Memorandum

U.S. Department
of Transportation

Federal Aviation Administration

Subject: **ACTION**: Equivalent Level of Safety for Compliance; Joint Aviation Requirements (JAR) 22, Change 5, dated 28 October 1995; Alexander-Schleicher ASW-28 Certification Basis; Finding No. ACE-02-13

Date: DEC 18 2002

From: Manager, Standards Office, ACE-110

Reply to Attn. of:

To: Manager, Small Airplane Directorate, ACE-100

BACKGROUND:

The Federal Aviation Administration received an application from Alexander-Schleicher Flugzeugbau GmbH (AS) for the Model ASW-28 sailplane. As provided in AC 21.17-2A, Alexander-Schleicher has proposed Joint Aviation Requirements (JAR) 22, Change 5, dated 28 October 1995, as the certification basis for this model sailplane.

JAR 22.335(f) provides an empirical formula to determine the design dive speed of the sailplane. This formula states that the dive speed is inversely proportional to the cube root of the minimum drag coefficient, and has been in existence prior to the development of the JAR 22 standards (German LFSM design rules). The design limitations of sailplanes, at the time the JAR 22 standard was released, supported the appropriate use of this formula.

However, this formula can be unnecessarily restrictive to advanced sailplane designs that are aerodynamically clean. Alexander-Schleicher has conducted flight tests on the Model ASW-28 and determined that the minimum drag value occurs at a lift coefficient of approximately 0.3. The corresponding drag coefficient when using the formula in JAR 22.335(f) yields a dive speed of 316 km/h.

Alexander-Schleicher contends that this dive speed is unreasonably high. They propose a maximum dive speed of 300 kilometers per hour (V_D = 300 km/hr) using the methodology in the attachment. This methodology is predicated on an industry accepted criterion that a maximum design speed be reached at a sink rate of 7.8 meters/second (25.6 feet/second). In fact, this same criterion is implicit in the empirical formula.

The methodology is an iterative approach used to correlate V_D and the sink rate, based on the actual Lift-to-Drag polar of the ASW-28. Again, the attachment provides a full explanation of this methodology. The German Civil Aviation Authority, Luftfahrt-Bundesamt (LBA), accepted this methodology and issued a positive ELOS finding to Alexander-Schleicher for JAR 22.335(f).

RECOMMENDATION:

The FAA reviewed the derivation of the empirical formula as provided by the Luftfahrt-Bundesamt. The FAA concurs with the Equivalent Level of Safety, as approved by the LBA and provided by Alexander-Schleicher. The FAA has determined that the methodology used by Alexander-Schleicher provides an equivalent level of safety as envisioned by the requirements of JAR 22.335(f). Therefore, the FAA hereby issues a positive finding of Equivalent Level of Safety to Alexander-Schleicher for JAR 22.335(f).

Dana R. Shane 12/18/02

Manager, Standards Office, ACE-110 Date

Concurred by:

Michael Gallagher 12/18/02

Manager, Small Airplane Directorate, Aircraft Certification Service Date

Iterative Calculation of Design Maximum Speed V_D

The calculated minimum drag-coefficient of the ASW 28 is so low that the Design Maximum Speed V_D calculated according to paragraph JAR 22.335 (f) seems to be unreasonable high (316,4km/h). In this calculation an iterative approach is made to use the actual drag-coefficient, basing on the JAR 22.335(f) formula. A criterion for a valid design maximum speed (implicitly used in the JAR 22.335(f) formula) is a sink-rate of 7.8m/s to be reached at V_D.

Basis of this proceeding are the calculated drag values for the ASW 28 (see page 4.1.2-15 of ASW28 substantiation). They are plotted in Fig.1

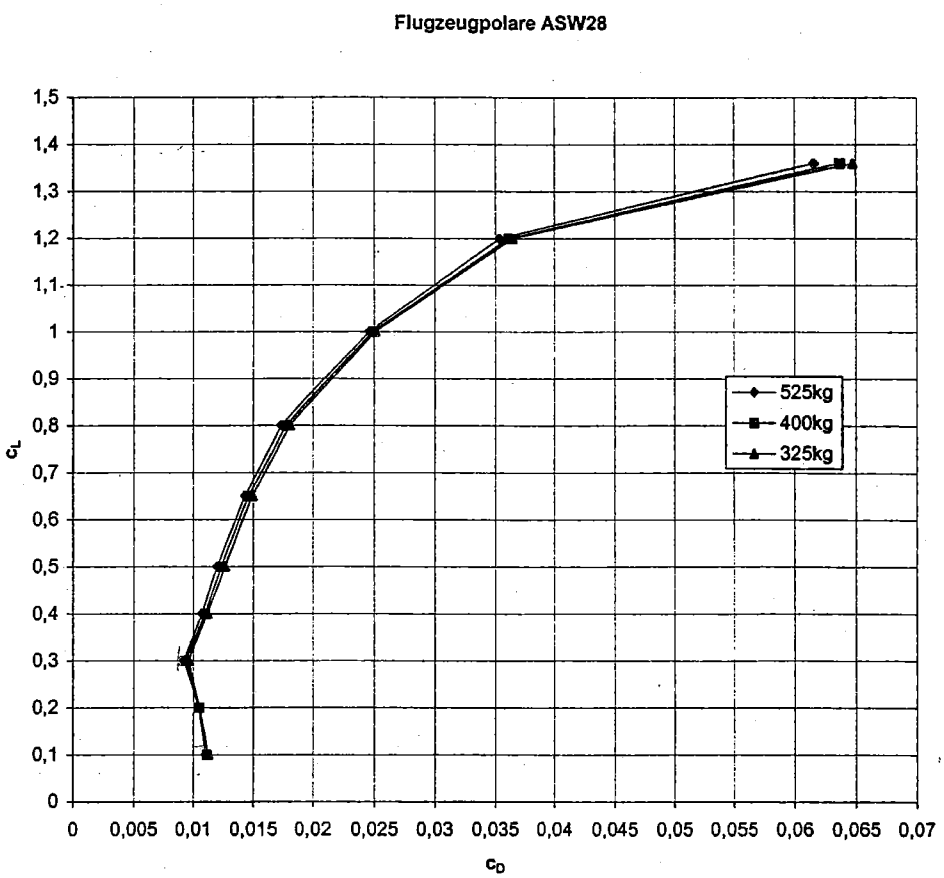


Fig1: *Calculated Lift-To-Drag Polar of the ASW 28*

In a first step the drag coefficient between lift coefficients of 0.1 to 0.2 can approximated as linear.

According to paragraph JAR 22.335 (f) the Design Maximum Speed V_D is calculated as:

$V_{D_{Test}} = 314$
analytical

$$V_D = 18 \cdot \sqrt[3]{\frac{m}{S}\frac{1}{c_{D,\min}}} \text{ [km/h]} \qquad (1)$$

4.1.9-335.5

with m=525kg, S=10,5m^2, and $c_{D,min}$=0,00921 this results in V_D^0=316,4km/h. The corresponding lift coefficient is c_L=0,104. The drag coefficient is interpolated between $c_D(c_L=0,1)$=0,01101 and $c_D(c_L=0,2)$=0,01046, and yields $c_D(c_L=0,104)$=0,010988. This value is set into equation (1). The results of the following iterations are presented in table 1:

i	0	1	2
V_D [km/h]	316.4	298.3	298.9
c_L []	0.10370	0.11666	0.11616
c_D []	0.01099	0.01092	0.01092

Tab1: *Iteration of Design Maximum Speed and force coefficients*

After two iterations four digits of the drag coefficient do not change any more. The design maximum speed converges to V_D=298,9km/h.

With respect to the linearization of the lift-to-drag polar a higher value of V_D=300km/h is chosen. For this case a lift coefficient of c_L=0,115 and a linear interpolated drag coefficient of c_D=0.0109 is calculated und results in a sink rate of:

$$w = V\frac{c_D}{c_L} = 83.33\frac{0.0109}{0.115} = 7.9\ \text{m/s}$$

4.1.9-335.4

ALEXANDER SCHLEICHER SEGELFLUGZEUGBAU

D-36163 Huhnrain 1
D-36161 Postfach 60
POPPENHAUSEN WASSERKUPPE

TELEFON: +49 6658/88-0
TELEFAX: +49 6658/8840 ; +49 6658/6623
BANK: DRESDNER BANK AG; FULDA KONTO NR. 80 44258 (BLZ 530 800 30)
KREISSPARKASSE FULDA KONTO NR. 8009933 (BLZ 530 501 80)
POSTBANK: FRANKFURT/ MAIN 349 50 -601
BAHNSTATION: FULDA

Alexander Schleicher GmbH & Co. Segelflugzeugbau
Postfach 60 , D-36161 Poppenhausen

Luftfahrt-Bundesamt
Geschäftsfeld M
Fachbereich 3
z.H. Herr Irmer

Postfach 3054
D-38020 Braunschweig

Ihr Zeichen	Ihr Schreiben	Unser Zeichen	Datum
		MKWNG	11. Mai 2000

Segelflugzeug ASW 28, Änderung der Bemessungshöchstgeschwindigkeit V_D

Sehr geehrte Damen und Herren,
verehrter Herr Irmer!

Aufgrund einer Anregung aus unserem Gespräch vom 10.5.00 möchten wir die Bemessungshöchstgeschwindigkeit V_D des Segelflugzeugstyps ASW 28 von 316,4km/h auf 300km/h senken.

Durch den geringen Minimalwiderstand $c_{W,min}$ des Gesamtflugzeuges bei c_A=0,3 ergibt sich der sehr hohe Wert von 316,4km/h für V_D. Für den stationären Sturzflug (n=1) sind die Widerstandsbeiwerte jedoch größer. Daher wird vorgeschlagen die Bemessungshöchstgeschwindigkeit durch ein iteratives Verfahren zu bestimmen. Eine Ausführung findet sich im Anhang.

Ein ähnliches Verfahren wurde bereits bei der Nachweisführung der ASW 27 angewendet (siehe beigefügten Briefverkehr).

Mit freundlichem Gruß,

Michael Greiner

Anlagen: Briefwechsel betreffs V_D der ASW27 (3 Seiten) ASW 27 4.9-181 bis -183
Tabelle gerechneter Flugleistungen aus ASW 28-Nachweis (Seite 4.1.2-15)
Ausführung der iterativen Bestimmung der Bemessungshöchstgeschwindigkeit

Kommanditgesellschaft, Sitz Poppenhausen, Amtsgericht Fulda, Zweigstelle Gersfeld (Rhön), HRA 272. Persönlich haftende Gesellschafterin: Schleicher GmbH, Sitz Poppenhausen, Amtsgericht Fulda, Zweigstelle Gersfeld (Rhön), HRB 62, Geschäftsführer Edgar Kremer

4.1.9-335.4

15m-Class Sailplane
ASW 27
G.Waibel 03 Mar. '93

Alexander Schleicher
Segelflugzeugbau
6416 Poppenhausen 4.9-18.1

Luftfahrt-Bundesamt

Luftfahrt-Bundesamt Postfach 3054 D-3300 Braunschweig

Eingegangen
20. Dez. 1991
Erledigt:

Firma
Alexander Schleicher
Segelflugzeugbau
Postfach 60
Huhnrain 1

6416 Poppenhausen

Ihre Zeichen und Nachricht vom	(Bitte bei Antwort angeben) Unsere Zeichen	Unsere Durchwahl	Braunschweig
GW-st 11.11.91	I411-389/91	257	19.12.1991

Musterprüfung ASW 27

Sehr geehrter Herr Waibel,

Ihre iterative Berechnung der Bemessungshöchstgeschwindigkeit V_D für die ASW 27 haben wir durchgesehen. Es ergaben sich keine Einwände.

Da die standardmäßig verwendete Formel von einer Sinkgeschwindigkeit von 7,8 m/s ausgeht, haben wir zu Vergleichszwecken die Sinkgeschwindigkeit bei V_D=317 km/h berechnet. Für die ASW 27 ergibt sich ein Wert von 8,61 m/s. Da dieser Wert über dem von 7,8 m/s liegt, haben wir auch in dieser Hinsicht keine Probleme, das Verfahren zu akzeptieren.

Wir wünschen Ihnen und Ihren Mitarbeitern ein frohes Weihnachtsfest und einen gesundes und erfolgreiches neues Jahr

Mit freundlichen Grüßen
Im Auftrag

(Schmaljohann)

4.9-18.1

Weitergabe, Vervielfältigung dieser Unterlage, Verwendung und Mitteilung ihres Inhalts nicht gestattet, soweit nicht ausdrücklich zugestanden. Zuwiderhandlungen verpflichten zu Schadenersatz. Alle Rechte für den Fall der Patenterteilung oder Gebrauchsmuster-Eintragung vorbehalten.

Dienstgebäude Braunschweig Lilienthalplatz 6
Telefon: (0531) 23 55-0
Telex: 9 52 701 LBA
9 52 749 Unfall
Telefax: (0531) 23 55 254
Bundeskasse Hannover für Luftfahrt-Bundesamt
Postgiroamt Hannover 50 18-304 (BLZ 250 100 30)
Landeszentralbank Hannover 250 01 000 (BLZ 250 000 00)

(On the occasion of issuance of the Type Certification of the Sailplane ASW 28)

V_D, the Design Maximum Speed to be used for the design of Category U Sailplanes is given in the Airworthiness Requirements JAR 22 by the formula

$$V_D = 18 \cdot \sqrt[3]{\frac{W}{S} \cdot \frac{1}{C_{d\,min}}} \left[km/h \right]$$

where W/S is the wing loading at maximum design weight in daN/m^2 and
$C_{d\,min}$ the lowest possible drag coefficient of the sailplane.

The formula, as used first in the German Airworthiness Requirement LFS, is an empirical formula that allowed to make a reasonable estimate for the Maximum Design Speed.

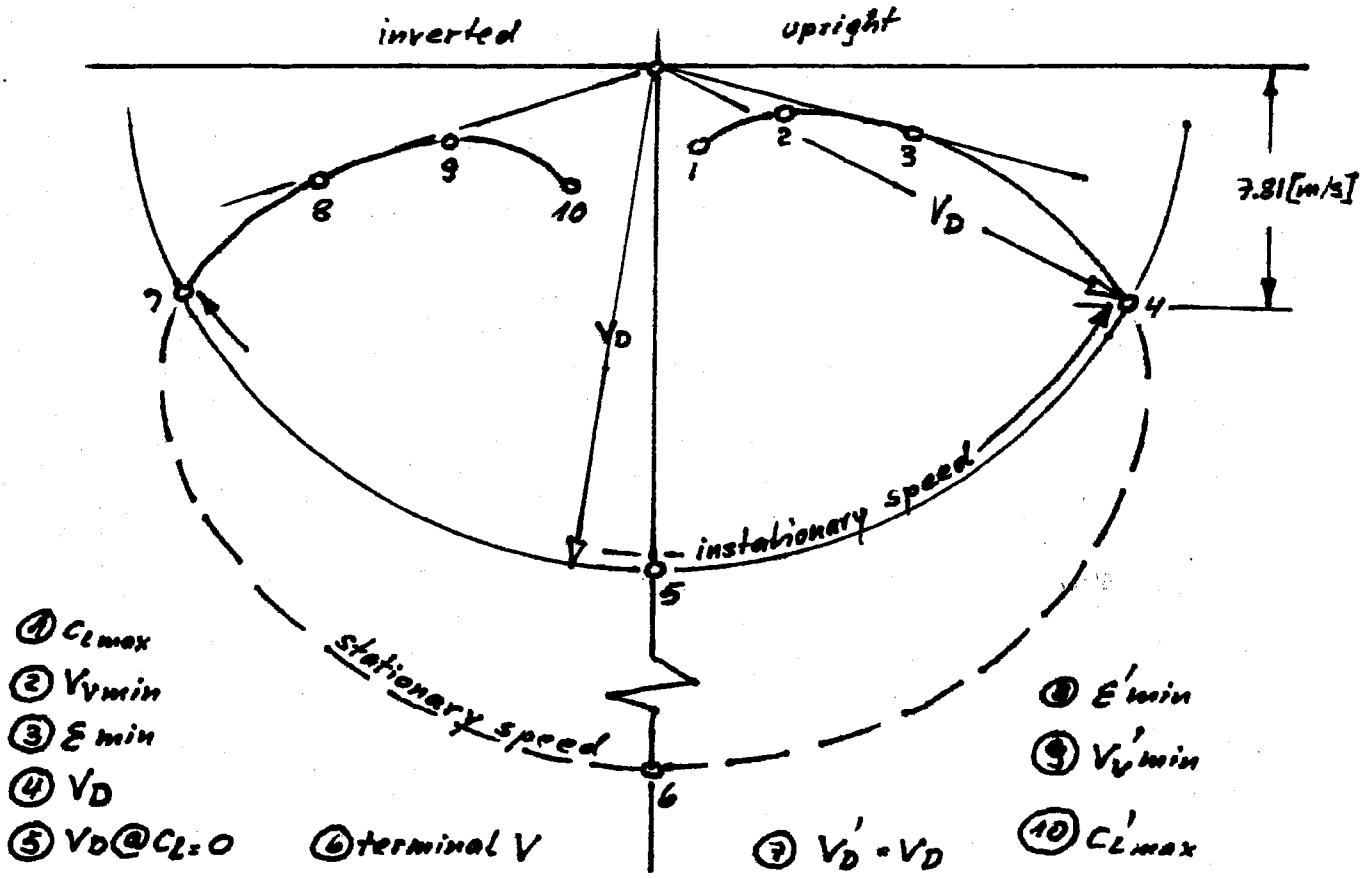
The present review , admittedly incomplete, is made to check if it is possible to use another C_d different from $C_{d\,min}$ or the formerly used C_{d0} to reach a usefull V_D.

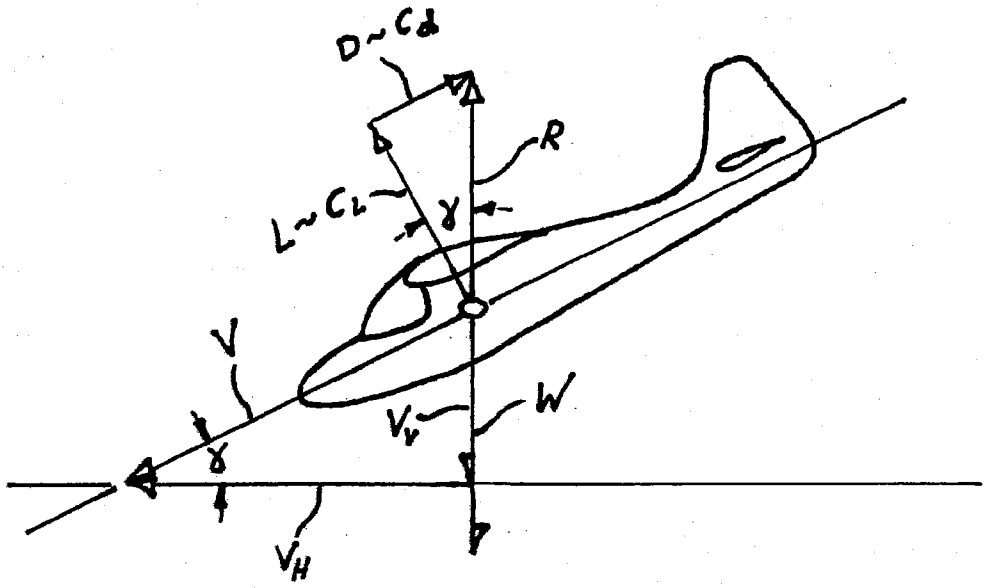
The use of C_{d0}, the one that occurs at zero lift, does not make much sense, because the speed calculated for this condition can be kept only momentarily. The stabilised speed belonging to this condition, the Terminal Velocity , will never be attained by a modern sailplane because of running out of sufficient height.

The $C_{D\,min}$ occurs in the laminar bucket at a C_L higher than that connected to a real dive speed.

The dive-speed derived using $C_{d\,min}$ may be overconservative, the one derived by using C_{d0} may be unconservative, the correct approach must be somewhere in between.

If the thoughts of the „inventors" of the dive-speed-formula can be back-traced, may be a better interpretation for the dive-speed of the ASW 28 can be made:


inverted
upright
7.81[m/s]
V_D
instationary speed
stationary speed
1 $c_{L\,max}$
2 $V_{V\,min}$
3 ε min
4 V_D
5 V_D@c_L=0
6 terminal V
7 $V_D' = V_D$
8 ε'min
9 V_V'min
10 c_L'max


D~Cd
R
L~CL
γ
V
W
V_V
V_H

$$\sin\gamma = \frac{V_V}{V} \qquad V_V = \sin\gamma \cdot V$$

$$\tan\gamma = \frac{C_d}{C_l} = \frac{D}{L}$$

At $\gamma = 10^0$, an angle that may be expected, the difference between SIN and TAN is about 1,6%, so that SIN = TAN may be assumed with sufficient accuracy.

$$\frac{V_V}{V} = \frac{C_d}{C_l} = \frac{D}{L} \qquad L = C_l \cdot q \cdot A$$

$$C_d = C_l \cdot \frac{D}{L} \qquad \frac{C_l}{L} = \frac{1}{q \cdot A}$$

$$C_d = \frac{D}{q \cdot A} \qquad q = \frac{\rho}{2} \cdot V^2$$

$$C_d = \frac{D \cdot 2}{V^2 \cdot \rho \cdot A} \cdot \frac{V}{V} \qquad R = W$$

$$C_d = \frac{\sin\gamma \cdot W \cdot 2 \cdot V}{V^3 \cdot A \cdot \rho} \qquad D = \sin\gamma \cdot W$$

$$C_d = \frac{V_V \cdot W \cdot 2}{V^3 \cdot A \cdot \rho} \qquad V_V = \sin\gamma \cdot V$$

$$V^3 = \frac{V_V}{C_d} \cdot \frac{W}{A} \cdot \frac{2}{\rho}$$

$$V = \sqrt[3]{\frac{W}{A} \cdot \frac{2}{\rho} \cdot \frac{V_V}{C_d}} \cdot [meter / \sec]$$

The aerodynamic-mechanic relations together with the assumed simplifications lead to the above formula that is valid with acceptable accuracy.

If this formula is compared with the empirical formula that is used in LFS, LFSM, OSTIV an JAR 22 for the determination of V_D the thoughts that led to the V_D-formula become evident.

$$V_D = 5 \cdot \sqrt[3]{\frac{W}{A} \cdot \frac{1}{C_d}} \quad \text{[m/sec]}$$

(A factor of 18 instead of 5 changes the dimension of result to [Km/h])

$$V_D = V$$

$$5 \cdot \sqrt[3]{\frac{W}{A} \cdot \frac{1}{C_d}} = \sqrt[3]{\frac{W}{A} \cdot \frac{2}{\rho} \cdot \frac{V_V}{C_d}} \qquad \frac{\rho}{2} = \frac{1}{16}\left[\frac{kg \cdot \sec}{m^4}\right]$$

$$5 \cdot \sqrt[3]{1} = \sqrt[3]{\frac{2}{\rho} \cdot V_V}$$

$$5 = \sqrt[3]{16 \cdot V_V}$$

$$125 = 16 \cdot V_V$$

$$V_V = \frac{125}{16} = 7{,}8125 \quad \text{[m/sec]}$$

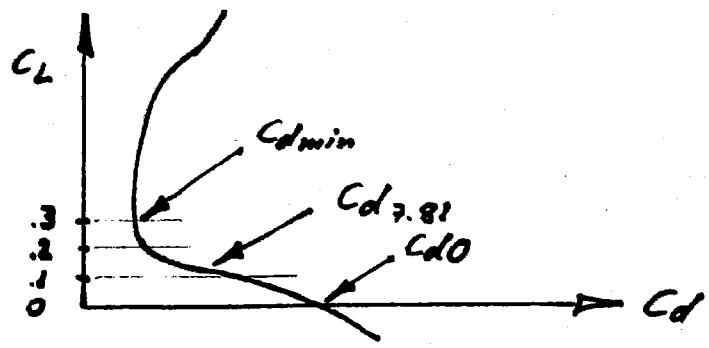
From a conversation with Mr. Heiko Frieß, the retired chief of LBA´s sailplane section, I learned that in the early sixties the late Mr. Walter Stender spent a lot of thoughts on the V_D-determination.
Based on the knowledge of complete polars of sailplanes, that where considered modern at that time, he finally felt able to present a formula.
After a lot of discussion, the formula even passed the Ostiv Sailplane Development Panel, and was entered into the Ostiv Requirements as well as into the German LFS.
The empirical formula

$$V_D = f \cdot \sqrt[3]{w \frac{W}{A} \cdot \frac{1}{C_{d0}}}$$

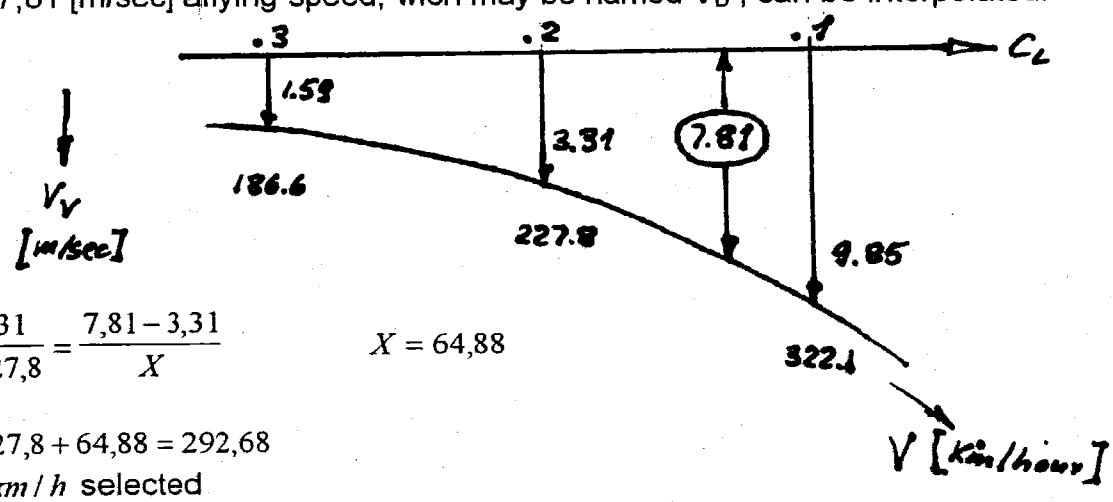
received a „pleasing" form by the use of $f = 5$ for results in [m/sec] and $f = 3{,}6 \cdot 5 = 18$ for results in [km/hour].
The formula is arbitrary for any C_d except the C_d that belongs to the sinking-speed V_V = 7,8125 [m/sec], where C_L, C_d, V_v and V= V_d belong together.

The sinking-speed of V_V =7,8125 [m/sec] had been found by the Ostiv Sailplane Developement Panel, at that time, as sufficient or typical for the leaving of clouds or cloud-streets.

The original LFS-formula made use of C_{d0}, that is the drag coefficient at C_L= 0, the vertical dive case.



Modern sailpanes usually have C_{d0} that are outside the lamiar bucket of the polar. The accompanying high value of the C_d may therefore result in an unconservatively low V_D.
On the other hand gave the introduction of $C_{d\,min}$ into the LFS in the year 1967 also no undisputable facts.
The $C_{d\,min}$ of the ASW 28 occures at an C_L~0.3 and therefore the V_D derived from that $C_{d\,min}$ does not match the C_L.
Based on the ASW 28´s speed-polar, that is very precisely calculated, for a sinking-speed of 7,81 [m/sec] aflying-speed, wich may be named V_D , can be interpolated.



$$\frac{9{,}85-3{,}31}{322{,}1-227{,}8}=\frac{7{,}81-3{,}31}{X} \qquad X=64{,}88$$

$$V_{D\,min}=227{,}8+64{,}88=292{,}68$$

$V_D = 300 km/h$ selected

The LBA accepted a <u>V_D = 300 km/hour</u> as suitable for the sailplane ASW 28.

Subject: Equivalent Safety Finding / V_D - Determination

Next action by: Fa. A. Schleicher CRI closure target: asap

Statement of Issue:

CRI A- 05

The formula in current JAR 22.335 (f) for the determination of „V_D" for Cat. U and Cat A are empirical ones, well applicable for sailplanes modern in the years 1960 to 1970. The latest edition of OSTIV - AS (March 1996) reintroduced already the actual c_d instead of the meanwhile unrealistic $c_{d\,min.}$ for V_D - determination.

Discussion

The OSTIV-AS (March 1996) proposes the formula:

$$V_D = 18 \cdot \sqrt{\frac{G}{W} \cdot \frac{1}{c_d}} \quad \left[\frac{km}{h}\right]$$

for V_D -determination. The factor 18 (or 5 for result in m/sec.) gives a hint to the origin of the formula. The factor 18 or 5 connects the empirical V_D -formula to real aerodynamic conditions with the assumption of a sinking speed of 7,81 m/sec. (see Appendix to this CRI). So a carefully calculated speed polar will give the physically correct diving speed V_D of a sailplane under the assumption of a sinking speed of 7,81 m/sec. and the appropriate c_d.

Applicants position:

Since the use of the formula presently offered in JAR 22 together with $c_{d\,min.}$ results in excessively high V_D that lead to various problems, Fa. Alexander Schleicher proposes to use the speed V_D derived from the speed-polar at the place of the sinking speed w_s = 7,81 m/sec.

LBA position:

The LBA has checked into that problem (see Appendix to this CRI) and agrees to the above V_D -determination as proposed by the Applicant

Conclusion:

The CRI - 05 can be closed.

for Fa. Alexander Schleicher

11JUL01

for LBA

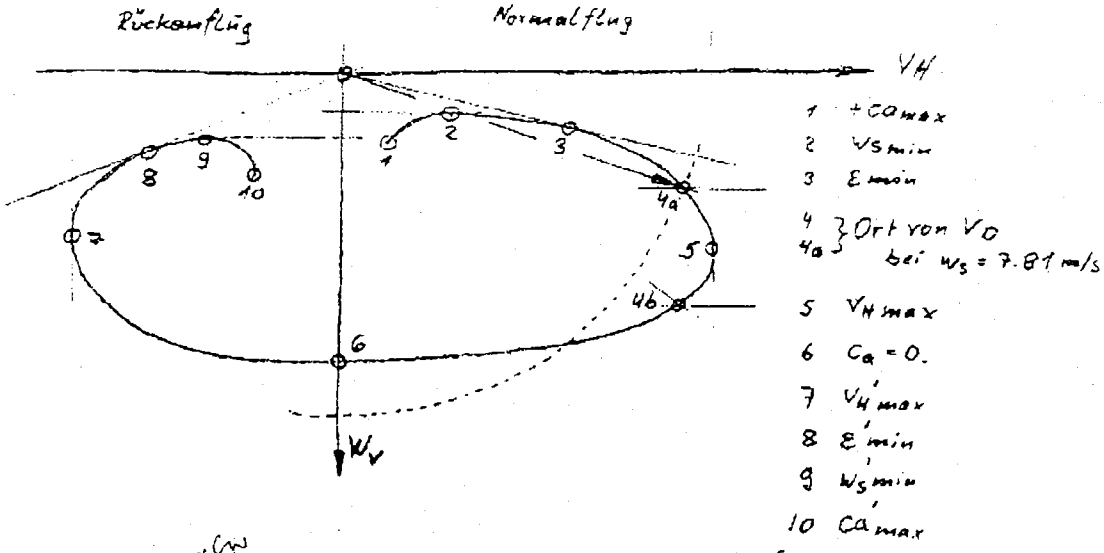
11.7.01

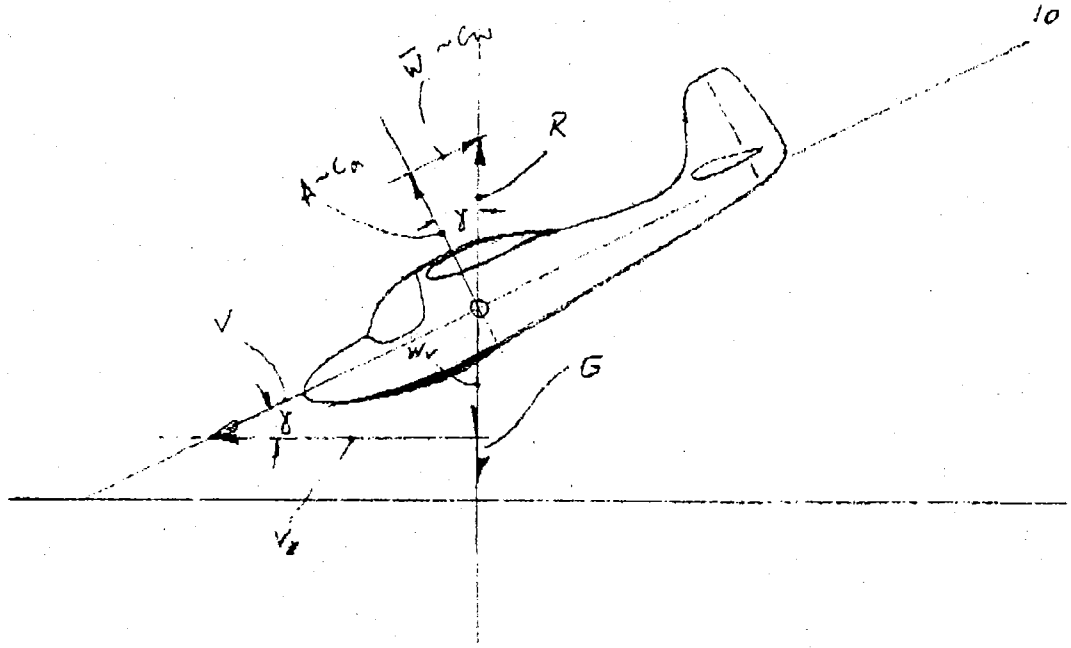
*** Definition of Issue Status applicable to all CRIs:**

OPEN:	**Agreement on acceptable means of compliance to be reached.**
CLOSED:	**Agreement on acceptable means of compliance established. Compliance still to be demonstrated.**
COMPLETE:	**Compliance has been demonstrated and accepted. No further action necessary.**

BS - 24.4.2001

Zur Ableitung der Bemessungsgeschwindigkeit v_D in den Bauvorschriften LFS, LFSM, Ostiv und JAR 22. (Anläßlich Zulassung ASW 28)





Draft for CRI A-05

$$\sin\gamma = \frac{W_V}{V} \qquad W_V = \sin\gamma \cdot V$$

$$\operatorname{tg}\gamma = \frac{c_W}{c_a} = \frac{\bar{W}}{A}$$

bei $\gamma = 10°$, denn $\measuredangle$ der zu erwarten ist, ist $\sin 10° = 0.1736$ und $\operatorname{tg} 10° = 0.1763$ und damit die Abweichung 1.6 %, so dass $\sin \approx \operatorname{tg}$ mit ausreichender Genauigkeit angenommen werden kann.

$$\frac{W_V}{V} = \frac{c_W}{c_a} = \frac{\bar{W}}{A}$$

$$c_W = c_a \cdot \frac{\bar{W}}{A} \qquad A = c_a \cdot q \cdot F$$

$$c_W = \frac{\bar{W}}{q \cdot F} \qquad \frac{c_a}{A} = \frac{1}{q \cdot F}$$

$$q = \frac{\rho}{2} \cdot V^2$$

$$c_W = \frac{\bar{W} \cdot 2}{V^2 \cdot \rho \cdot F} \quad \Big| \cdot \frac{V}{V}$$

$$R = G$$

$$c_W = \frac{\bar{W} \cdot 2 \cdot V}{V^3 \cdot \rho \cdot F} \qquad \bar{W} = \sin\gamma \cdot G$$

$$W_V = \sin\gamma \cdot V$$

$$c_W = \frac{\sin\gamma \cdot G \cdot 2 \cdot V}{V^3 \cdot F \cdot \rho}$$

$$c_W = \frac{W_V \cdot G \cdot 2}{V^3 \cdot F \cdot \rho}$$

$$V^3 = \frac{W_V}{C_W} \cdot \frac{2}{\rho} \cdot \frac{G}{F}$$

$$V = \sqrt[3]{\frac{G}{F} \cdot \frac{2}{\rho} \cdot \frac{W_V}{C_W}} \quad [m/s]$$

Die aerodynamischen Zusammenhänge führen mit den o.a. Vereinfachungen (sin ≈ tg) zu dieser Formel mit hinreichender Genauigkeit.
Diese Formel in Bezug gesetzt mit der empirischen Formel zur Berechnung der V_D gem. LFS, LFSM, Ostiv und JAR22 läßt die Gedanken die zur V_D-Formel führten erkennen.

$$V_D = 5 \cdot \sqrt[3]{\frac{G}{F} \cdot \frac{1}{C_W}} \quad [m/s]$$

$$V_D = V$$

$$5 \sqrt[3]{\cancel{\frac{G}{F}} \cdot \frac{1}{\cancel{C_W}}} = \sqrt[3]{\cancel{\frac{G}{F}} \cdot \frac{2}{\rho} \cdot \frac{W_V}{\cancel{C_W}}} \qquad \frac{\rho}{2} = \frac{1}{16}$$

$$5 \cdot \sqrt[3]{1} = \sqrt[3]{\frac{2}{\rho} \cdot W_V}$$

$$5 = \sqrt[3]{\frac{2}{\rho} \cdot W_V}$$

$$125 = 16 \cdot W_V$$

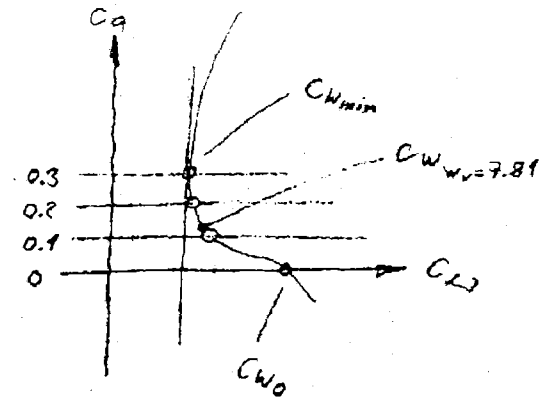
$$\underline{W_V} = \frac{125}{16} = \underline{7.8125 \ m/s}$$

Aus einem Gespräch mit Herrn Frieß wurde entnommen, daß aufgrund der Kenntnisse vollständiger Polaren von damals moderne Segelflugzeuge, ca 1960-66 von Walter Stender eine Formel für die LFS entwickelt wurde um v_D zu bestimmen.
Diese halbempirische Formel

$$v_D = 5 \sqrt[3]{\frac{G}{F} \cdot \frac{1}{c_{w_0}}} \quad [m/s]$$

erhielt mit dem Faktor 5 "eine gefällige Form. $5 \times 3.6 = 18$ führt zur Angabe von v_D [km/h].
Die der Formel zugrunde liegende Sinkgeschwindigkeit $w_v = 7.8125$ [m/s] wurde damals vom Ostiv Sailplane Developement Panel als ausreichend bzw typisch für das Verlassen von Wolken bzw Wolkenstraßen angesehen.

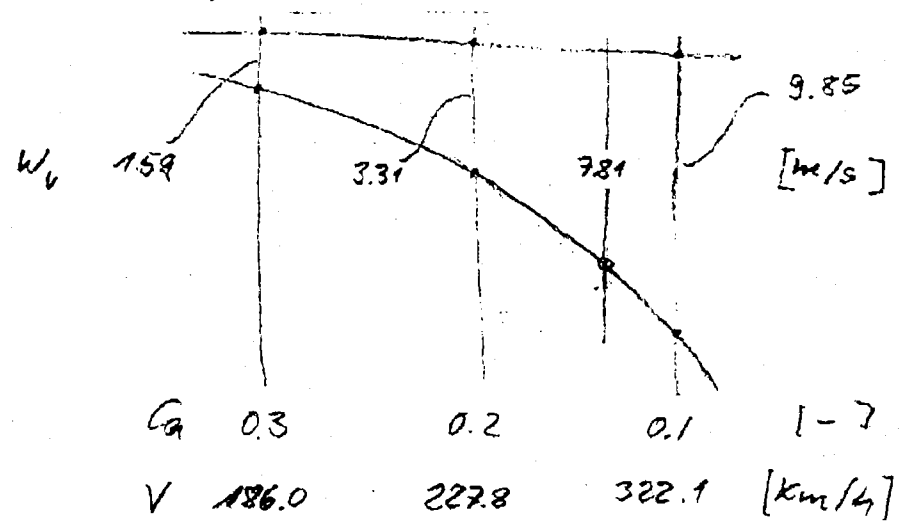
Die ursprünglich in der LFS verwendete Formel bezog sich auf c_{W_0}, d.h. auf das c_W bei $c_a = 0$ bzw. den Stürzflugfall.



Zur Ermittlung der v_D bei modernen Laminarflugzeugen kann gegebenenfalls bei Flugzeugen die bei $c_a = 0$ aus der Laminardelle heraus fallen zu unkonservativ niedrigen v_D führen.

Andererseits führte die Änderung der LFS, im Jahr 1967, mit der Einführung des $c_{W_{min}}$ in die v_D-Formel wiederum an den physikalischen Beziehungen vorbei: Die für das Segelflugzeug ASW 28 ermittelten $c_{W_{min}}$ liegen für die unterschiedlichen Flächenbelastungen bei $c_a = 0.3$. Eine Sinkgeschwindigkeit von

7.81 m/s läßt sich bei diesen Gegebenheiten nicht erreichen.
Stattdessen wird unter Zugrundelegung der Polaren eine zur Sinkgeschwindigkeit 7,81 m/s passende Fluggeschwindigkeit, die man als V_D bezeichnen kann, bei einem $C_a = 0{,}1 \div 0{,}15$ erreicht.



$$\frac{9.85 - 3.31}{322.1 - 227.8} = \frac{7.81 - 3.31}{x}$$

$$\frac{6.54}{94.3} = \frac{4.5}{x}$$

$$x = 64.88$$

$$V_{D_{min}} = 227.8 + 64.88 = 292{,}68$$

$$V_{D\,gewählt} = 300 \text{ Km/h}$$

$$\sin\gamma = \frac{W_v}{V} = \frac{7.81}{292.7} = 0.0960$$

$$\gamma = 5.51^\circ$$