

---

UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua  
Sidang Akademik 2005/2006  
*Second Semester Examination  
2005/2006 Academic Session*

April/Mei 2006  
*April/May 2006*

**ESA 362/3 – Kawalan Penerbangan Pesawat**  
*Aircraft Flight Control*

Masa : [ 3 jam]  
*Hour : [3 hours]*

---

**ARAHAN KEPADA CALON :**  
**INSTRUCTION TO CANDIDATES:**

Sila pastikan bahawa kertas soalan ini mengandungi **DUA PULUH (20)** mukasurat termasuk lampiran dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan.  
*Please ensure that this paper contains **TWENTY (20)** printed pages including attachment and **FIVE (5)** questions before you begin examination.*

Jawab **EMPAT (4)** soalan. Soalan nombor **1, 2 dan 3** mesti dijawab. Sila pilih salah satu soalan nombor **4 atau 5**.  
*Answer **FOUR (4)** the questions. Question number **1, 2 and 3** must be answered. Please choose one question number **4 or 5**.*

Soalan boleh dijawab dalam Bahasa Inggeris kecuali satu soalan mestilah dijawab dalam Bahasa Malaysia.  
*The question can be answered in English but one question must be answered in Bahasa Malaysia.*

Setiap soalan mestilah dimulakan pada mukasurat yang baru.  
*Each questions must begin from a new page.*

1. (a) Sila senaraikan enam langkah dalam merekabentuk pengawal (hukum kawalan) untuk sistem kawalan automatik penerbangan.

*Please list down six steps in designing the controller (control law) for an automatic flight control system.*

**(10 markah/marks)**

- (b) Senaraikan 3 jenis sistem kawalan automatik?

*List 3 kinds of automatic flight control system?*

**(10 markah/marks)**

- (c) Sebutkan jenis-jenis mod pandu automatik bagi pesawat udara dan fungsi-fungsinya.

*Mention the autopilot modes for aircraft and their functions.*

**(10 markah/marks)**

- (d) Sila berikan empat jenis persamaan yang membentuk persamaan tidak linear gerak pesawat dan fungsi-fungsinya.

*Please give four equations which form the nonlinear equations of motion of the aircraft and their functions.*

**(10 markah/marks)**

- (e) Mengapakah kita perlu menentukan keadaan mantap penerbangan trim sebelum memulakan proses lurus dan simulasi penerbangan.

*Why do we need to determine a steady-state, trimmed flight condition before starting the linearization process and flight simulation.*

**(10 markah/marks)**

- (f) Sila tuliskan model lurus gerak pesawat membujur dalam bentuk perwakilan keadaan ruang.

*Please write the linear model for longitudinal motion in the form of state space representation.*

**(10 markah/marks)**

- (g) Apakah perbezaan di antara "short period mode" dan "phugoid mode"?

*What are the differences between short period and phugoid modes?*

**(10 markah/marks)**

- (h) Tuliskan fungsi pindah yang menggambarkan

*Write the approximated transfer function describing*

- (i) sambutan kadar anggul disebabkan oleh pesongan sudut elevator

*the response of pitch rate due to the elevator deflection*

- (ii) sambutan halaju udara di sebabkan oleh kedudukan "throttle"

*the response of airspeed due to the lever throttle*

**(10 markah/marks)**

- (i) Sila lukiskan gambarajah aliran isyarat (SFD) bagi tempoh mod "short period" yang dipemudahkan.

*Please draw the signal flow diagram (SFD) of simplified Short period-mode.*

**(10 markah/marks)**

- (j) Sila lukiskan gambarajah aliran isyarat (SFD) bagi mod-'phygoid' yang dipemudahkan.

*Please draw the signal flow diagram (SFD) of simplified phygoid - mode.*

**(10 markah/marks)**

2. Pesawat penumpang jenis A 300 sedang membuat penerbangan di dalam keadaan atmosfera tidak terganggu ( udara tenang dan tiada angin). Keadaan penerbangan yang pegun dan secara simetri diberi seperti berikut:

*A passenger aircraft of Type A 300 is performing level flight in the undisturbed atmosphere (still air , no wind). The stationary, symmetrical flight condition is given below*

Jisim pesawat	$m = 140,000.00 \text{ kg}$
Kelajuan Angin	$V = 120 \text{ m/s}$
Kedudukan pusat graviti	$(X_s - 0.25) = 0.05$
Kedudukan menegak tujahan enjin	$Z_E = 2.65 \text{ m}$
Sudut condong enjin	$\sigma = 2.2 \text{ degree}$

<i>Mass of the aircraft</i>	$m = 140,000.00 \text{ kg}$
<i>Airspeed</i>	$V = 120 \text{ m/s}$
<i>Position of the centre of gravity</i>	$(X_s - 0.25) = 0.05$
<i>Vertical position of engine thrust</i>	$Z_E = 2.65 \text{ m}$
<i>The Inclination angle of engine</i>	$\sigma = 2.2 \text{ degree}$

Selepas mendapatkan persamaan gerakan bagi penerbangan secara membujur dan penentuan keadaan mantap penerbangan trim, data penerbangan dalam keadaan ini diberi seperti yang berikut:

*After setting up equation of motion for longitudinal flight and determining the steady-state trimmed flight condition, the data of that trim flight condition is provided as follows:*

$$\alpha_0 = 0.0925 = 5.3^\circ$$

$$C_{L,0} = 0.74$$

$$C_{D,0} = 0.045$$

$$C_{m,0} = -0.0182$$

$$C_{\mu,0} = 0.0455 \text{ (thrust coefficient)}$$

$$i_{H,0} = -0.0068 = 0.39^\circ$$

- (a) Kira terbitan dimensi aerodinamik yang berikut

$$M_q, M_\alpha, M_u, Z_\alpha, Z_u, X_\alpha, X_u$$

*Calculate the following dimensional aerodynamic derivatives:*

$$M_q, M_\alpha, M_u, Z_\alpha, Z_u, X_\alpha, X_u$$

**(100 markah/marks)**

- (b) Tentukan terbitan dimensi kawalan yang berikut:

$$M_\eta, M_f, Z_\eta, Z_f, X_\eta, X_f$$

*Determine the following dimensional control derivatives:*

$$M_\eta, M_f, Z_\eta, Z_f, X_\eta, X_f$$

**(100 markah/marks)**

3. Sila nyatakan persamaan lurus gerak penerbangan membujur

*Represent the linear equation of motion for longitudinal flight*

- (a) dalam bentuk perwakilan keadaan ruang  $\dot{\underline{X}} = \underline{A}\underline{X} + \underline{B}\underline{U}$

*in form of the state – space representation  $\dot{\underline{X}} = \underline{A}\underline{X} + \underline{B}\underline{U}$*

- (b) gambarajah blok isyarat

*signal diagram block*

**(100 markah/marks)**

4. Berdasarkan persamaan hampir bagi mod kalaan pendek, tentukan yang berikut:

*Based on the approximate equation for short-period mode, determine the following:*

- (a) fungsi pindah  $f_{q\eta}$

*the transfer function  $f_{q\eta}$*

- (b) redaman  $\zeta$  dan frekuensi tabii  $\omega_0$  kalaan pendek

*the damping  $\zeta$  and natural frequency  $\omega_0$  of short period*

- (c) ciri-ciri awalan dan akhiran kepegunan  $q$  yang disebabkan oleh input langkah  $\eta$ .

*initial – and stationary characteristics of  $q$  due to step input of  $\eta$*

**(100 markah/marks)**

5. Berdasarkan persamaan terdekat untuk mod phugoid, tentukan yang berikut:

*Based on the approximate equation for phugoid mode, determine the following:*

- (a) fungsi pindah  $f_{uf}$

*the transfer function  $f_{uf}$*

- (b) redaman  $\zeta$  dan frekuensi tabii  $\omega_0$  mod phugoid

*the damping  $\zeta$  and natural frequency  $\omega_0$  of phugoid mode*

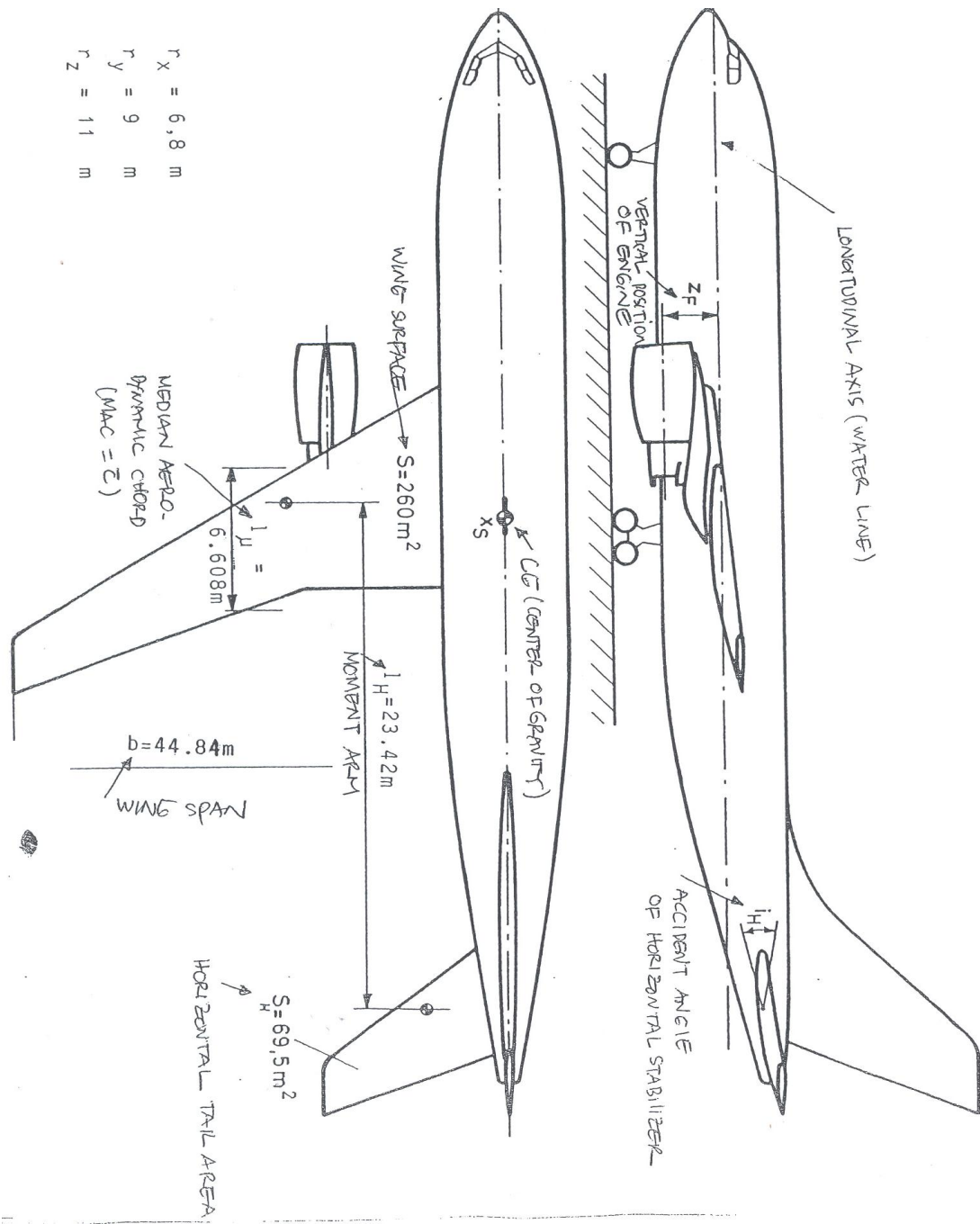
- (c) ciri-ciri awalan dan akhiran kepegunan  $u$  yang disebabkan oleh input langkah pengesetan pengawal imbang  $f$

*initial – and stationary characteristics of  $u$  due to step input of throttle setting  $f$*

**(100 markah/marks)**

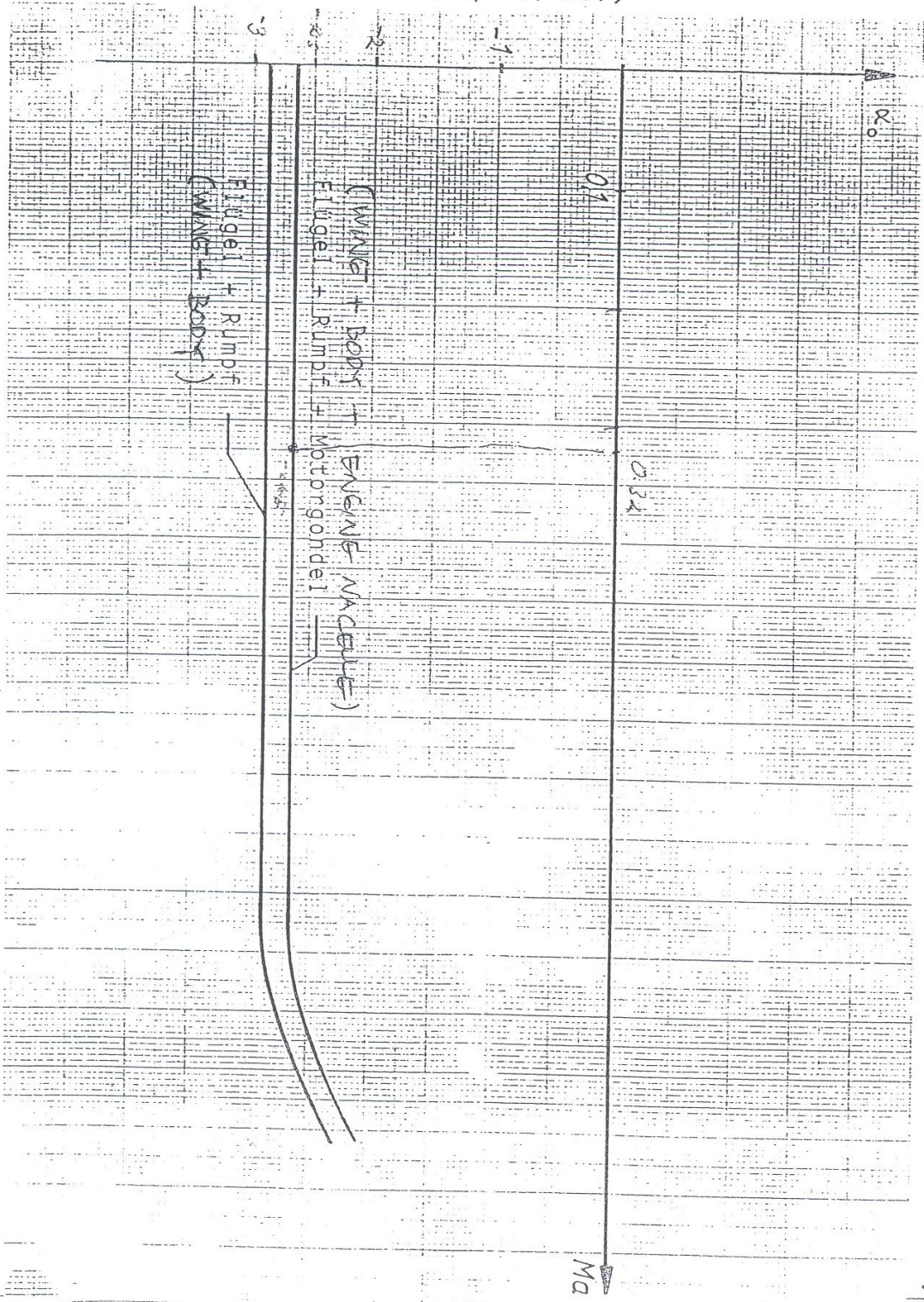
ooo000ooo

**LAMPIRAN/ATTACHMENT**

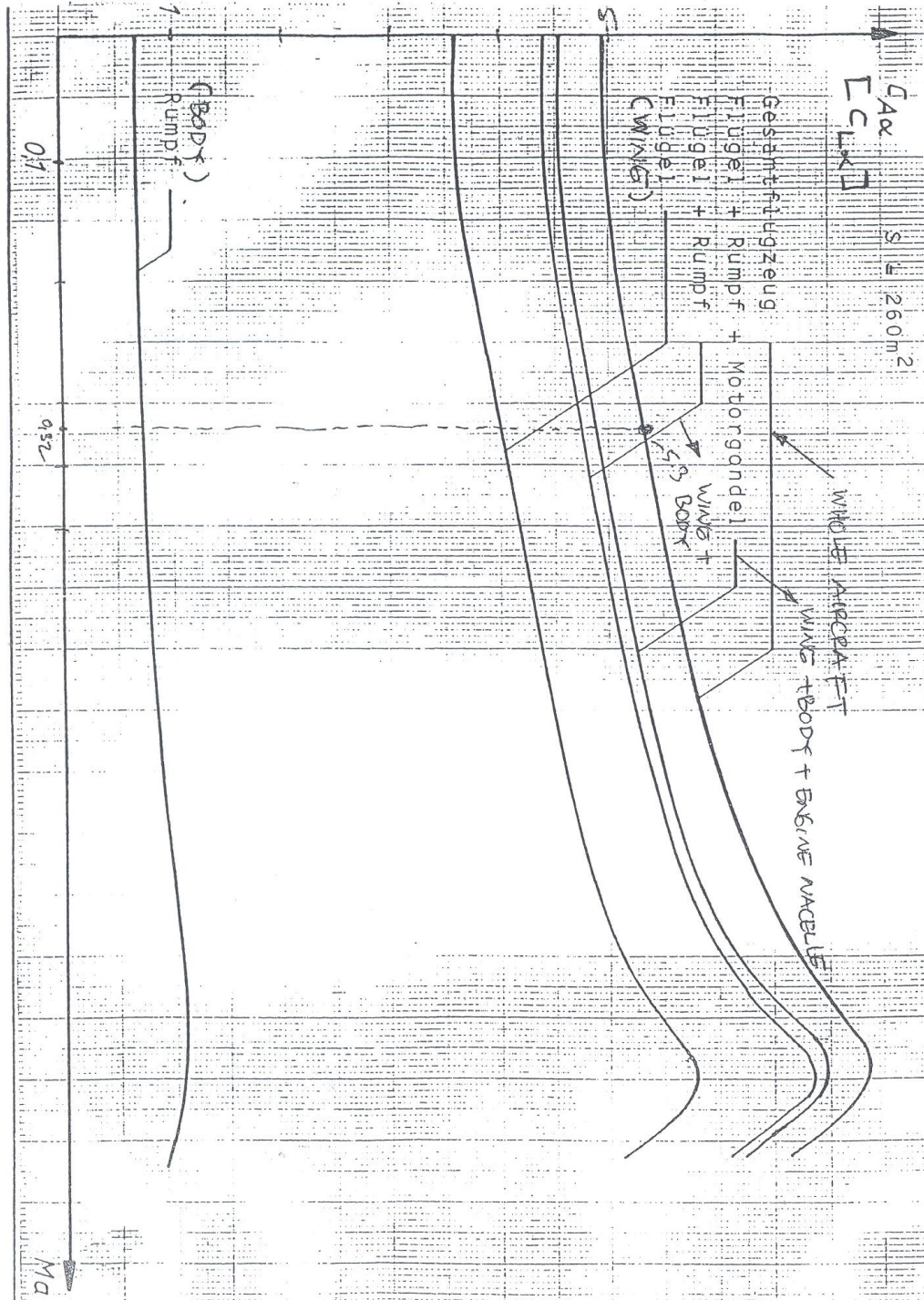


- $r_x = 6,8 \text{ m}$
- $r_y = 9 \text{ m}$
- $r_z = 11 \text{ m}$

Anstellwinkel bei Auftrieb Null  
(ZERO LIFT ANGLE OF ATTACK)



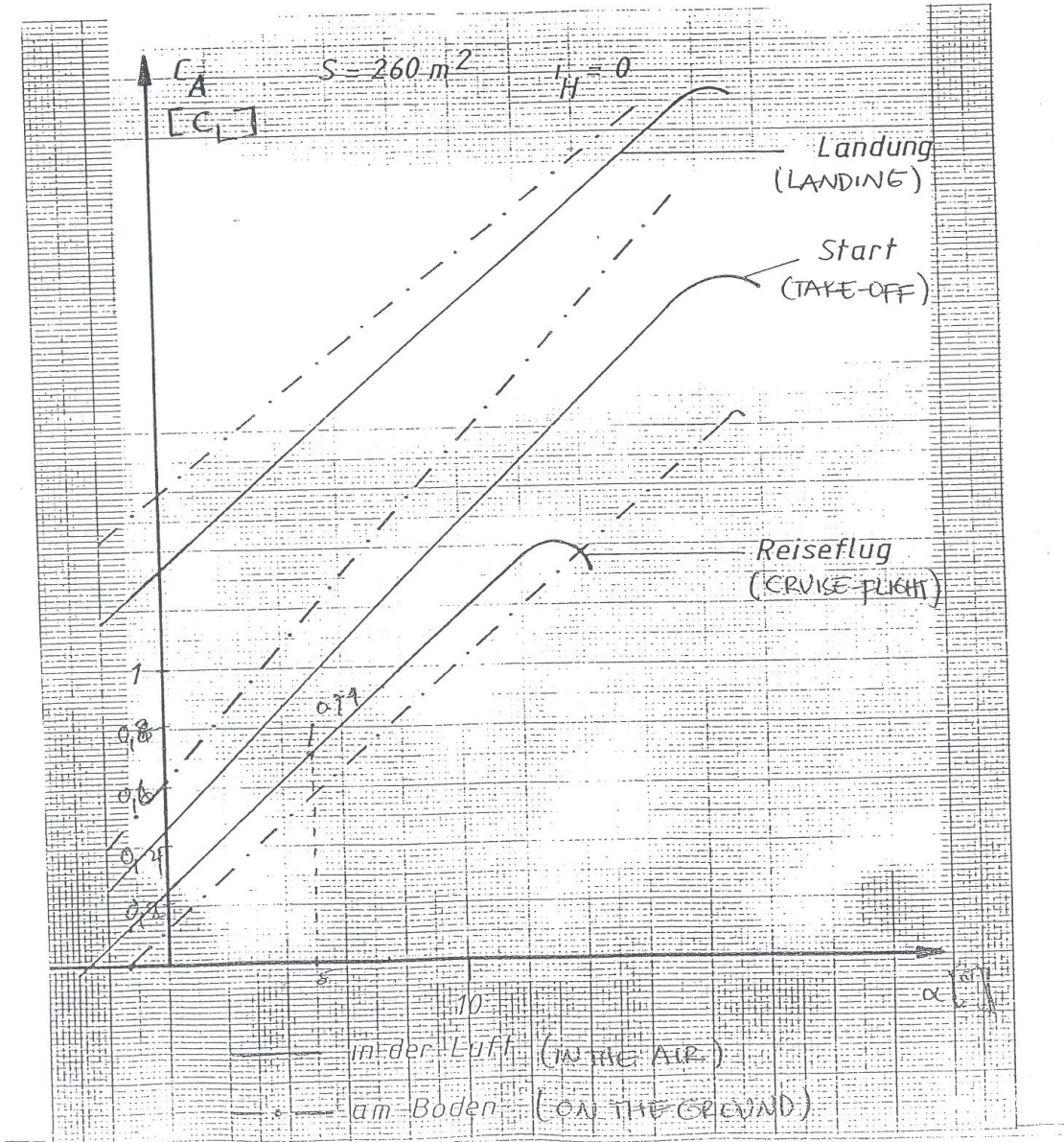
Auftriebsanstieg als Funktion der Machzahl  
(LIFT-SLOPE AS FUNCTION OF MACH-NUMBER)



... 10/

(LIFT-COEFFICIENT OF WHOLE AIRCRAFT  
AT SLOW AIRSPEEDS )  
Auftriebsbeiwert des Gesamtflugzeugs

bei niedrigen Geschwindigkeiten

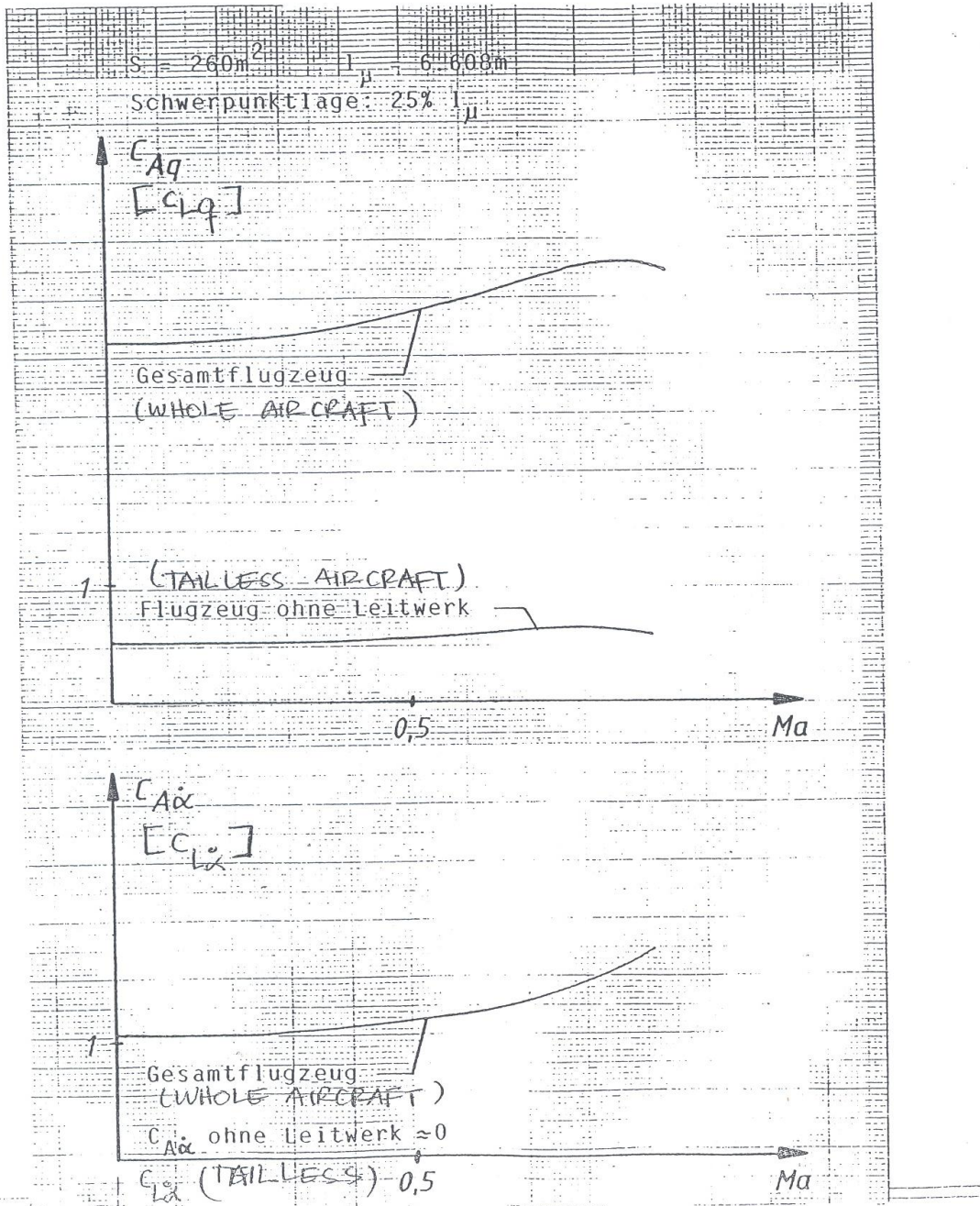


(LIFT-SLOPE DUE TO PITCH-RATE)

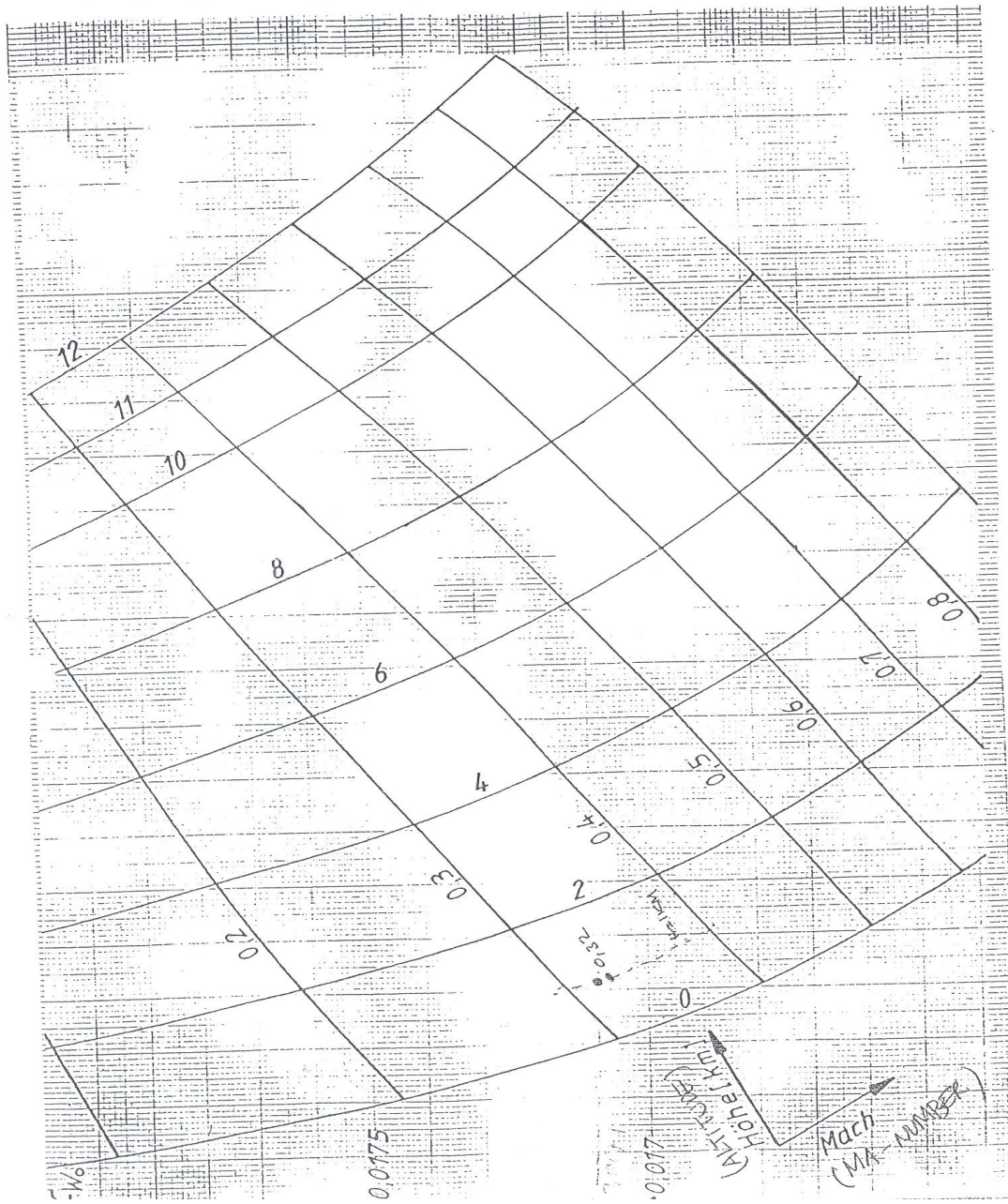
Auftriebsanstieg infolge Nickgeschwindigkeit

(LIFT-SLOPE DUE TO AOA-CHANGE)

Auftriebsanstieg infolge Anstellwinkeländerung

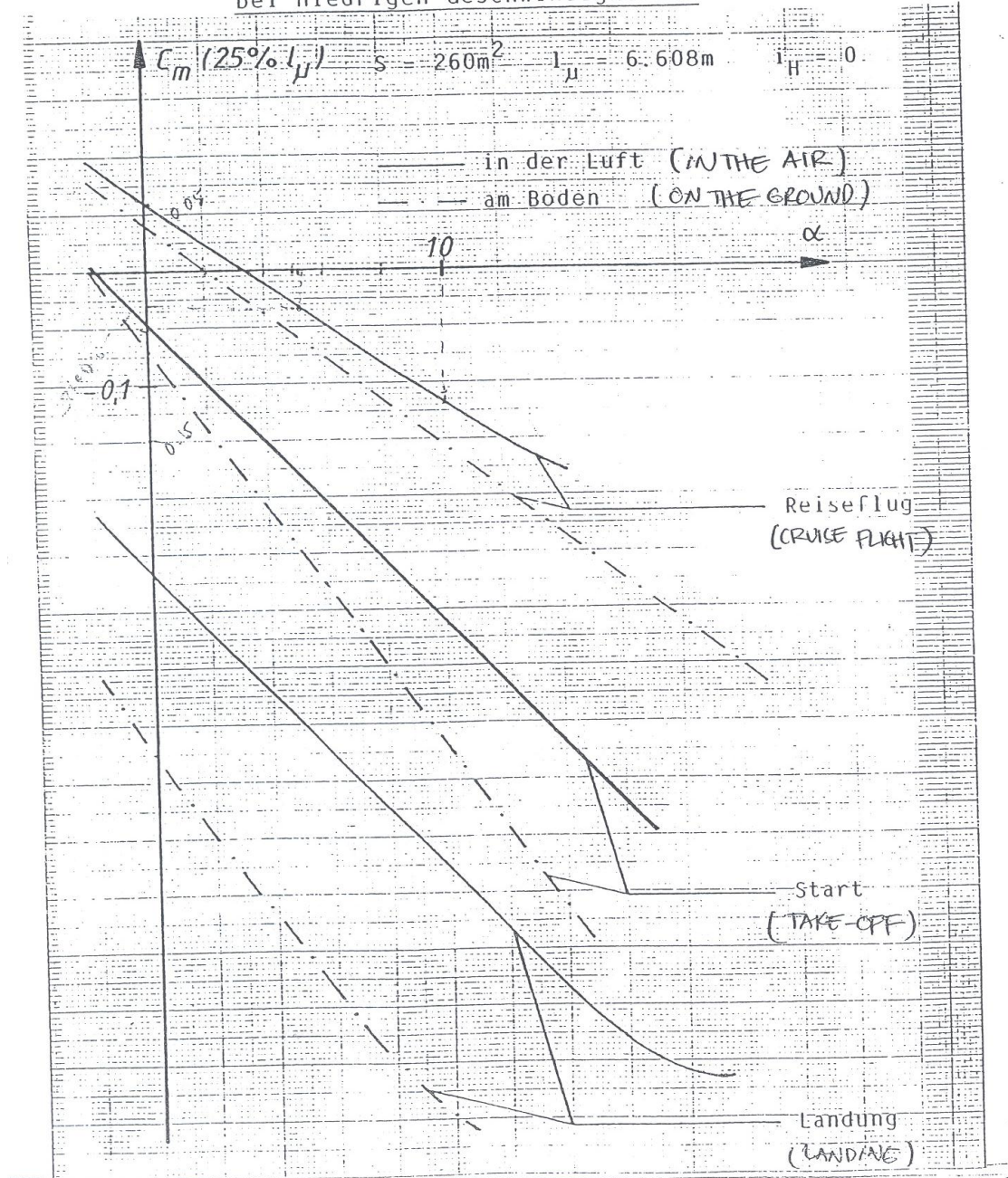


Nullwiderstandsbeiwert als Funktion von Höhe und Machzahl  
(ZERO DRAG COEFFICIENT ALS FUNCTION OF ALTITUDE & MA-NUMBER)

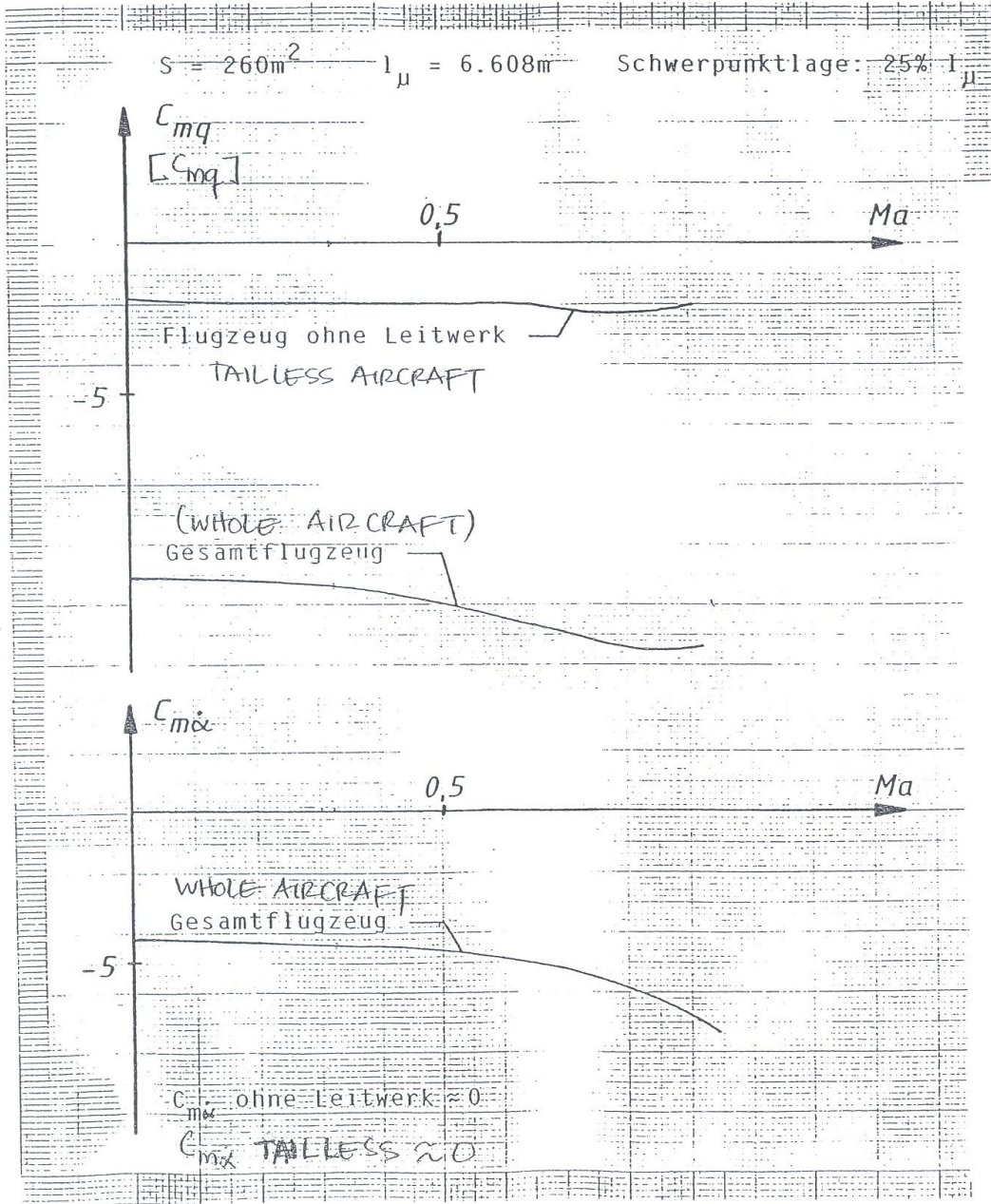


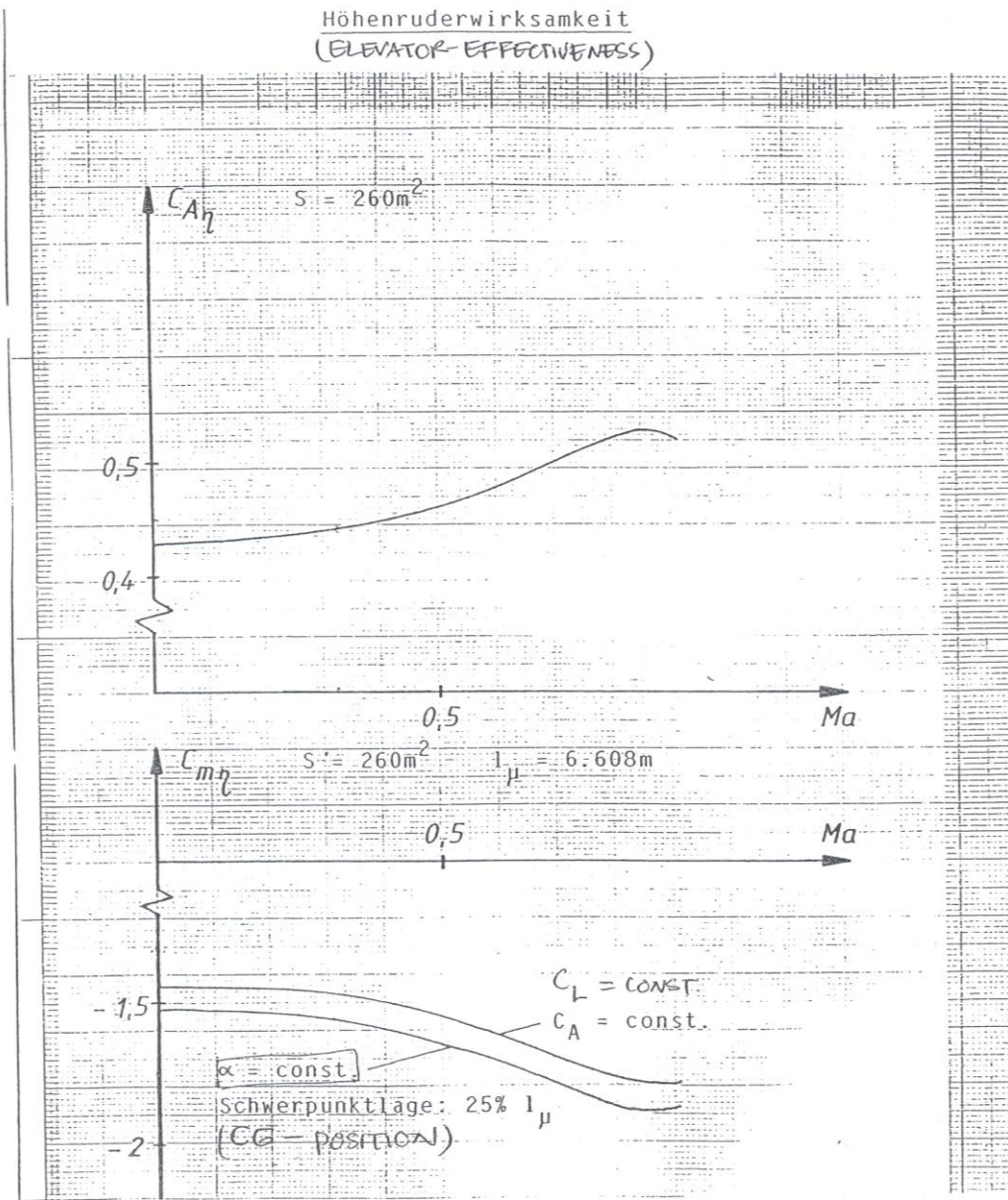
PITCH MOMENT COEFFICIENT OF WHOLE AIRCRAFT  
AT LOW AIRSPEEDS

Nickmomentenbeiwert des Gesamtflugzeugs  
bei niedrigen Geschwindigkeiten

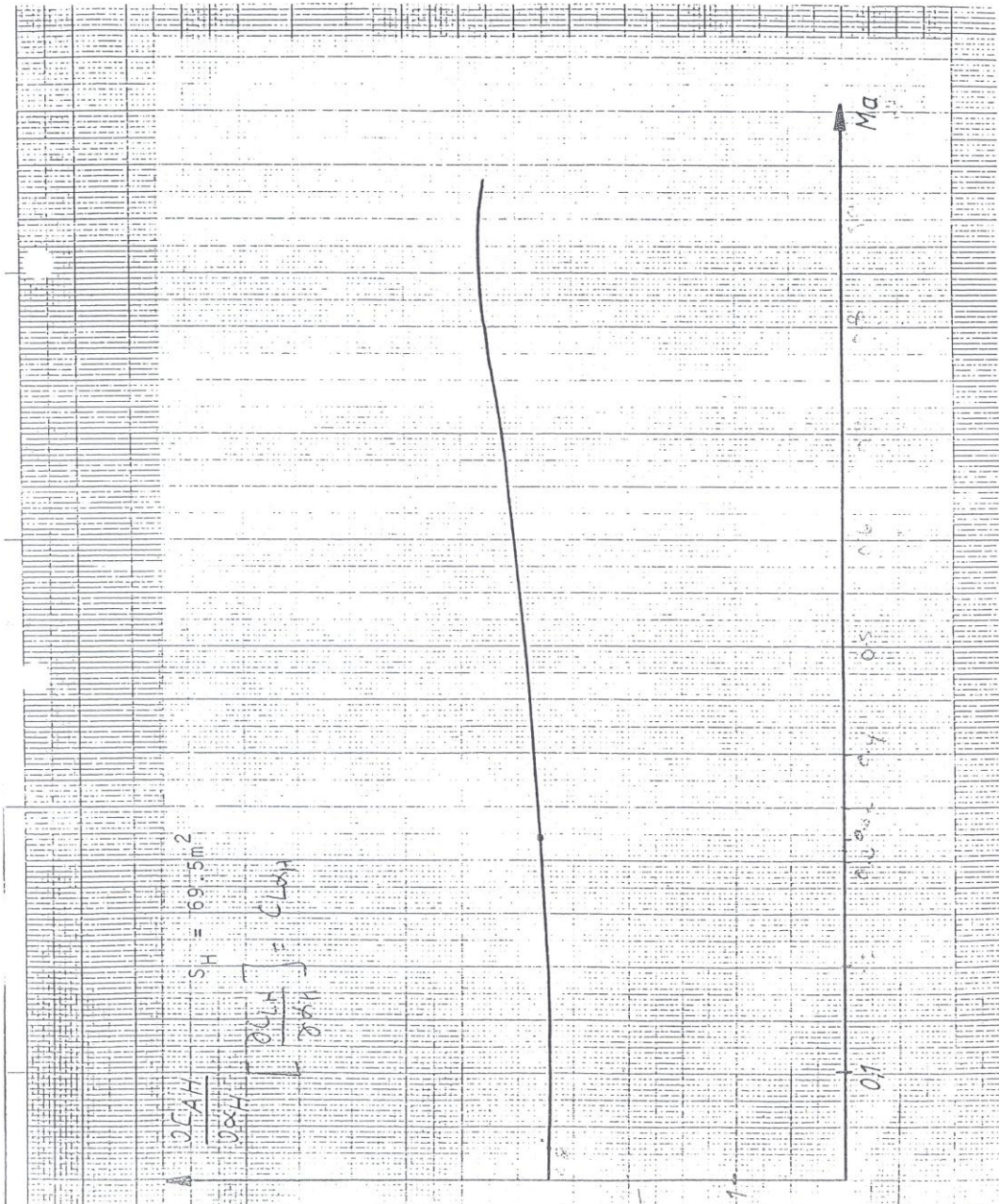


Nickdämpfung und Abwindverzögerung  
 PITCH DAMPING & UPWIND LAG)





Auftriebsgradient des Höhenruders  
(LIFT COEFFICIENT OF ELEVATOR)



Abwindwinkel des Leitwerks  
(DOWNWASH ANGLE OF HORIZONTAL TAIL)

