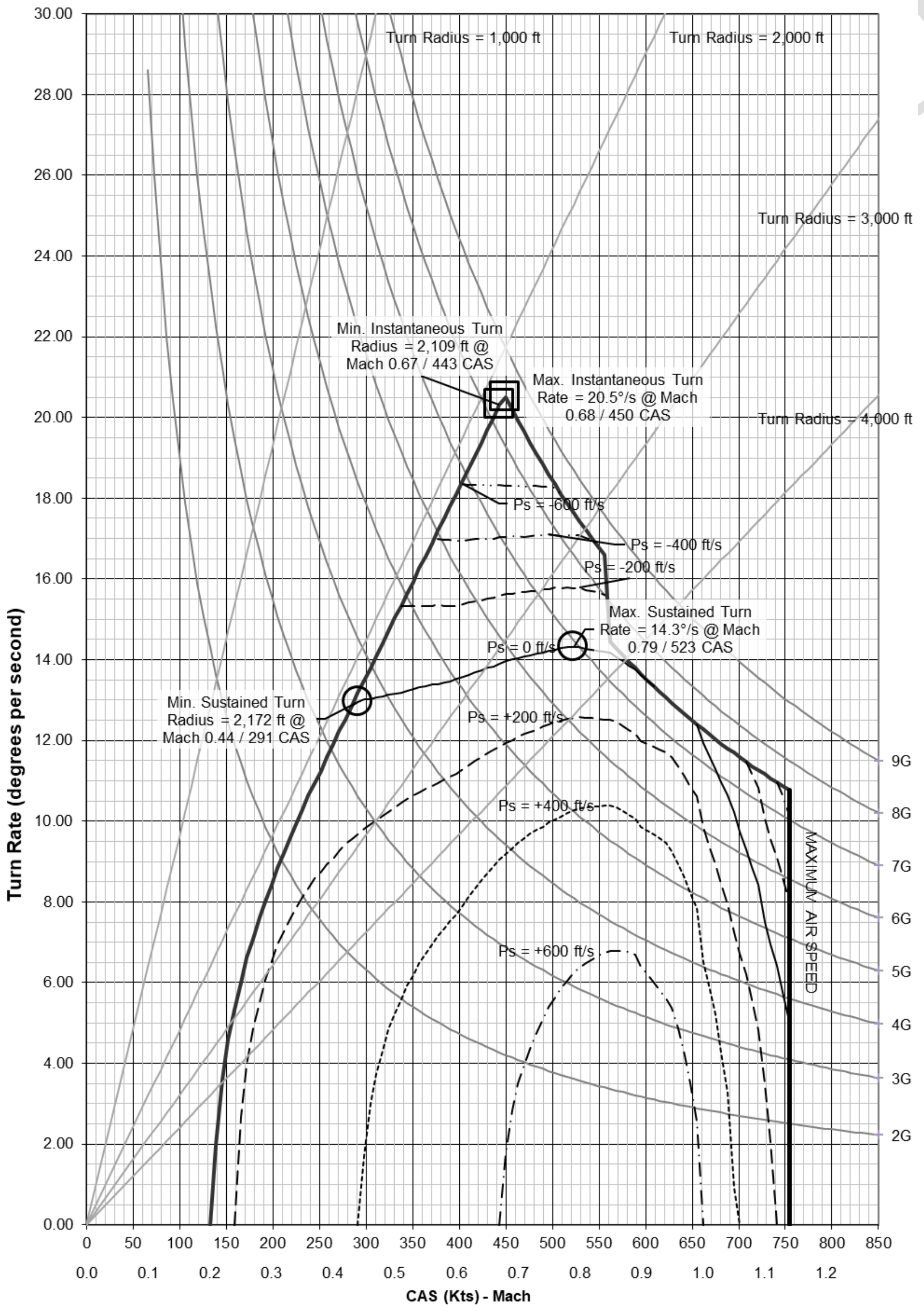


Figure 5.2

Energy-Mach Diagram at 5,000ft

DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs

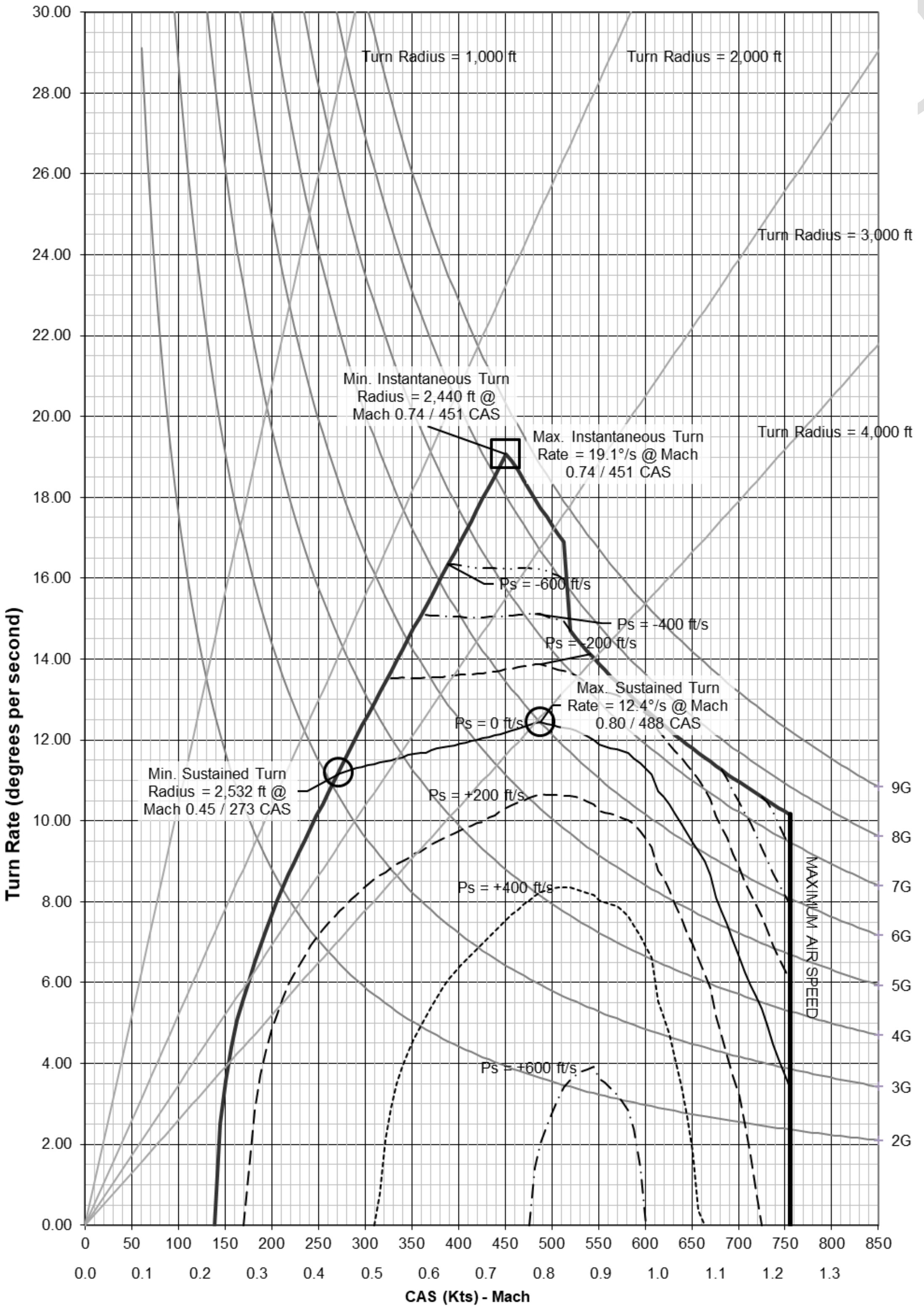


Figure 5.3

Energy-Mach Diagram at 10,000ft

DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs

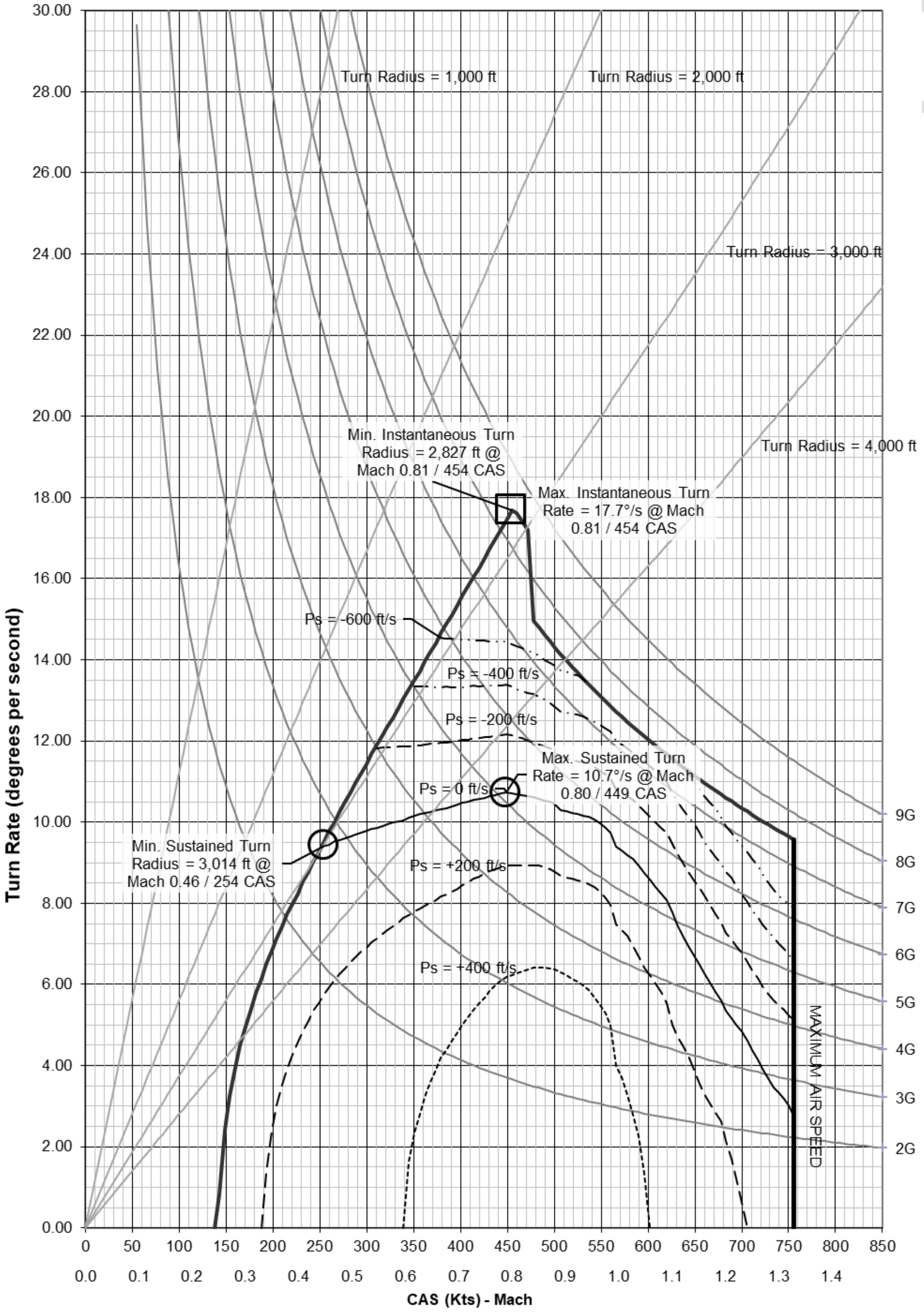
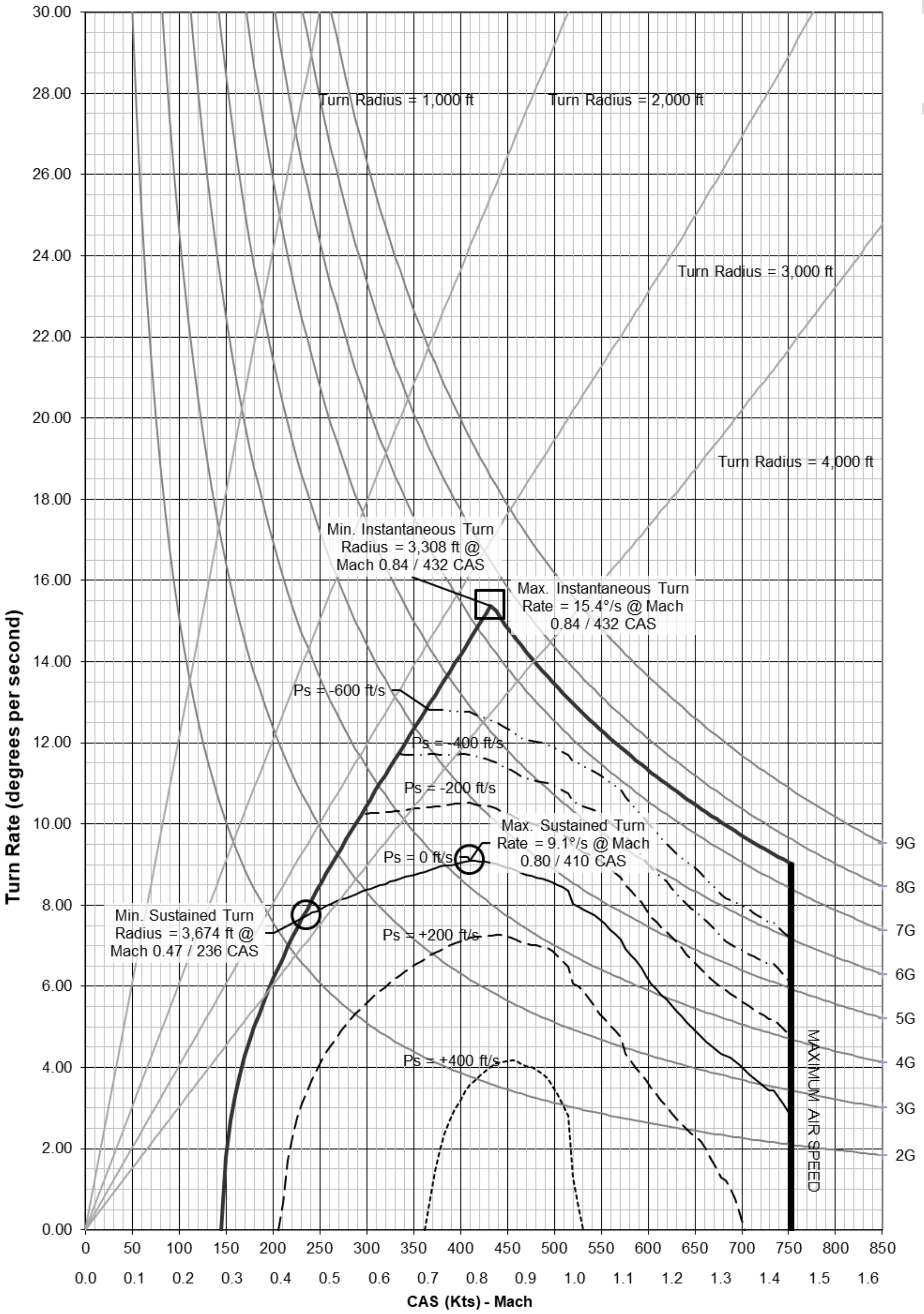


Figure 5.4

Energy-Mach Diagram at 15,000ft

DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs



Min. Instantaneous Turn Radius = 3,308 ft @ Mach 0.84 / 432 CAS

Max. Instantaneous Turn Rate = 15.4°/s @ Mach 0.84 / 432 CAS

Max. Sustained Turn Rate = 9.1°/s @ Mach 0.80 / 410 CAS

Min. Sustained Turn Radius = 3,674 ft @ Mach 0.47 / 236 CAS

Figure 5.5

Energy-Mach Diagram at 20,000ft

DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs

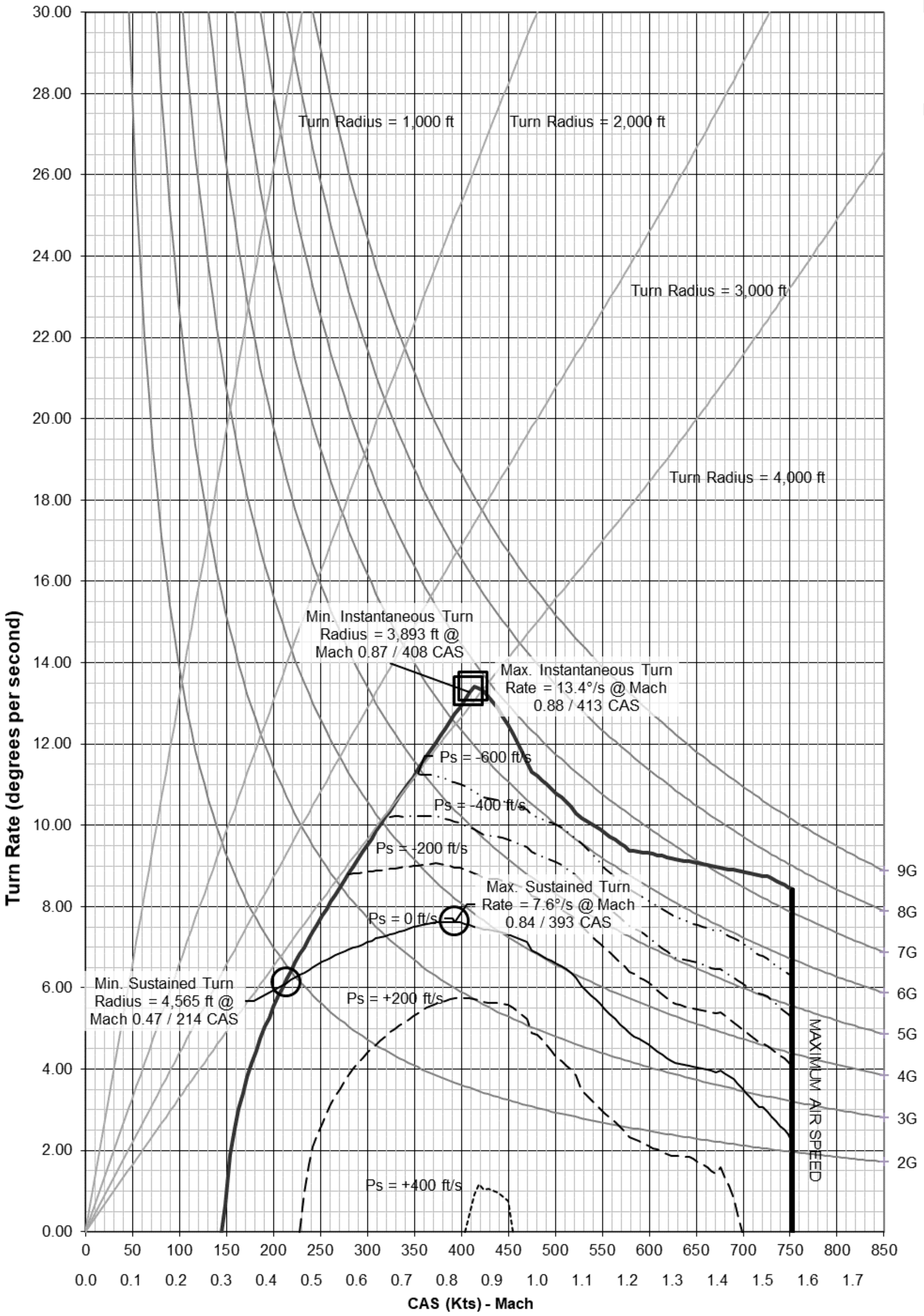


Figure 5.6

Energy-Mach Diagram at 25,000ft

DATA BASIS : COMPUTED

CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A

ENGINE: R35

Wing Swept Angle : 45°

Loads : 2xR-60M/MK + 2xR-24R/T

Gross Weight : 13,000 Kg / 28,697 lbs

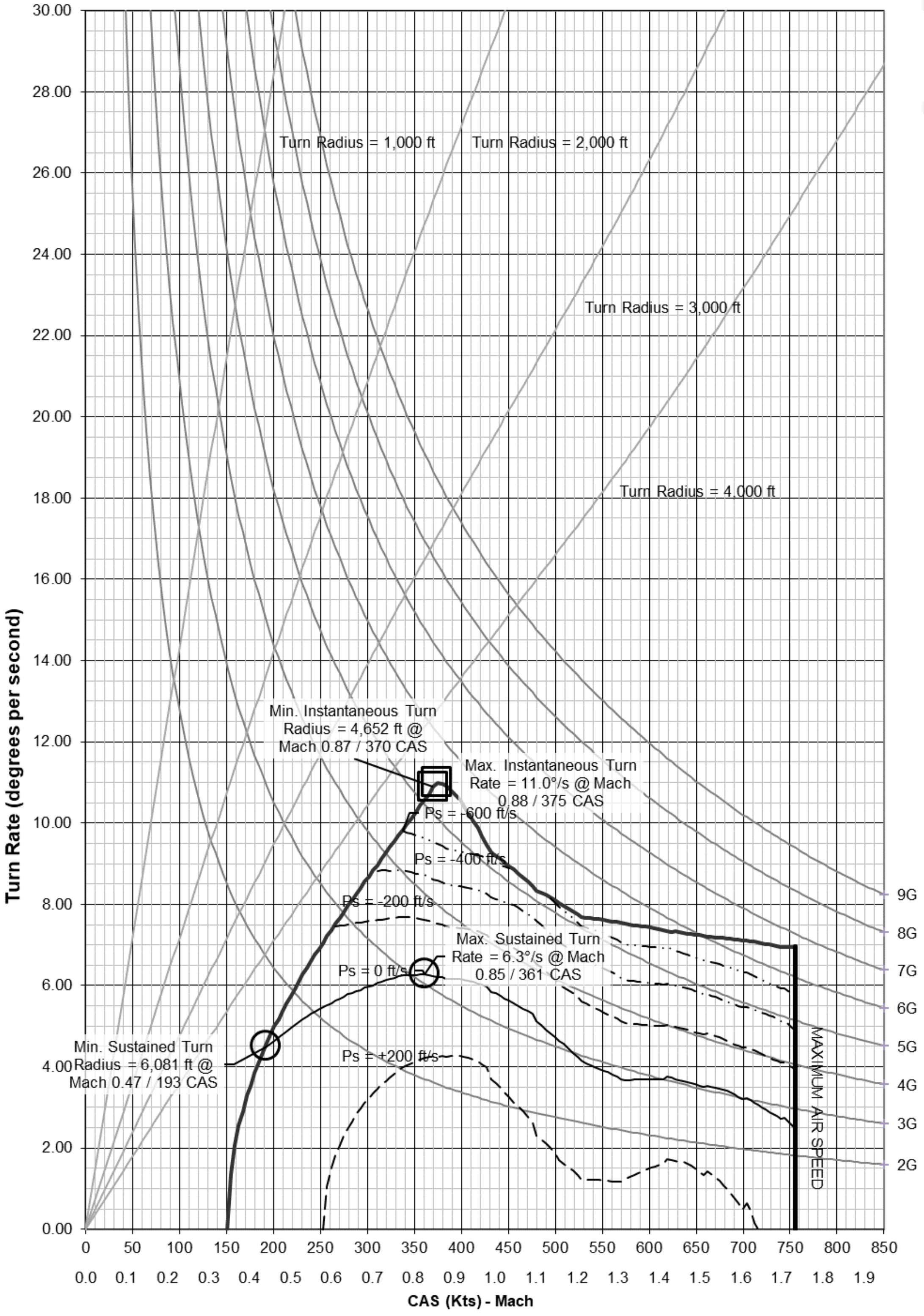


Figure 5.7

Energy-Mach Diagram at 30,000ft

DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs

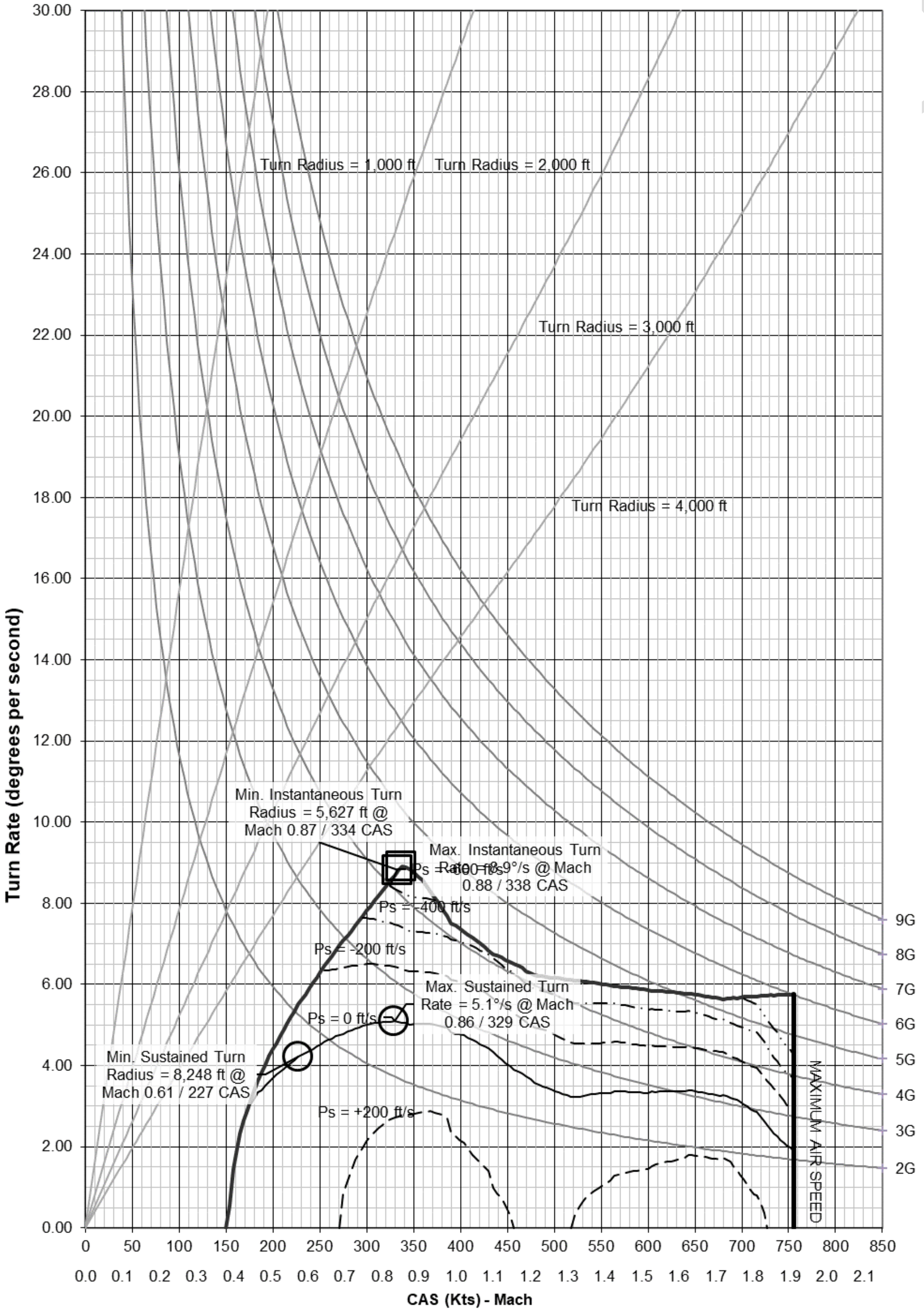


Figure 5.8

Energy-Mach Diagram at 35,000ft

DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs

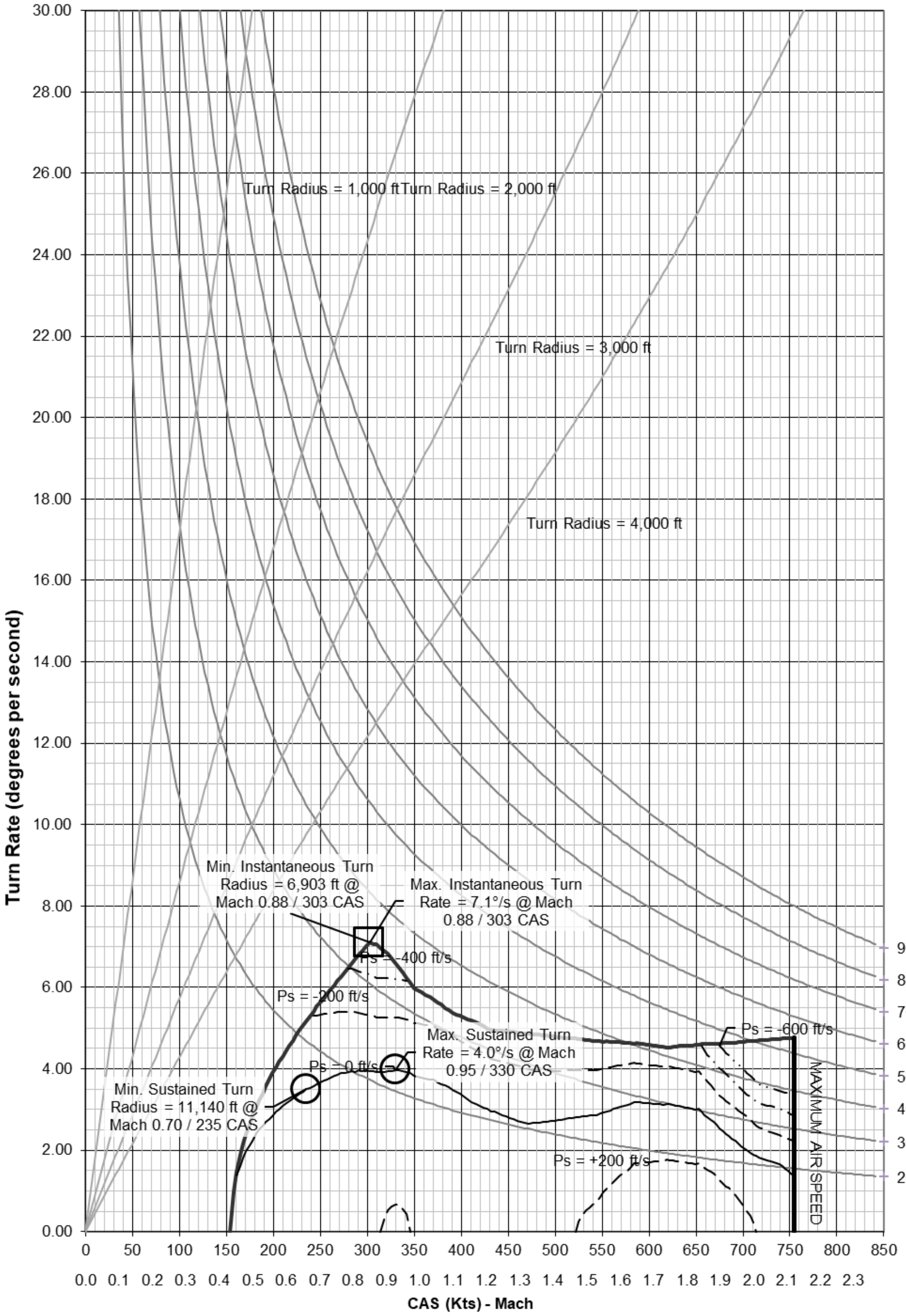


Figure 6.1

Energy-Mach Diagram at Sea Level

DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 16°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs

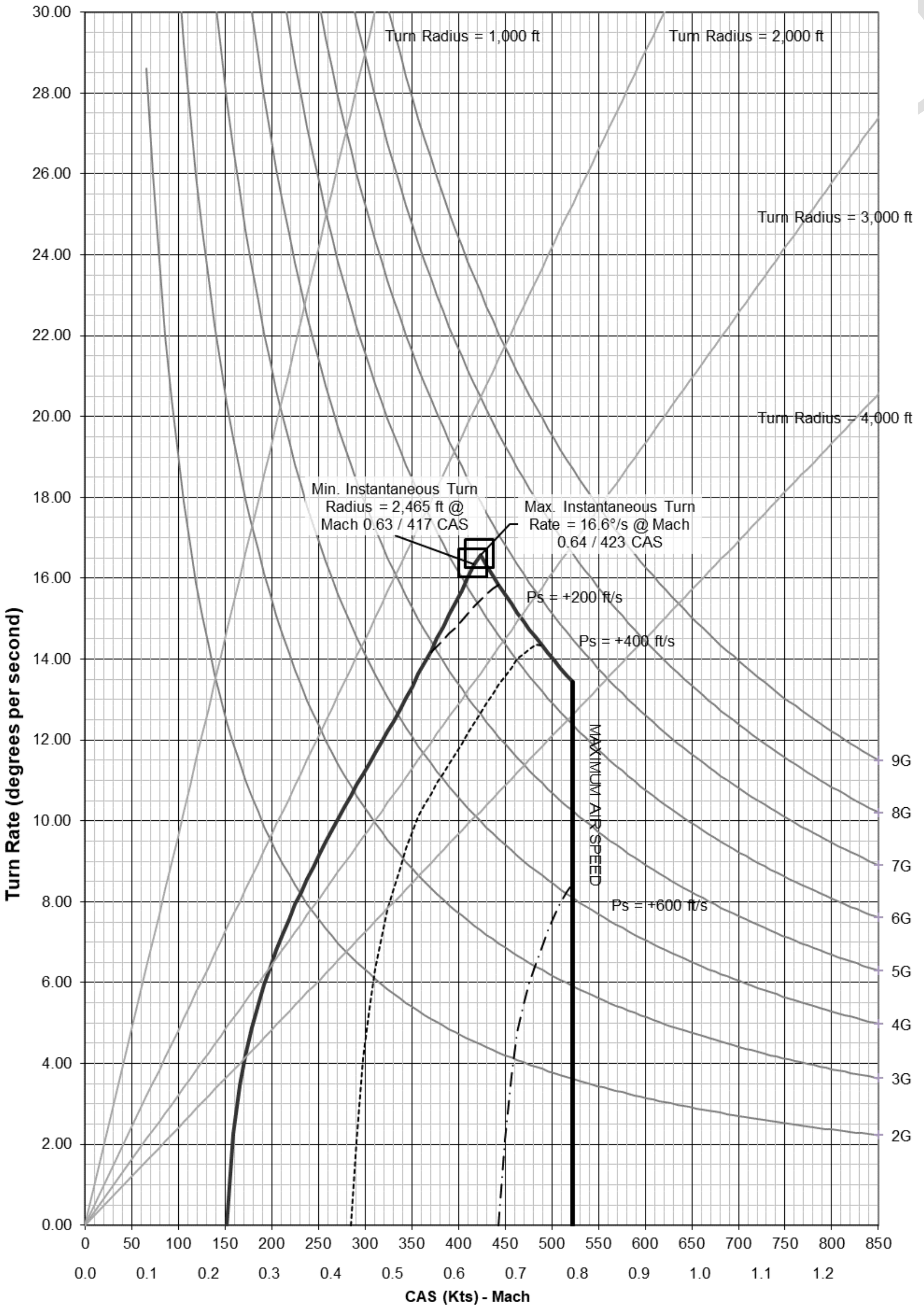


Figure 6.2

Energy-Mach Diagram at 5,000ft

DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged or Disengaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 16°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs

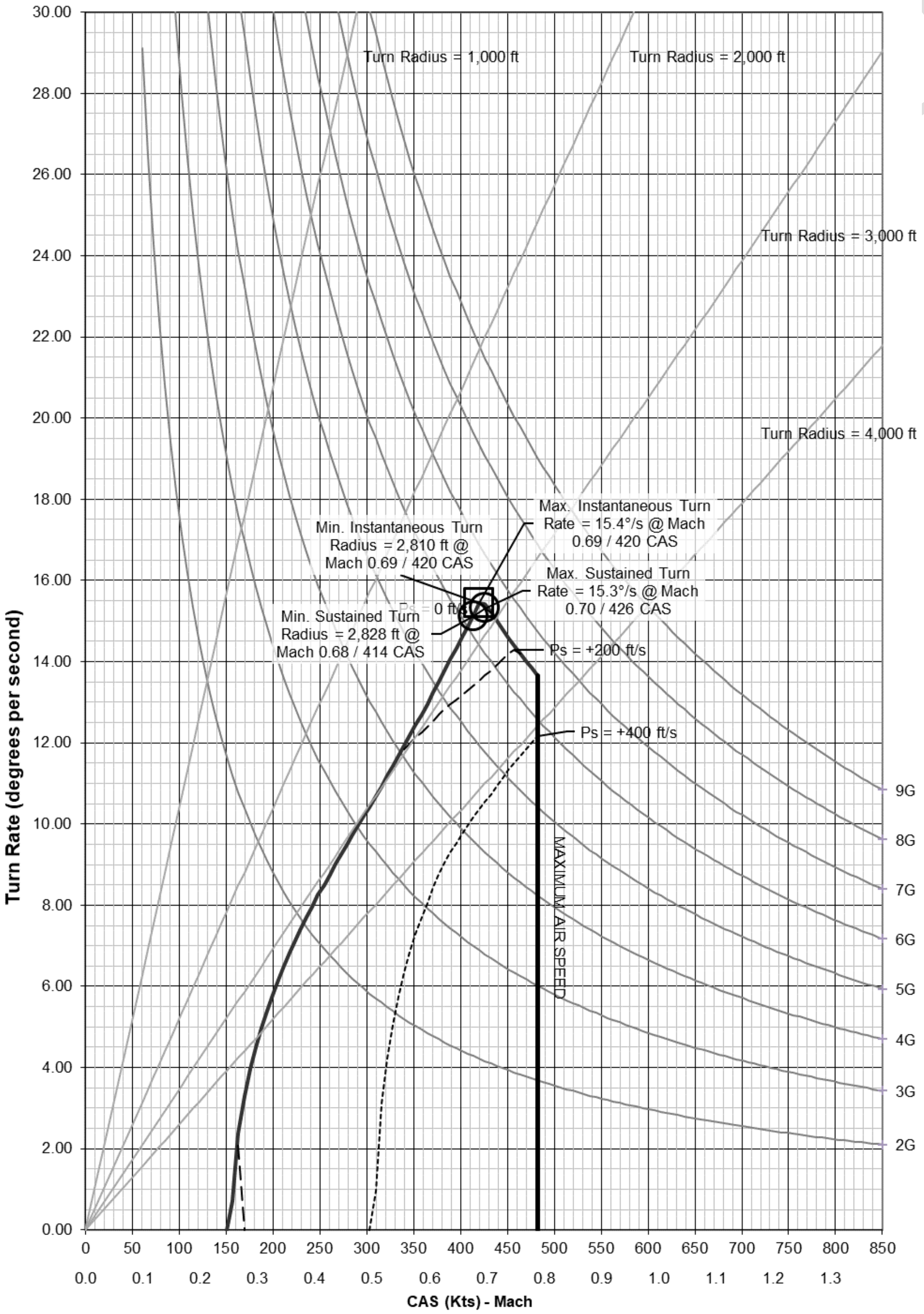


Figure 6.3

Energy-Mach Diagram at 10,000ft

DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 16°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs

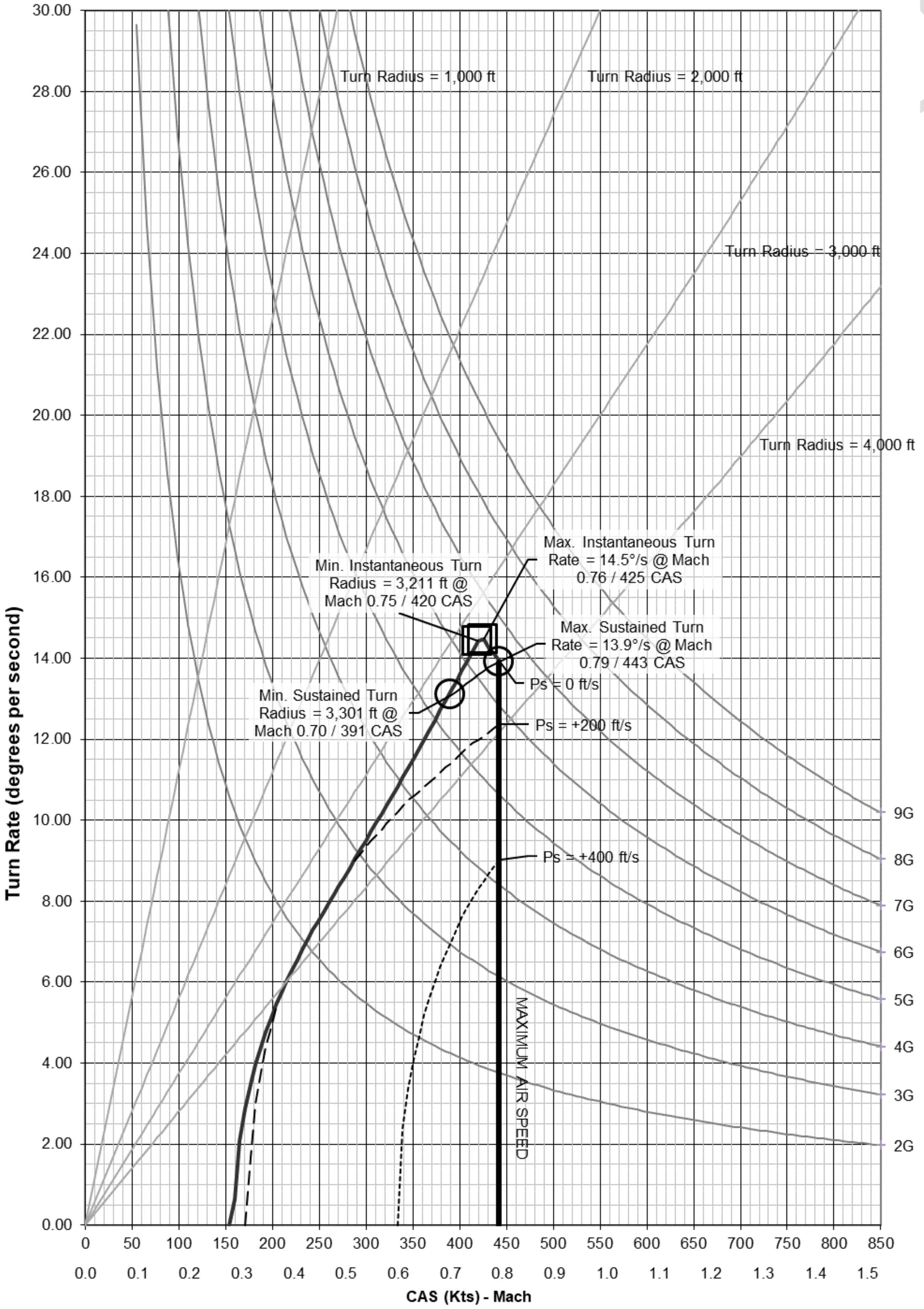


Figure 6.4

Energy-Mach Diagram at 15,000ft

DATA BASIS : COMPUTED
CONDITIONS:
- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 45°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs

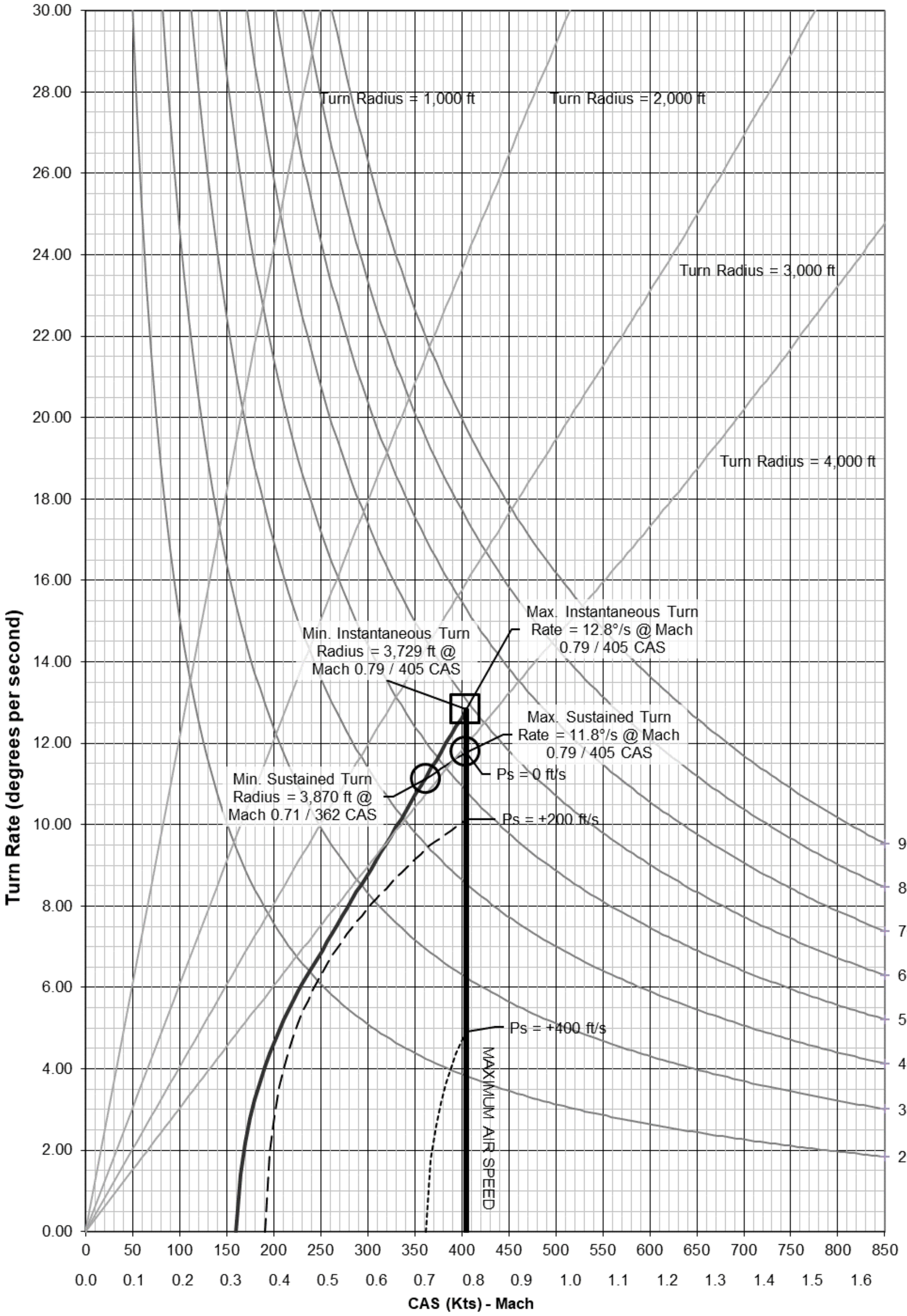


Figure 6.5

Energy-Mach Diagram at 20,000ft

DATA BASIS : COMPUTED

CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A

ENGINE: R35

Wing Swept Angle : 16°

Loads : 2xR-60M/MK + 2xR-24R/T

Gross Weight : 13,000 Kg / 28,697 lbs

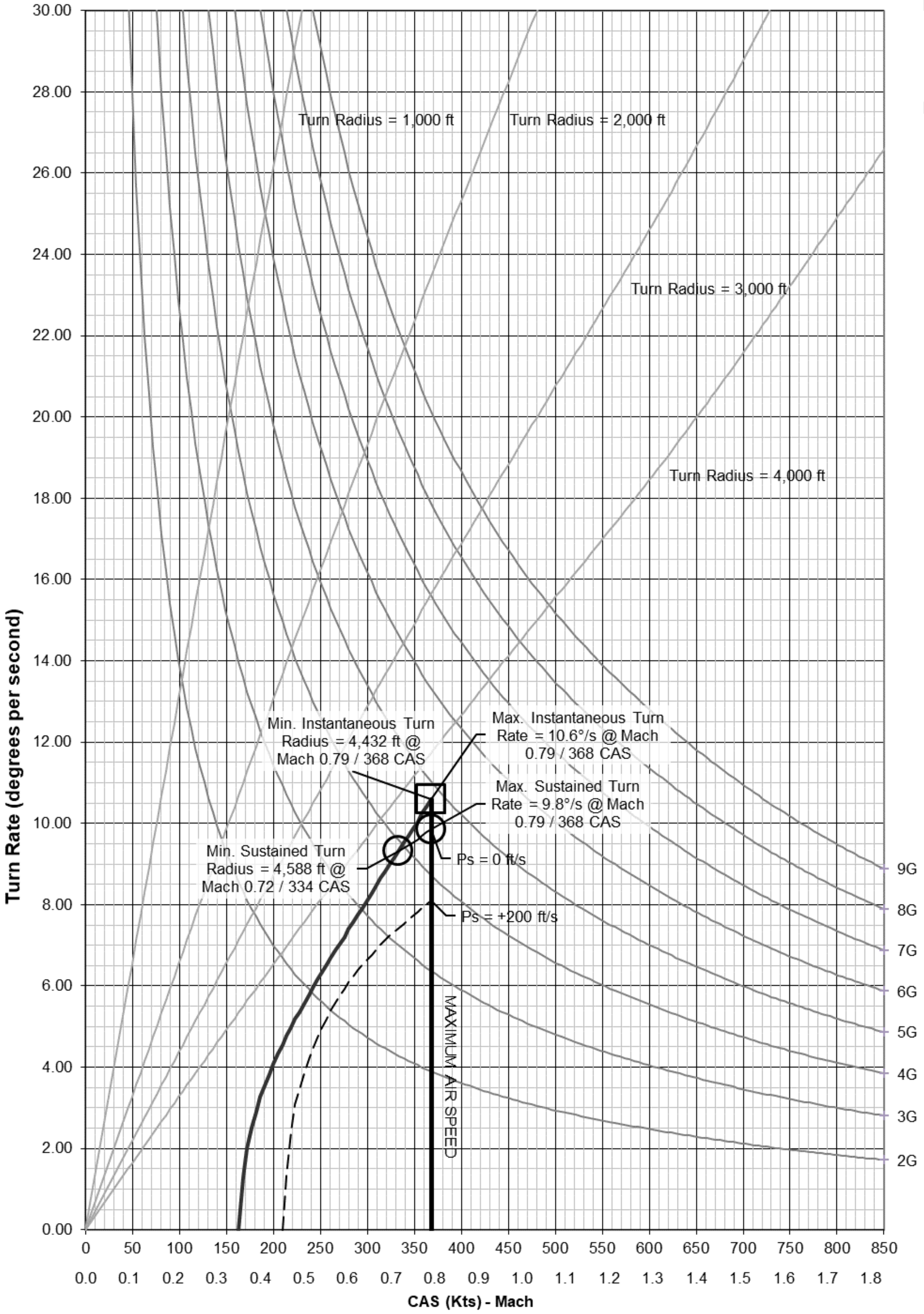


Figure 6.6

Energy-Mach Diagram at 25,000ft

DATA BASIS : COMPUTED
CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A
ENGINE: R35
Wing Swept Angle : 16°
Loads : 2xR-60M/MK + 2xR-24R/T
Gross Weight : 13,000 Kg / 28,697 lbs

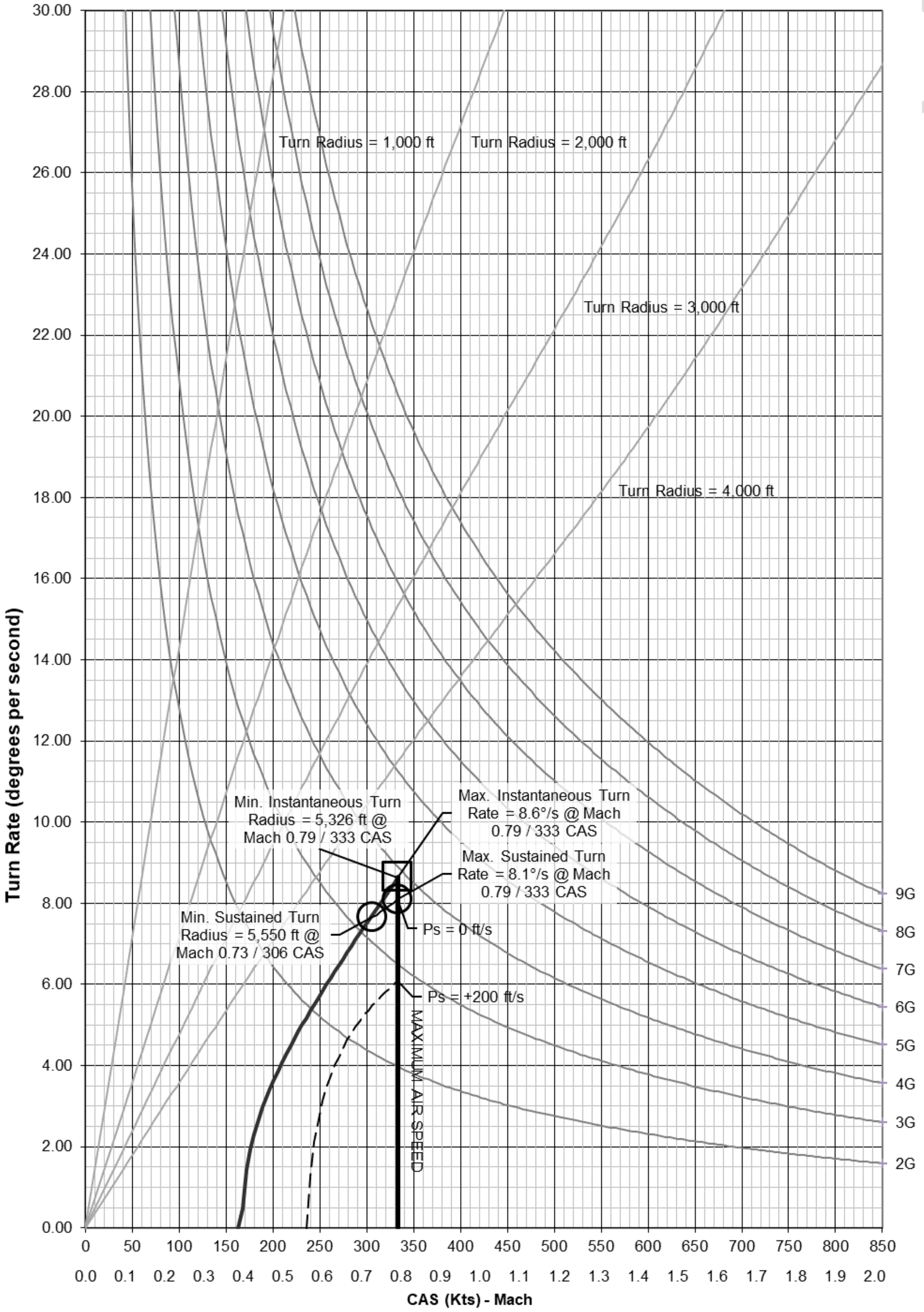


Figure 6.7

Energy-Mach Diagram at 30,000ft

DATA BASIS : COMPUTED

CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

AIRCRAFT : MiG-23ML izd.23-12A

ENGINE: R35

Wing Swept Angle : 16°

Loads : 2xR-60M/MK + 2xR-24R/T

Gross Weight : 13,000 Kg / 28,697 lbs

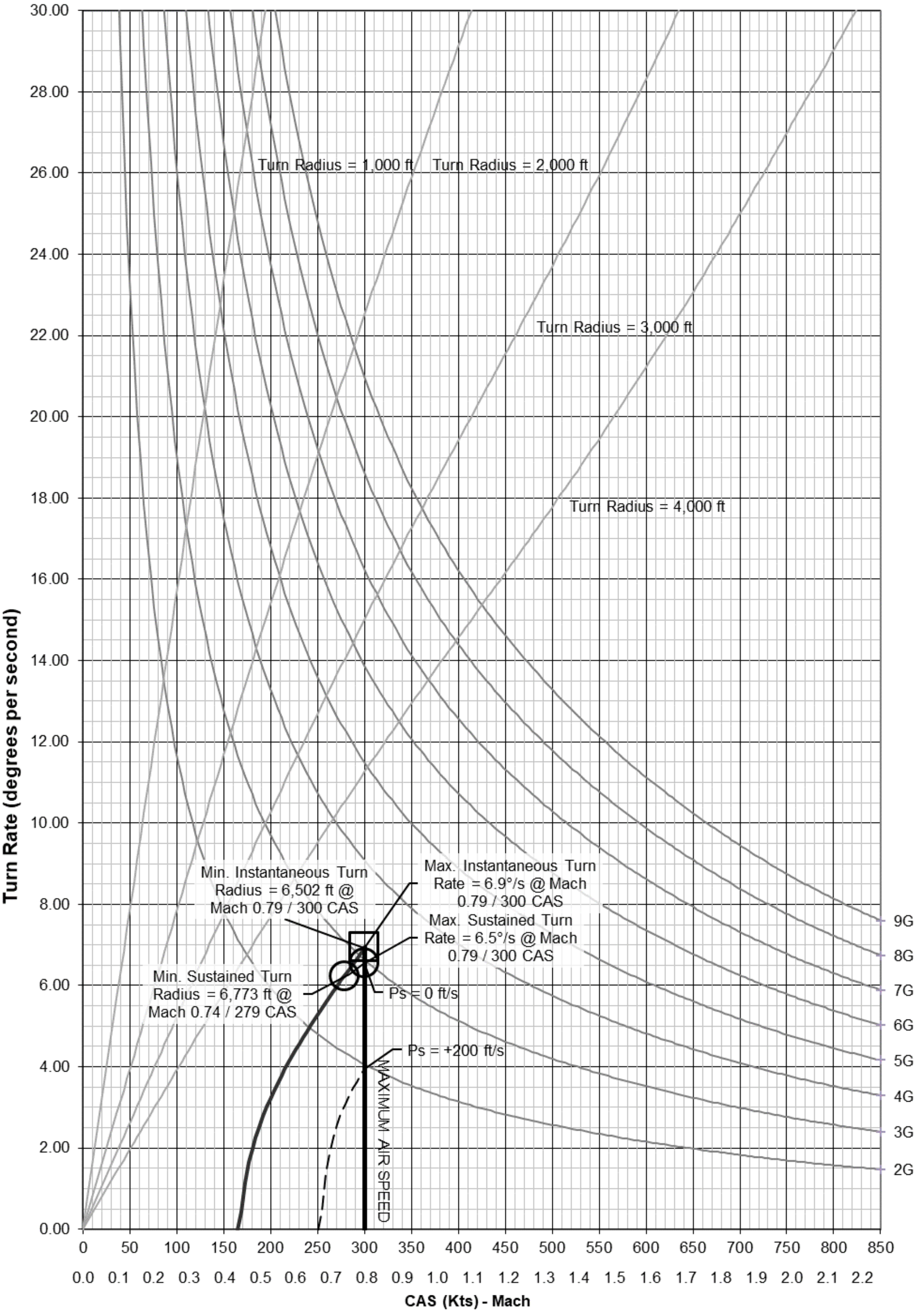


Figure 6.8

Energy-Mach Diagram at 35,000ft

DATA BASIS : COMPUTED

CONDITIONS:

- Atmosphere : Standard Day / ISA
- Engine regime: Max A/B
- SOUA System : Engaged

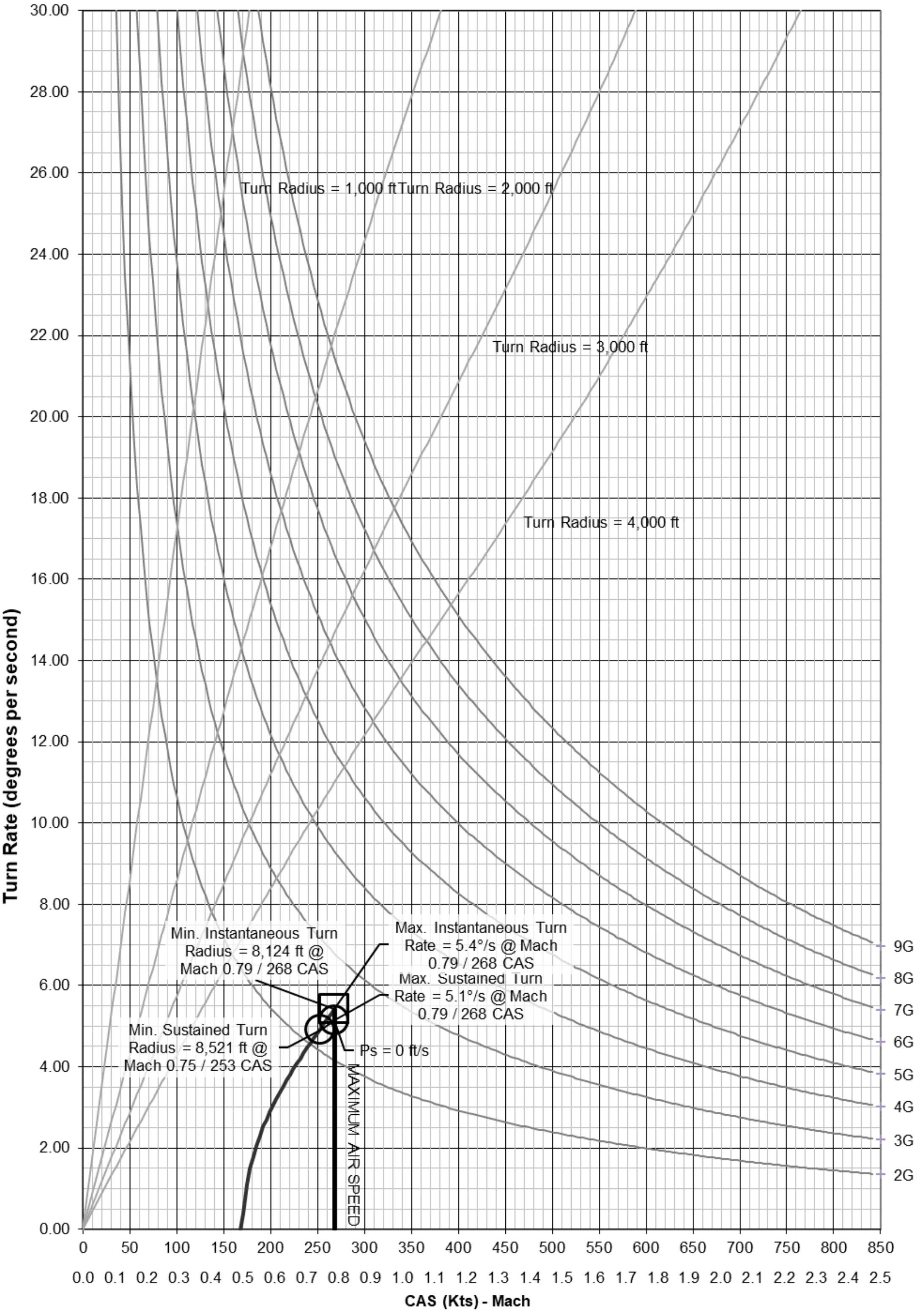
AIRCRAFT : MiG-23ML izd.23-12A

ENGINE: R35

Wing Swept Angle : 16°

Loads : 2xR-60M/MK + 2xR-24R/T

Gross Weight : 13,000 Kg / 28,697 lbs



I. Annexes and Figures

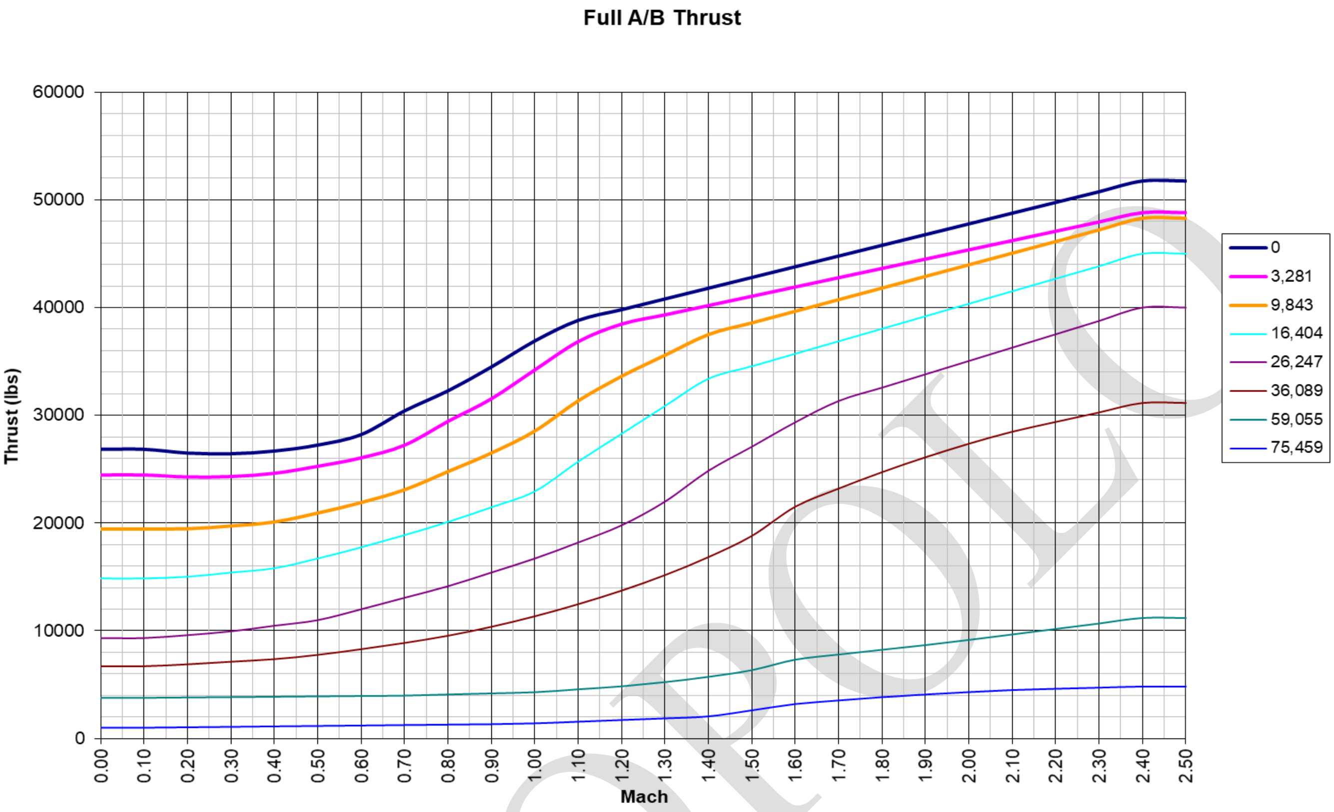
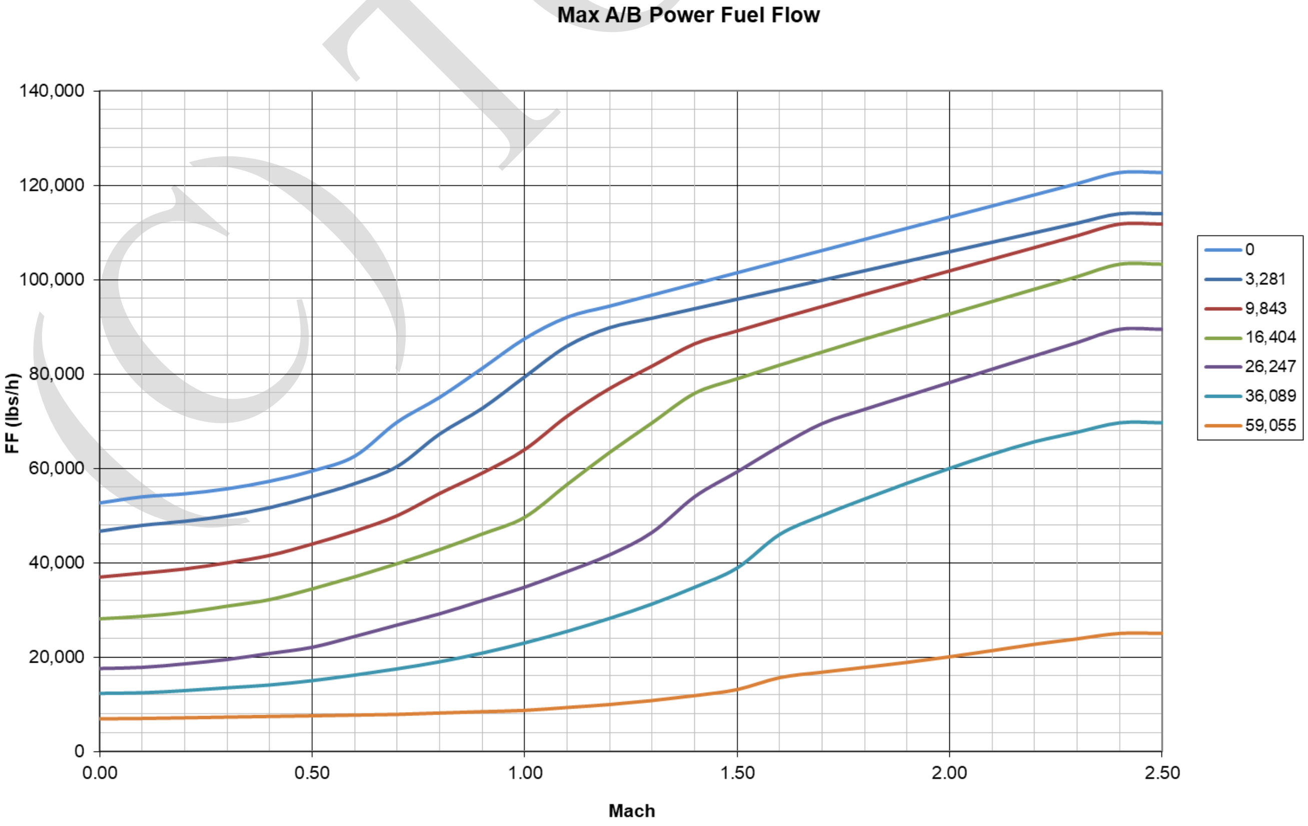


Figure I.1



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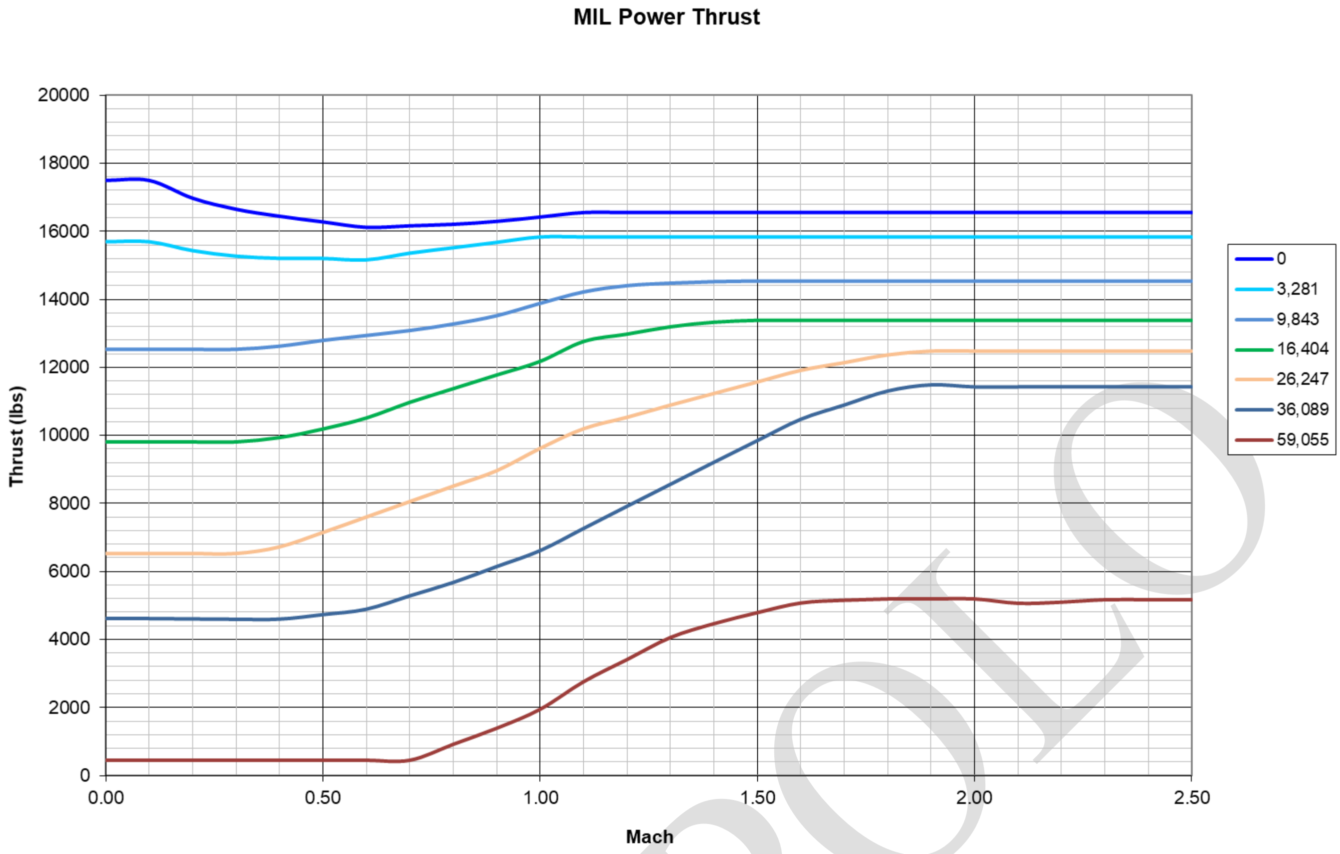

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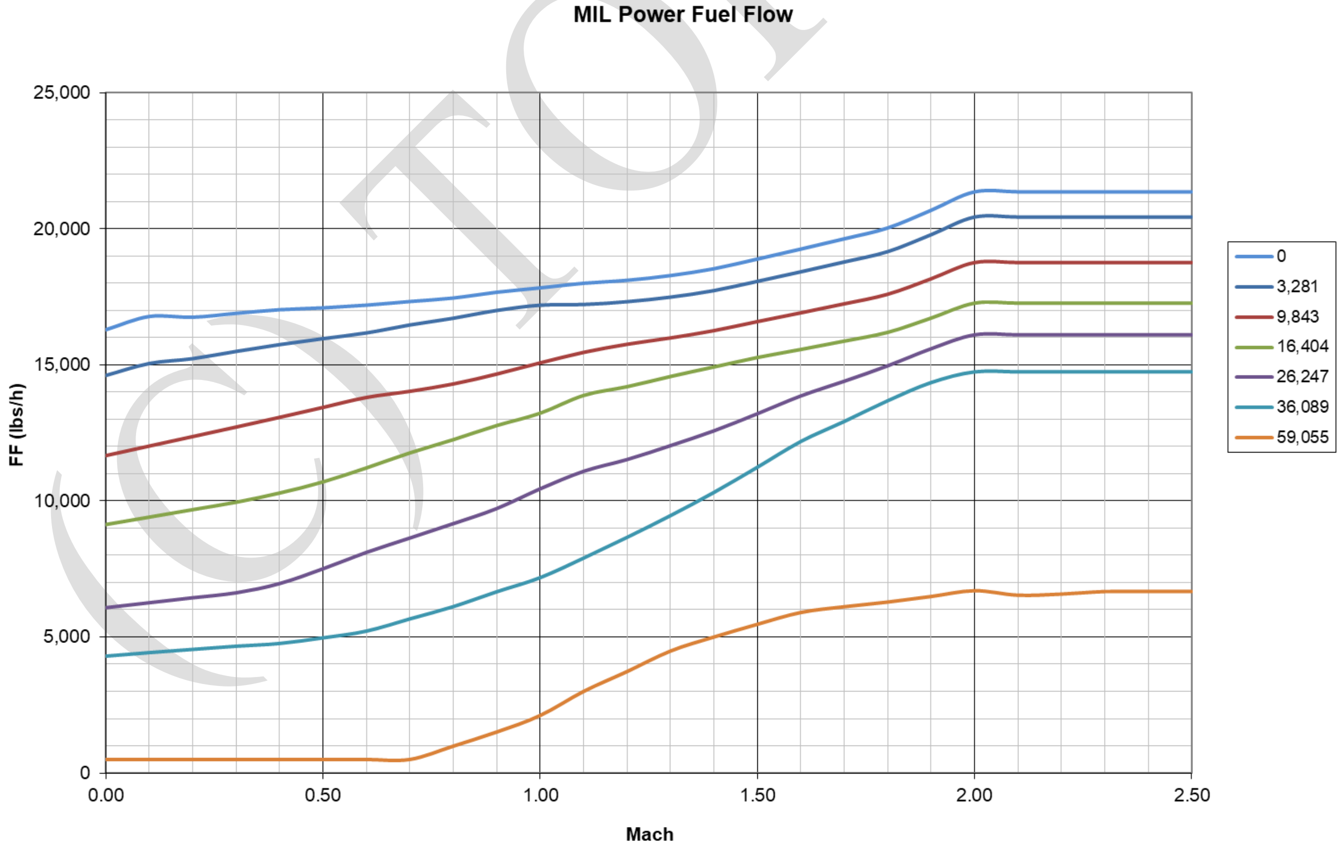
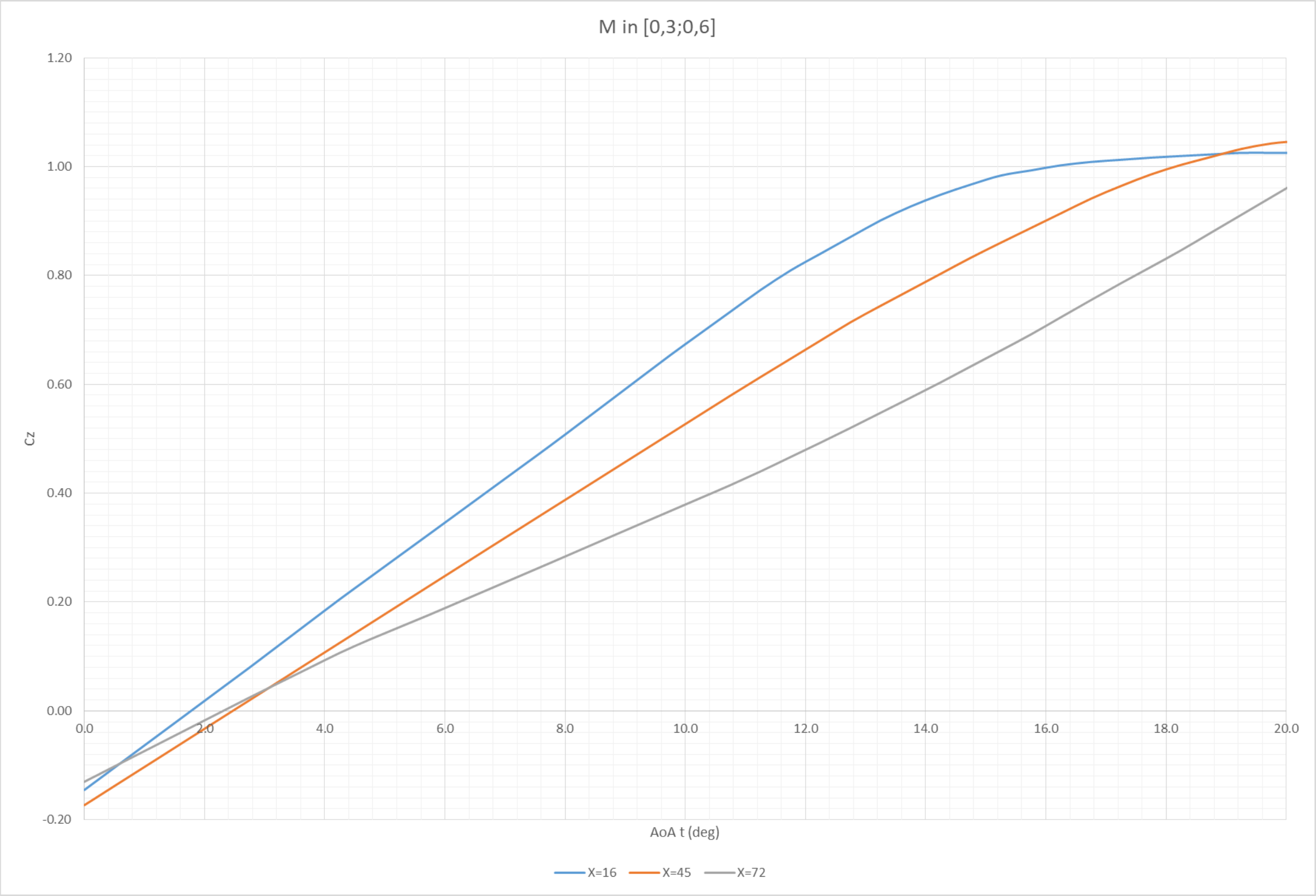


Figure I.4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Cz
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
AoA t (deg)
X=16
X=45
X=72

Figure I.5

J. Bibliography.

- Aircraft MiG-23UB Pilot’s Operating Instructions – Version B – Flight Performance
- Applied aerodynamic study of MIG23-ML and 23-UB, published by the Soviet Military Academy Library, (Aérodynamique pratique des avions MIG23-ML et 23-UB, Support d’enseignement, auteur : Bibliothèque de l’académie militaire). Available in Russian on AVIALOGS web site: http://www.avialogs.com/index.php/en/aircraft/ussr/mikoyangurevitch/mig-23/5379todo.html
- MiG-21 Flight Model Identification and Performance charts
  - Flight Model Identification - MiG-21
  - PERFORMANCE_CHARTS-MiG-21bis
  - PERFORMANCE_CHARTS-MiG-21M
  - PERFORMANCE_CHARTS-MiG-21MF
- Mirage III Flight Model Identification and Performance charts
  - Flight Model Identification - Mirage III
  - PERFORMANCE_CHARTS-Mirage-5
  - PERFORMANCE_CHARTS-Mirage-IIIC
  - PERFORMANCE_CHARTS-Mirage-IIICJ
  - PERFORMANCE_CHARTS-Mirage-IIIE
- F-4 Phantom II Flight Model Identification and Performance charts
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