

Exhibit 80. Projectile Path and Impact Angle

Without friction or drag, the projectile path is a parabola. I assume a drag coefficient. The path of a falling object can be described in terms of force equations, which take the following form (y is vertical, x is horizontal):

$$\begin{aligned}
 F_x &= ma_x = -m(V_x/V) * bV^2 \\
 F_y &= ma_y = -mg + m(V_y/V) * bV^2
 \end{aligned}$$

Where:

- b = air resistance (m⁻¹) = C_d ρ_{air} A / m
- m = mass of bomb
- ρ_{air} = density of air (kg/m³)
- A = cross-sectional area of bomb (m²)
- C_d = drag coefficient

These equations can be simplified by dividing by the mass, and substituting: a_x = dV_x/dt, and a_y = dV_y/dt, then estimating dt = Δt to obtain:

$$V_x(t + \Delta t) = V_x(t) - bV_x V \Delta t.$$

Similarly for the y-component:

$$V_y(t + \Delta t) = V_y(t) - g\Delta t - bV_y V \Delta t.$$

Using these equations, a spreadsheet was set up which computed V_x, V_y, X, and Y for discrete timesteps, given the specific initial conditions. Below is a table summarizing the initial angle (above horizontal), drag coefficient, impact angle, and impact velocity for several different conditions. The results of the table assume an initial velocity of 211m/s and a drag coefficient of 0.1.

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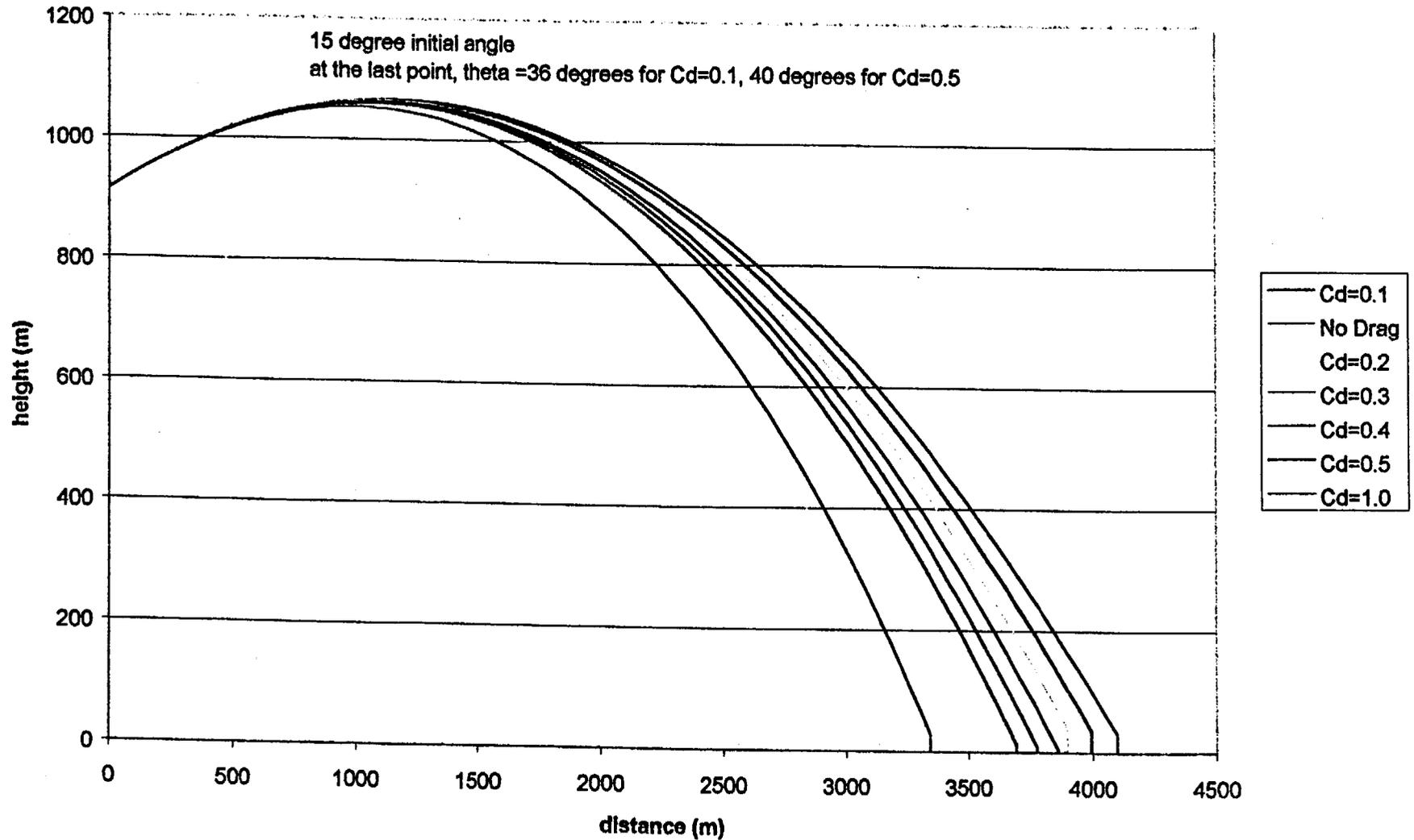
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Impact Angle and Velocity of Jettisoned Ordnance

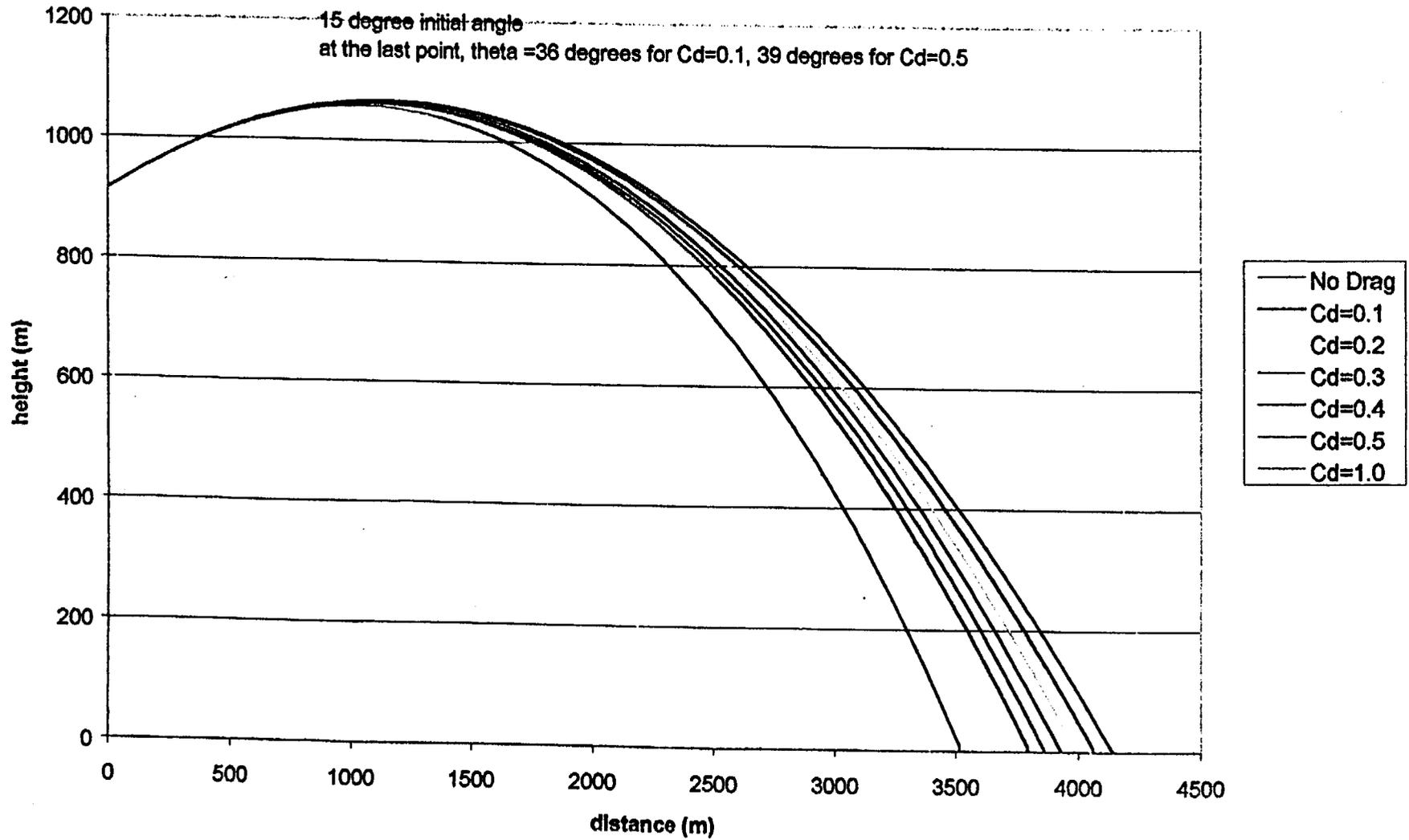
Bomb Type	Drop Height, ft	Drop Angle (above horizontal)	Impact Speed, m/s	Impact angle
MK-82	1000	0	221	20.8
	1000	15	217	25.7
	3000	0	243	33
	3000	15	241	36.5
MK-84	1000	0	222	20.5
	1000	15	219.5	25.6
	3000	0	245	33
	3000	15	243	36.3

The flight trajectories are presented in graphical form on the following pages.

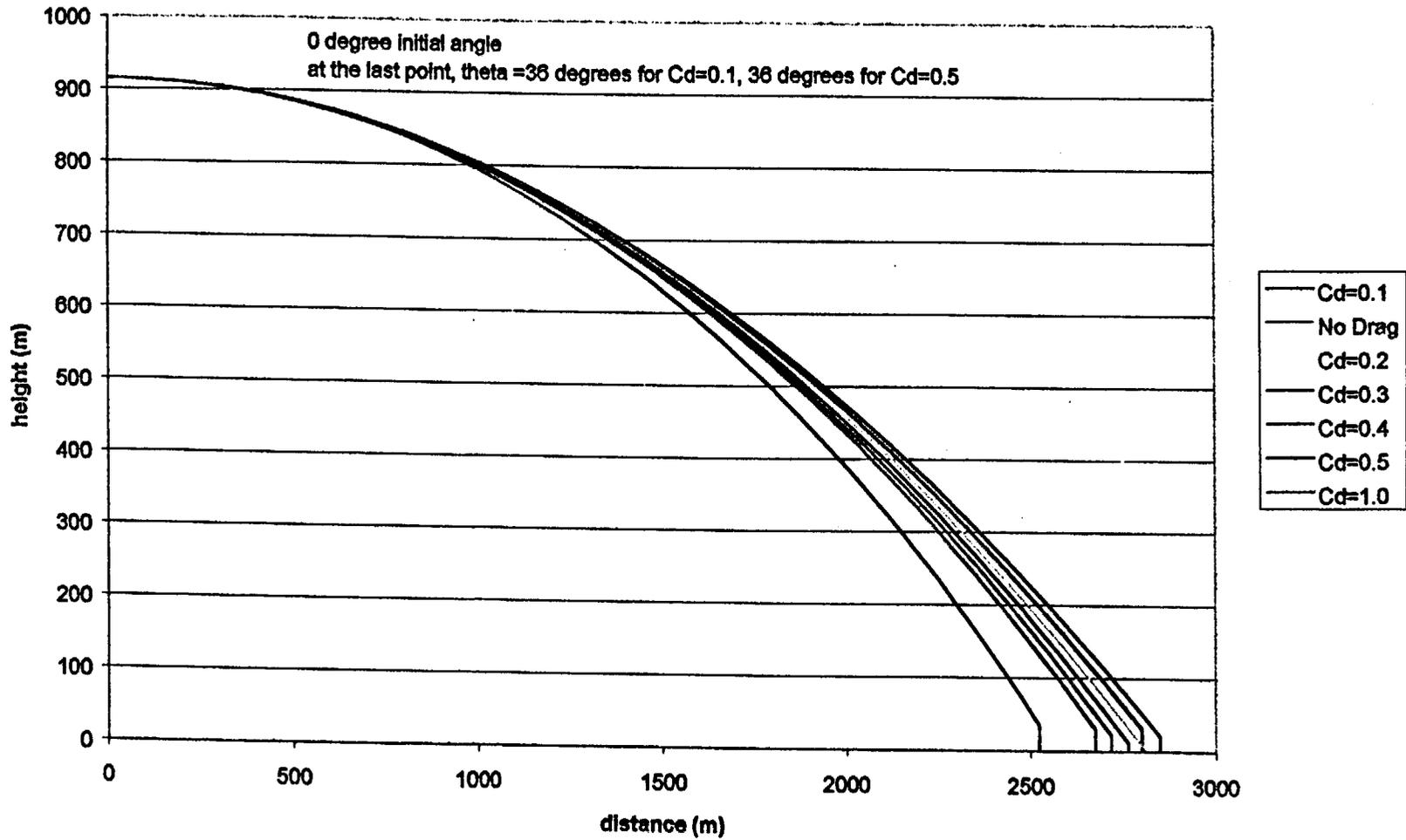
**Effect of Drag Coefficient on Bomb Trajectory:
MK-82 bomb, $V_{xo} = 211\text{m/s}$**



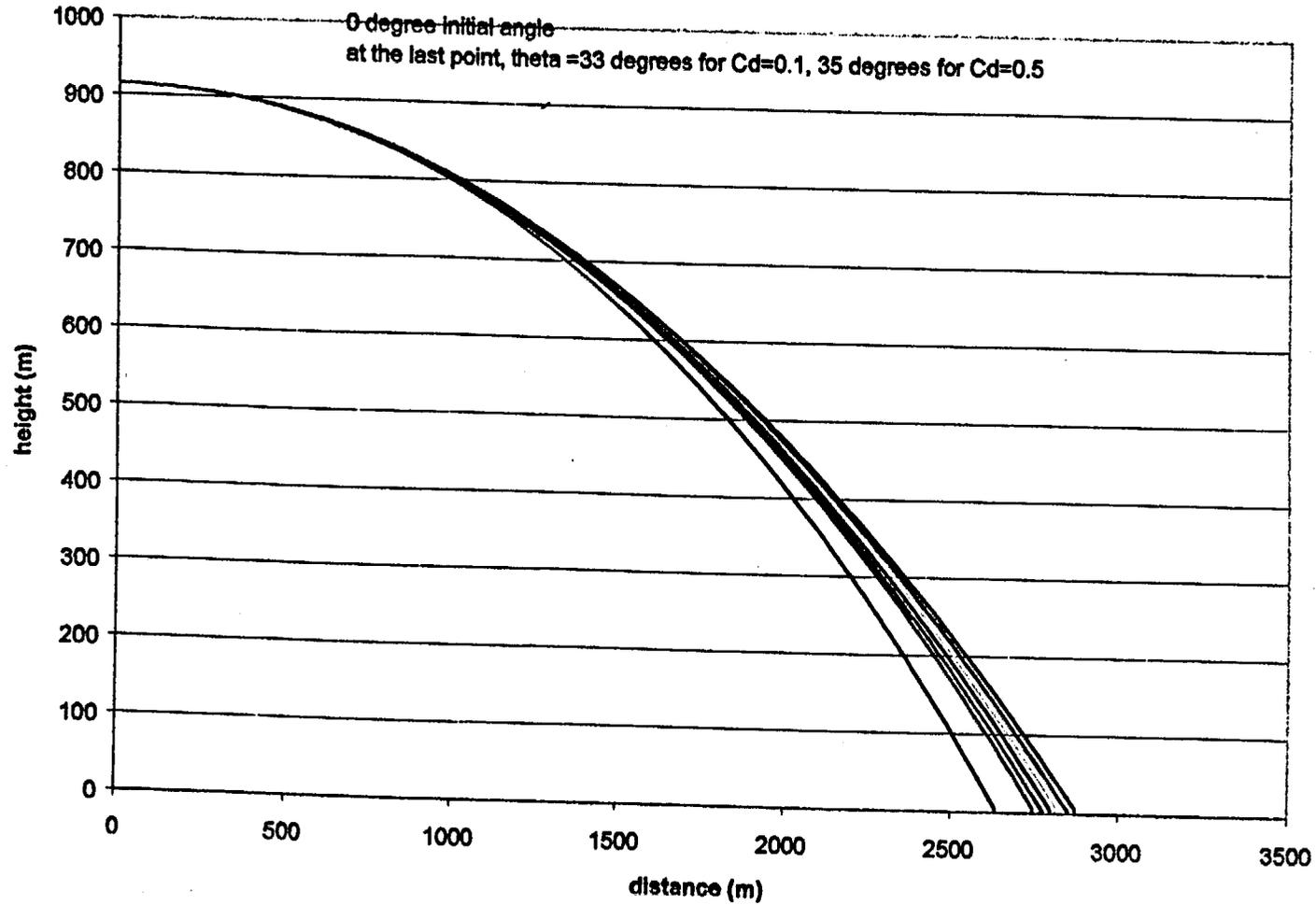
**Effect of Drag Coefficient on Bomb Trajectory:
MK-84 bomb, $V_{xo} = 211\text{m/s}$**



**Effect of Drag Coefficient on Bomb Trajectory:
MK-82 bomb, $V_{xo} = 211\text{m/s}$**



**Effect of Drag Coefficient on Bomb Trajectory:
MK-84 bomb, $V_{x0} = 211\text{m/s}$**



CLEAR REGULATORY COMMISSION

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