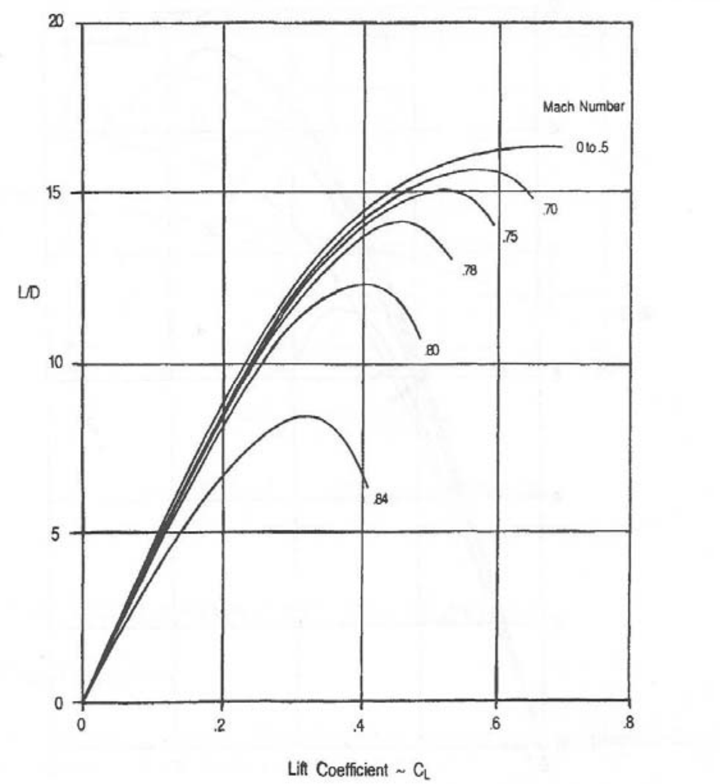
17.2.5 Range Optimization – Jet

Raymer derives the relationship that at the speed for best range, the *L/D* is 86.6% of $(L/D)_{max}$. This is true for aircraft for which flow is incompressible and C_{D0} and *K* are constant, as Raymer points out. For many high speed jets, including commercial passenger aircraft and business jets, the speed for best range using Eq. (17.25) would be above the drag divergence Mach number, and quite possibly supersonic.

In Raymer Section 12.5.10 Transonic Parasite Drag, it is shown that there is a rapid rise in compressibility drag, C_{D_C}, as the drag-divergence Mach number is approached, with a resulting reduction in *L/D*. Eq. (17.25) no longer applies, but the goal of optimizing *V(L/D)/C* does still apply. Performance engineers usually think of optimizing *M(L/D)*, which the same thing for a constant value of *C* and speed of sound.

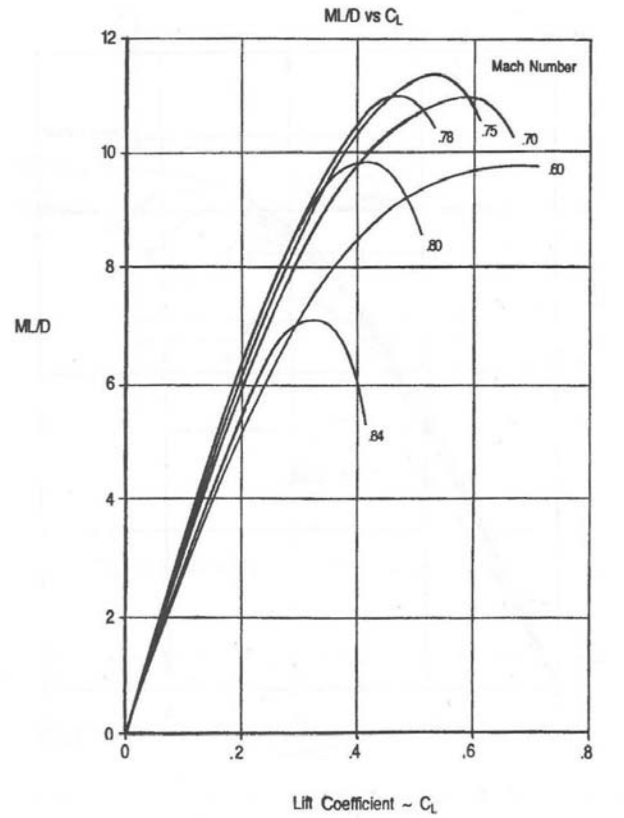
The data in the drag map, described in the annotation to Section 12.5.10, can be rearranged to plot *L/D* as a function of C_L and Mach number, as illustrated in Fig. 17.2.5.1. The curves shown here are for the DC-9, for which M_{DD} is approximately 0.75. Each curve represents a vertical slice through the drag plot, where *L/D* is the value of C_L/C_D at the intersection point on each curve.



Source: Schaufele

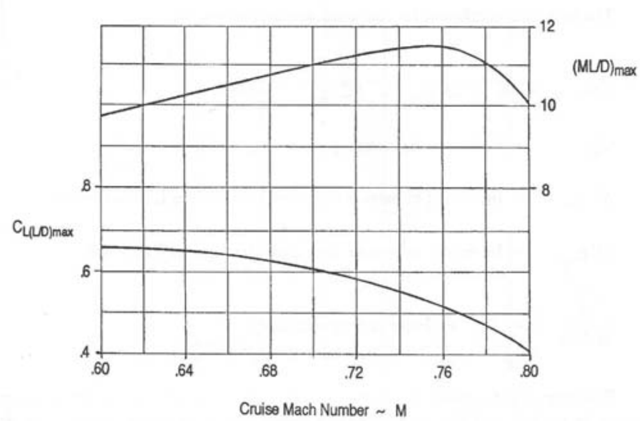
Fig. 17.2.5.1 *L/D* vs. C_L and Mach

Of even greater interest is a plot of *ML/D* vs. C_L, shown in Fig. 17.2.5.2. This shows the maximum value of *ML/D*, and the C_L and Mach number at which it occurs. If the airplane is flying above FL 360 (36,000 ft), and assuming that specific fuel consumption, *C*, is independent of speed and altitude (which is nearly the case), then it should fly at the Mach number and altitude that result in a C_L that maximizes *ML/D*.



Source: Schaufele

Fig. 17.2.5.2 *ML/D* vs. C_L and Mach



Source: Schaufele

Fig. 17.2.5.3 *ML/D* and $C_{L_{(L/D)max}}$ relationship

In Fig. 17.2.5.3 it can be seen that the value of $C_{L(L/D)max}$ at the value of $(ML/D)_{max}$ is somewhat less than the value of incompressible $C_{L(L/D)max}$. The corresponding value of L/D will not be exactly 0.866 $(L/D)_{max\ incompressible}$ but it will be fairly close.

In an industrial grade aircraft sizing program, the program will take account of minor changes in *C* and ATC limitations to find the optimum speed and altitude for the airplane. The program may be able to take account of the cost of fuel so that the total direct operating cost is minimized. In this case, higher fuel cost would bias the optimum Mach number to a lower value. The sizing program operates in a manner similar to that of an airplane's flight management computer as described in the annotation to Section 4.2.4.