# Schaufele Annotations
# Chapter 16 FAR Required Takeoff Field Length

## Example Problem

The example problem calculates the balanced field length, but not the FAR required takeoff field length. Fig. 16-1 states that the FAR field length is the greater of:

- 1.15 X (all engines operating field length)
- Balanced field length.

The all engines operating (AEO) field length therefore needs to be calculated.

For this example, from the bottom of page 289, in the takeoff condition $V_S = 110$ KEAS

So speed at 35 ft:

$V_{35} = 1.2\ V_S = 132$ KEAS $= 132$ KTAS for standard day sea level conditions

$$V_{35} = 1.69 \text{ X } 132 \frac{\text{ft}}{\text{sec}} = 223 \frac{\text{ft}}{\text{sec}}$$

From table at the top of page 290, static $T_{TOTAL} = 27{,}000$ lb

From Fig 8.5 $\dfrac{T_{132\ KEAS}}{T_{SLS}} = 0.8$, so $T_{132\ KEAS} = 21{,}600$ lb

For DC-9-30 $AR = 8.7$ (page 225) and $e_{cruise} = 0.8$ (from page 238)

So for clean condition $C_D = 0.0200 + 0.0457\,C_L^2$

But for initial climb condition $C_{D_p} = C_{D_{RTO}} - C_{D_{SPOILERS}} - \Delta C_{D_{gear}}$

$C_{D_p} = 0.1082 - 0.0500 - 0.0040$

(pages 289, 248 and Fig 12 - 15 for spoilers at $40^0$)

and $e_{low\ speed} = 0.9\, e_{cruise} = 0.72$ (page 244)

So $C_D = 0.0542 + 0.0508\,C_L^2$

$$q = \frac{1}{2}\rho V^2 = \frac{1}{2} \text{ X } 0.00238 \text{ X } 223^2 = 59.2 \frac{\text{lb}}{\text{ft}^2}$$

$$C_L = \frac{100{,}000}{59.2 \text{ X } 1000} = 1.69$$

$C_D = 0.1993$

Drag $= 0.1993 \text{ X } 59.2 \text{ X } 1000 = 11{,}800$ lb

$$\text{Climb gradient } \gamma = \frac{T - D}{W} = \frac{24{,}400 - 11{,}800}{100{,}000} = 0.126$$

From Fig 16 - 5: $\frac{V_{35}}{V_{LO}} = 1.038$ and $\frac{S_{air}}{V_{LO}} = 4.5\ \text{sec}$

$V_{LO} = \frac{223}{1.038} = 215\ \frac{ft}{sec}$ and $V_{LO}^2 = 46{,}225\left(\frac{ft}{sec}\right)^2$

So $S_{air} = 215\ X\ 4.5 = 968\ ft$

$S_{ground} = \frac{0.065 + 0.08}{2}\ X\ 46{,}225 = 3{,}351\ ft$

Total AEO takeoff distance $= (3{,}351 + 968)\ X\ 1.15 = 4{,}966\ ft$

FAR field length is the greater of:

- Factored AEO takeoff distance $= 4{,}966\ ft$
- Balanced field length $= 5{,}200\ ft$

Thus FAR field length $= 5{,}200\ ft$

In Schaufele page 293 the OEI initial climb gradient was assumed to be 0.024, and not calculated, although the equation is shown and the value could have been calculated from the available data. In the example above, the gradient could no longer be assumed, and to calculate the gradient the drag polar in the initial climb condition had to be determined.

Some assumptions had to be made in order to produce an airplane drag coefficient in the RTO condition to be close to 0.1082 (as shown at the bottom of page 289). These were that the flaps were at $15^0$ and spoilers at $40^0$. These settings produced the following drag buildup in the RTO zero lift condition:

$C_{D_{clean}}$ = 0.0200 (page 232)

$C_{D_{flaps}}$ = 0.0070 (Fig. 12-15)

$C_{D_{spoilers}}$ = 0.0500 (Fig. 12.15)

$C_{D_{slats}}$ = 0.0060 (page 244)

$C_{D_{gear}}$ = 0.0250 (Fig 12-17)

These values provide the basis for the drag polar for the initial climb condition. In the above calculations, the spoiler drag is zero and with the flaps at the takeoff flap setting of $15^0$, the gear drag is reduced by a $\Delta C_{D_{gear}}$ = 0.0040 (as shown in Fig. 12-17). The local air velocity is reduced under the wing, and thus gear drag is reduced. Some additional data on this topic is provided in the annotation to Chapter 12.

## FAR 23 Requirements

On page 293, Schaufele correctly states that for other FAR 23 category aircraft the balanced field length concept is not applicable. For aircraft with TOGW of 6,000 lb. or greater, the accelerate-stop distance must be determined (FAR 23.55) in addition to the all-engine takeoff distance (FAR 23.53).