Numerical Study of an Under-Expanded Jet

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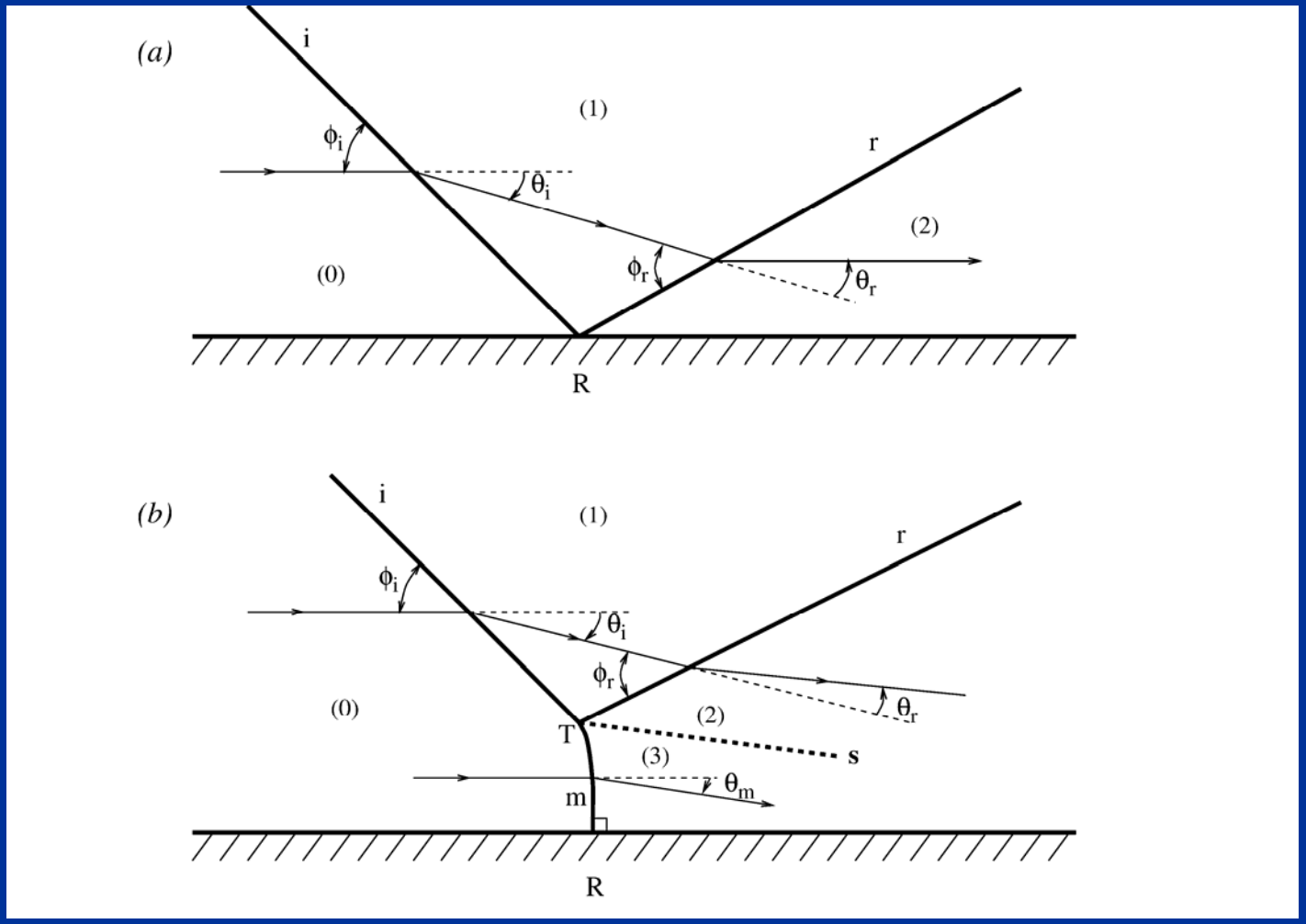
Motivation

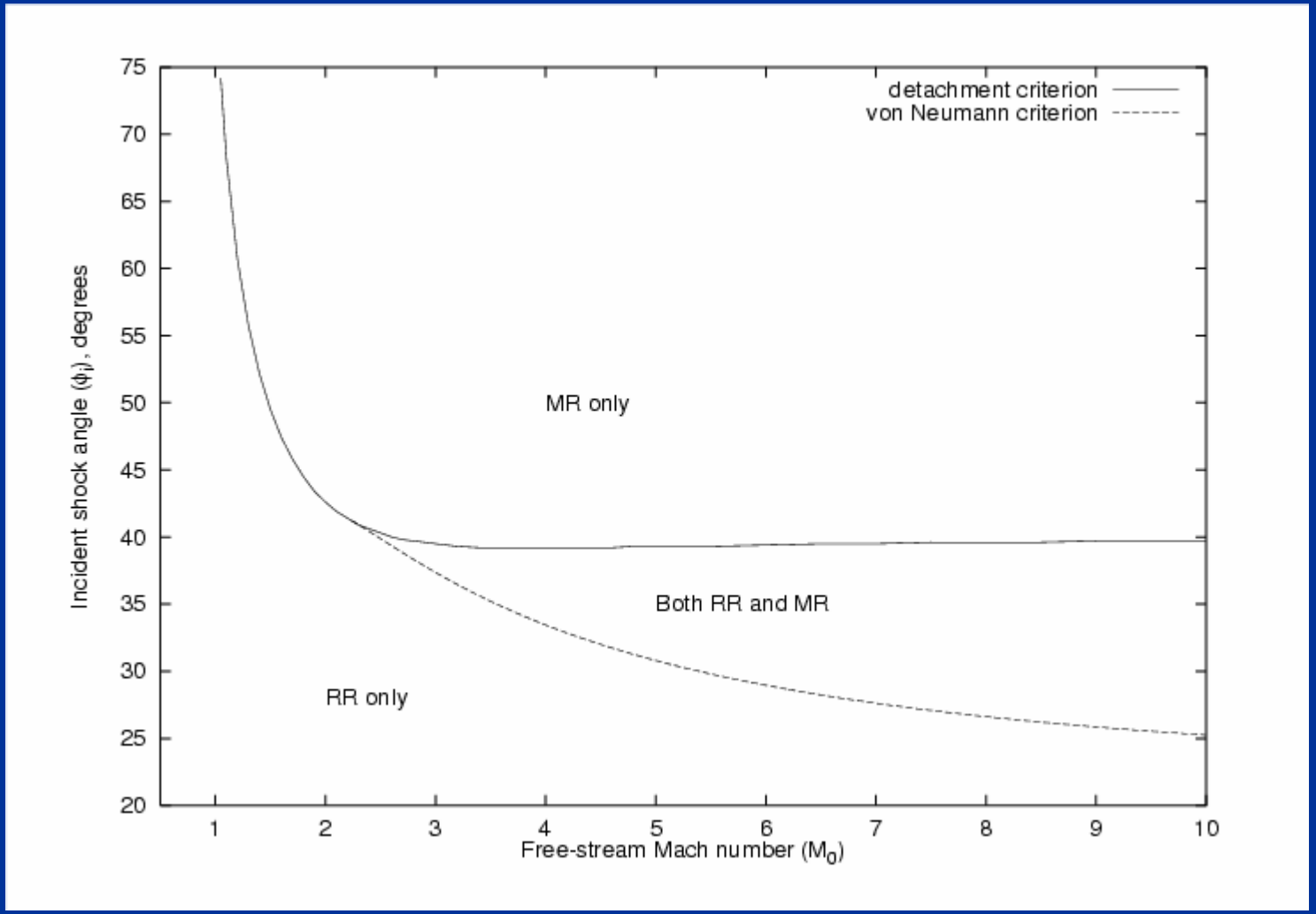
Experimental study of under-expanded jet plume (Welsh, Dera/Qinetiq Farnborough) :

- Repeated shock cell pattern
- Hysteresis in shock-reflection type

2D Shock Relection Hysteresis

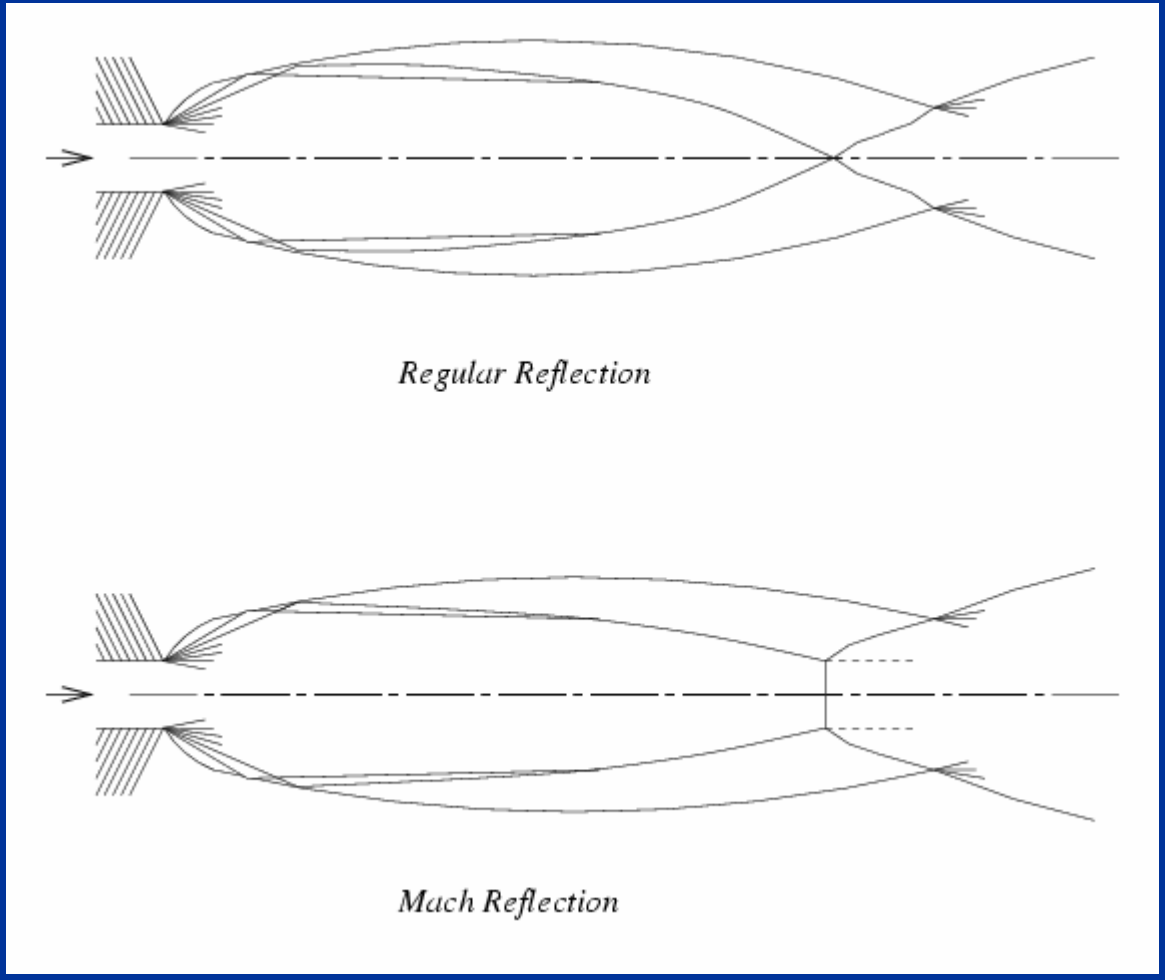


2D Shock Relection Hysteresis



Shock diamonds in plume

Structure of Under-expanded Jet



Regular Reflection

Mach Reflection

SRH in Under-expanded Jet

- LDT DERA/Qinetiq Farnborough
- Ambient pressure 35 mtorr
- Reservoir pressure varied from 2 to 70 torr
- Nozzle throat diameter 15mm
- First shock cell length ~ 300mm
- Exit Mach number between 2.4 and 2.8

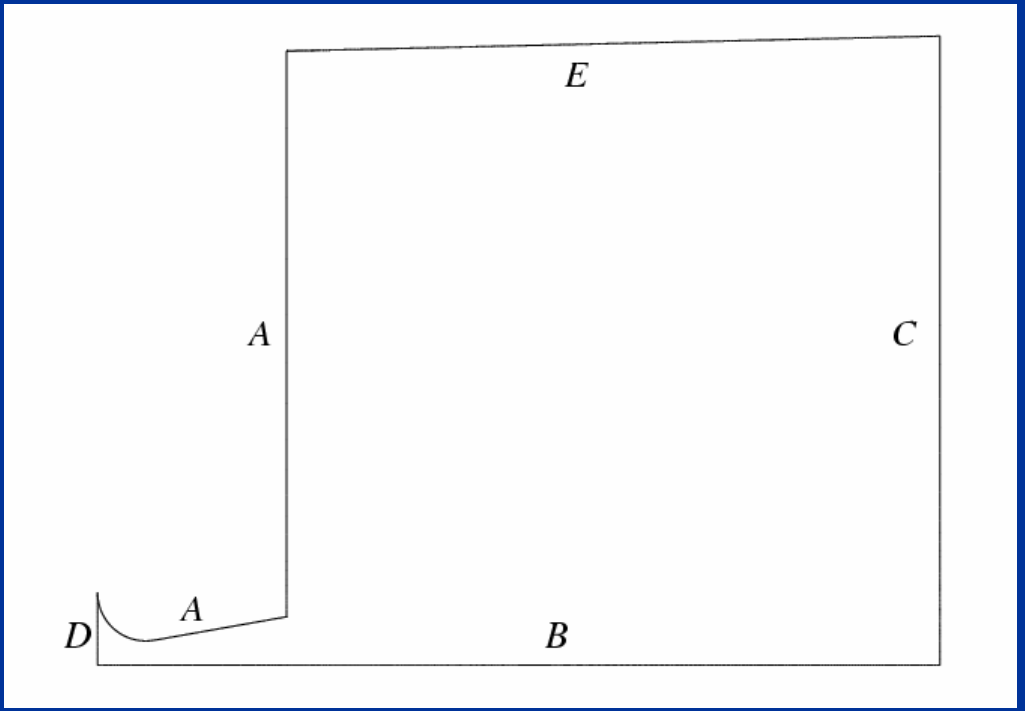
Numerical Method 1

- PMB (Glasgow University)
- Block structured, finite volume
- Osher’s scheme, MUSCL extrapolation
- Implicit scheme

Numerical Method 2

Boundary Conditions:

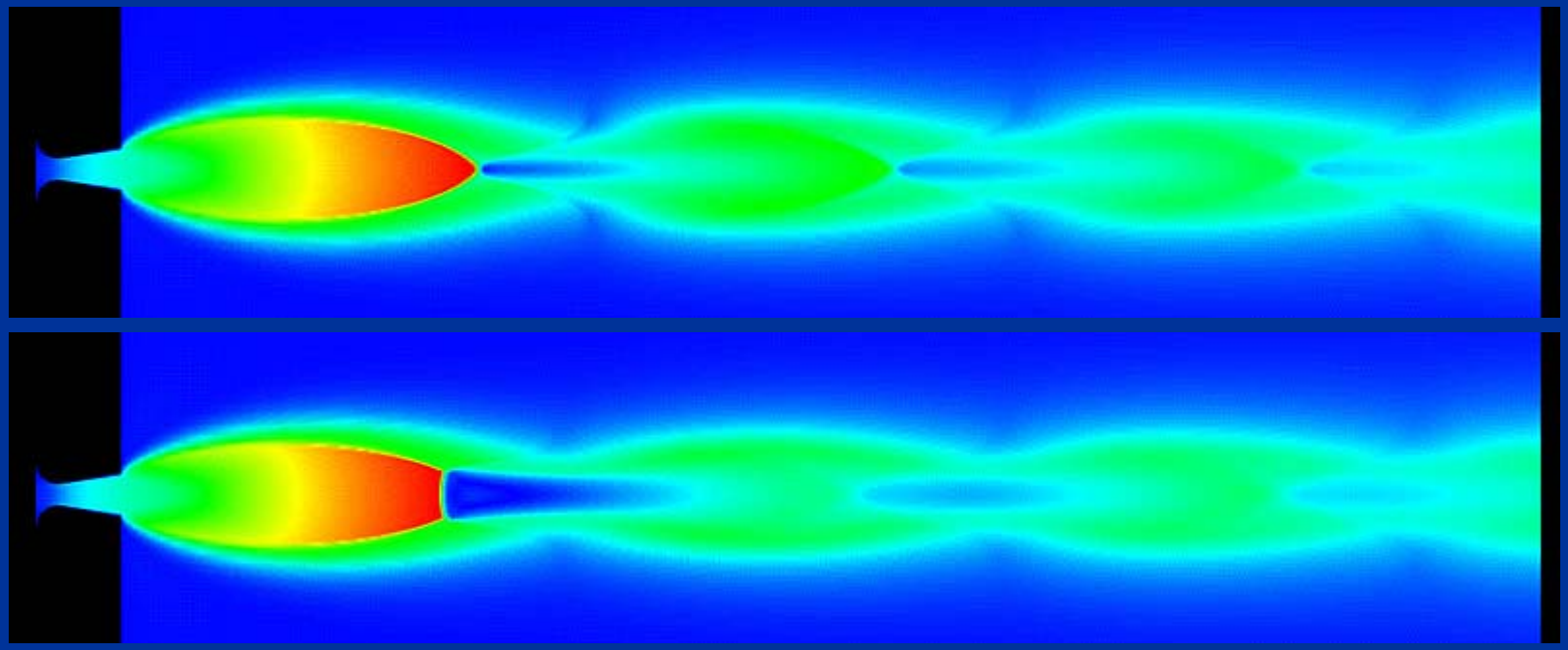
A. Adiabatic wall
B. Symmetry
C. Extrapolation (except when M<1, impose p)
D. Impose pressure and density, extrapolate velocity
E. As D

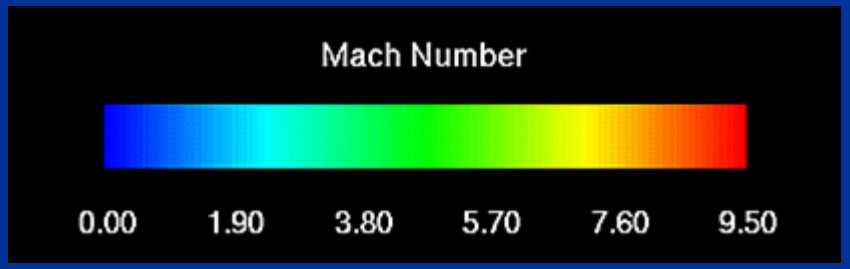


Pseudo-steady approach

- Step change in reservoir pressure of 0.1 torr

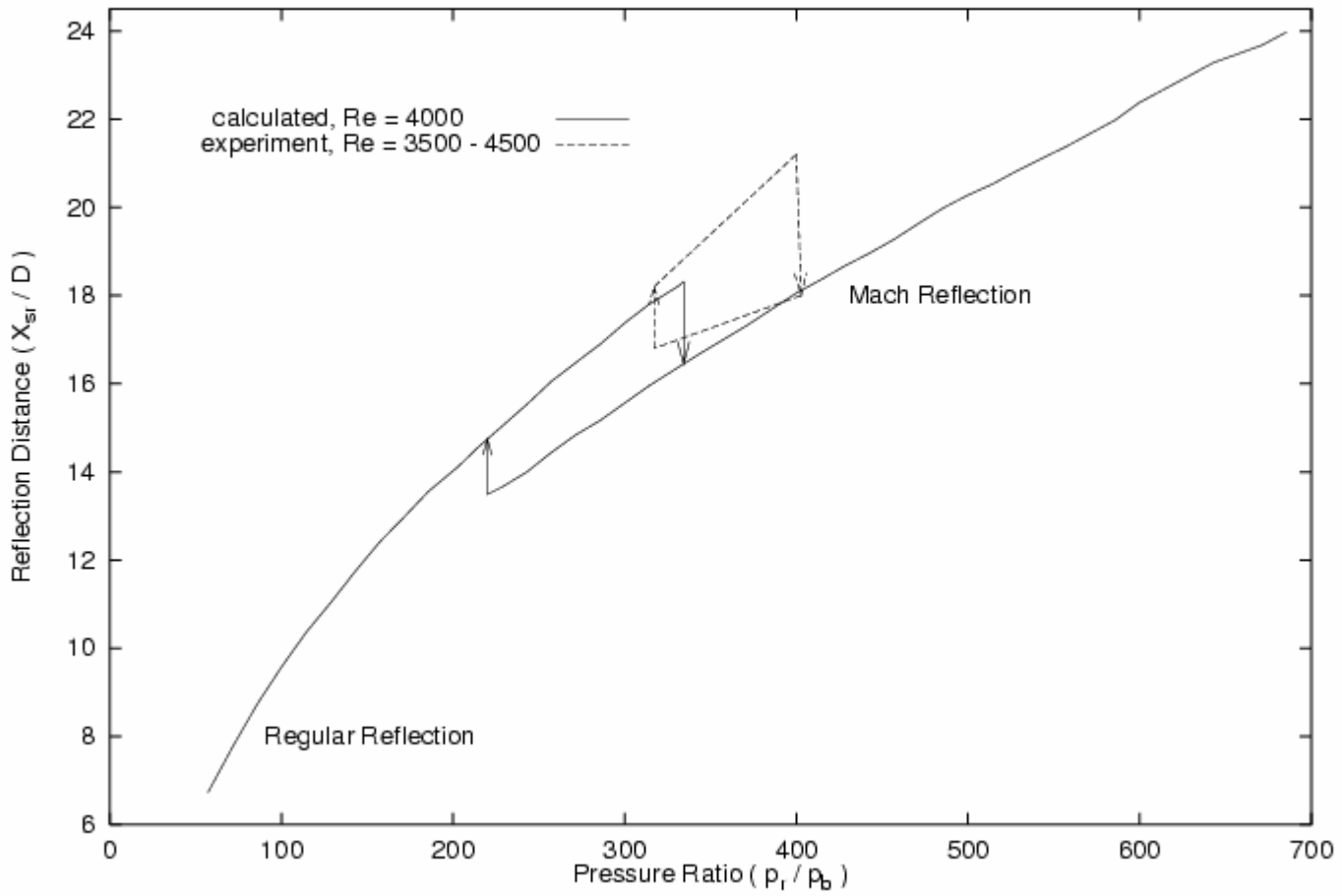
Results 1 : Plume Structure



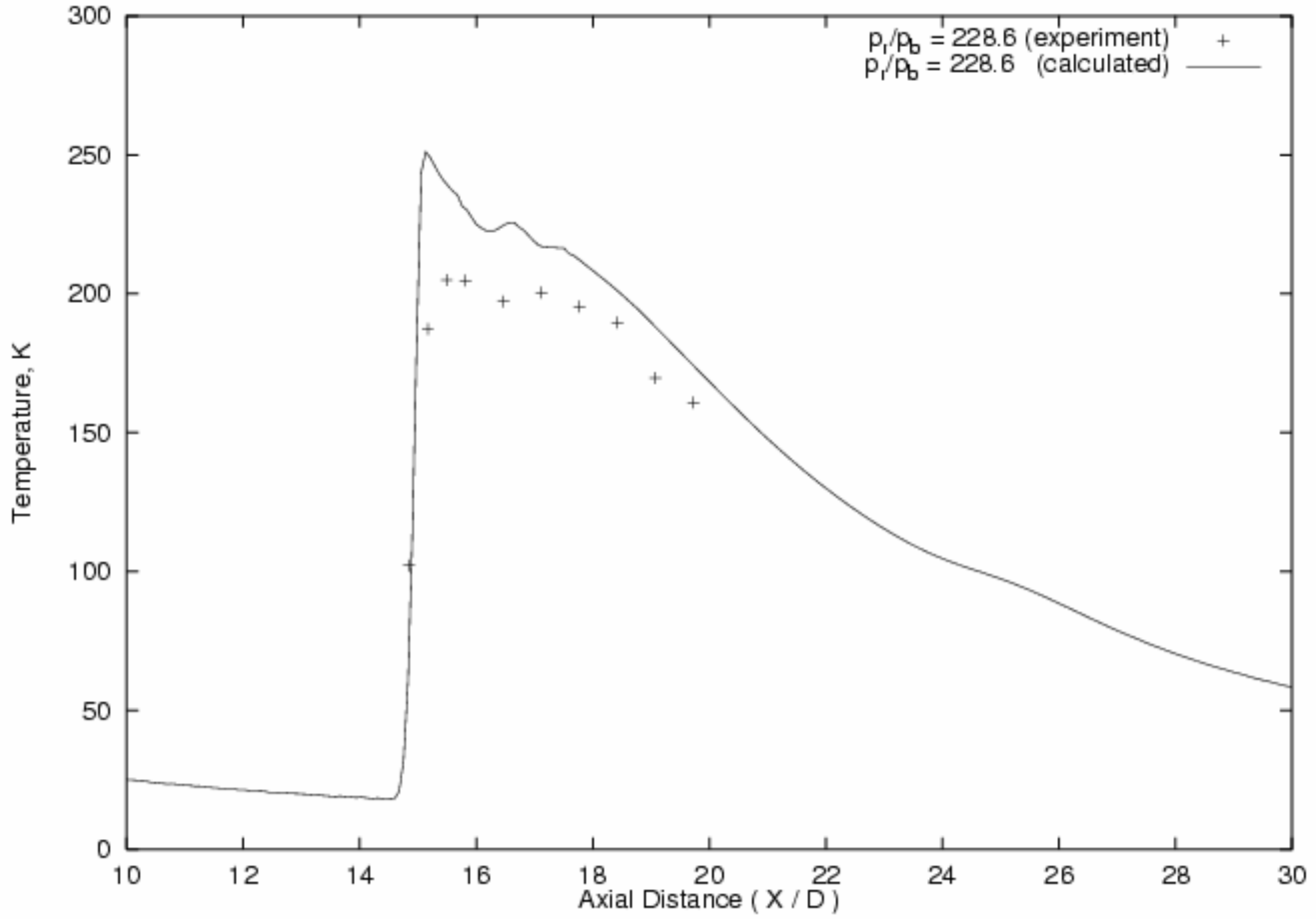


P_r/P_b = 285.7, 15mm nozzle

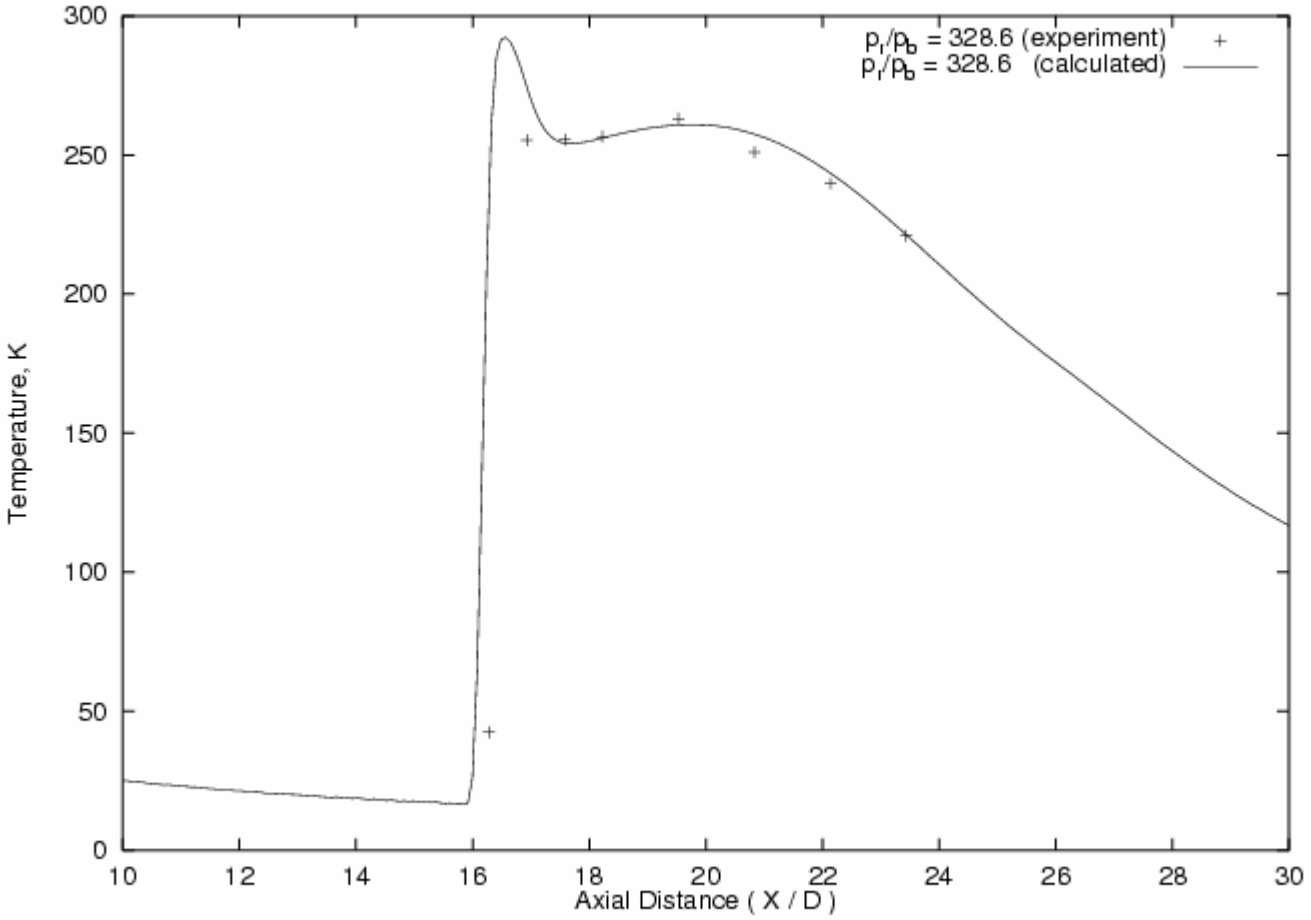
Results 2 : Hysteresis Loop



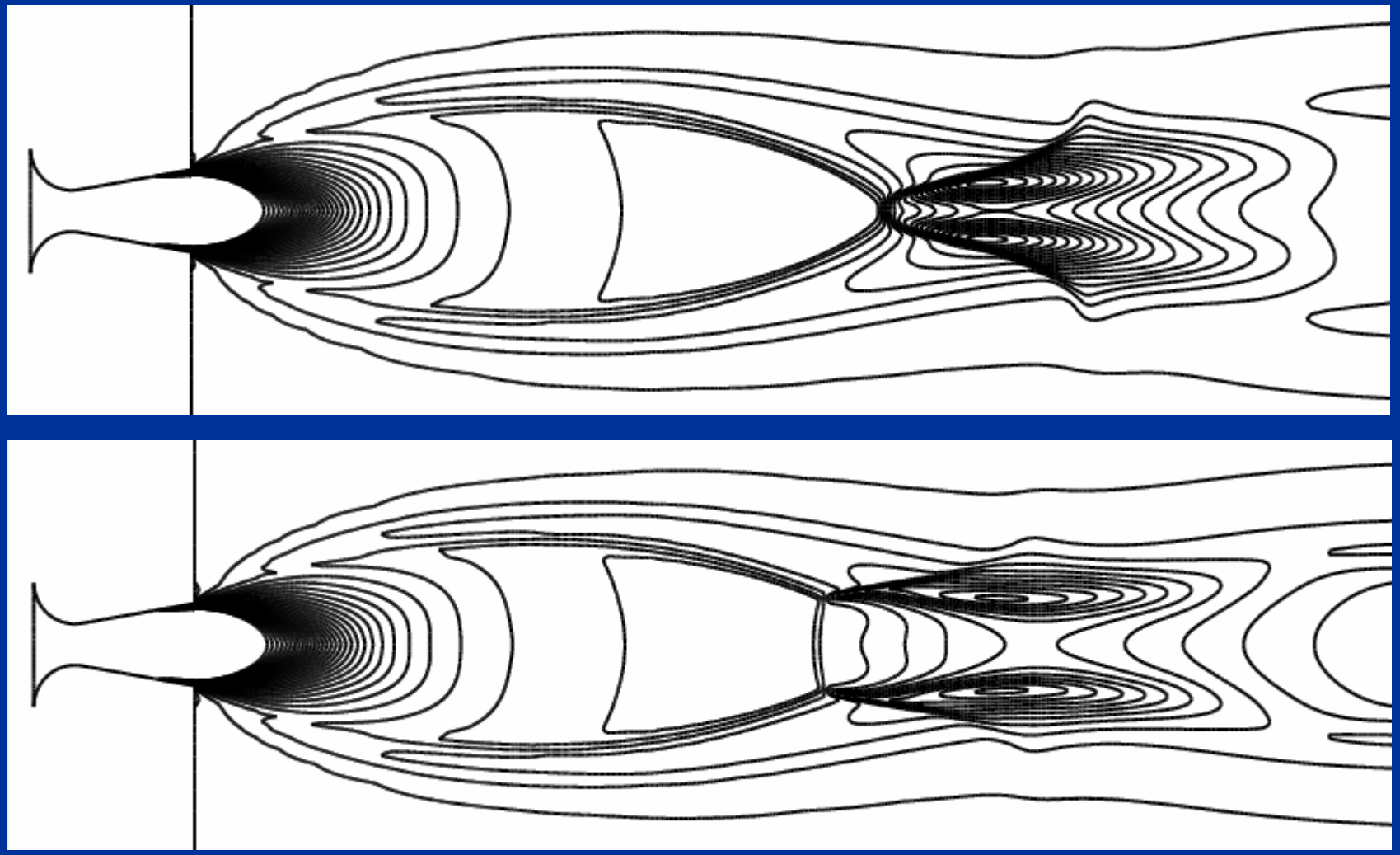
Results 3 : RR Centre-line temperature



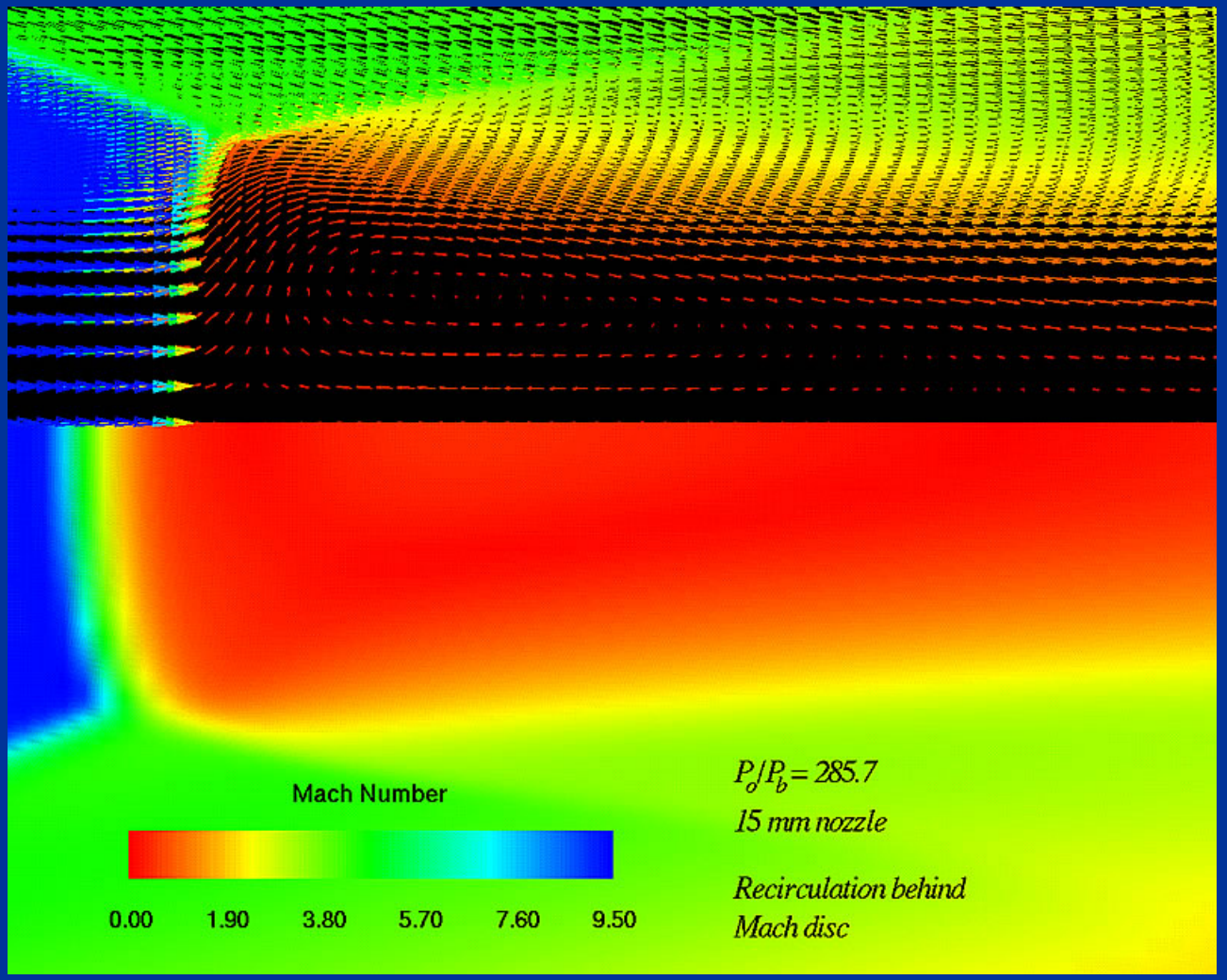
Results 4 : MR Centre-line temperature



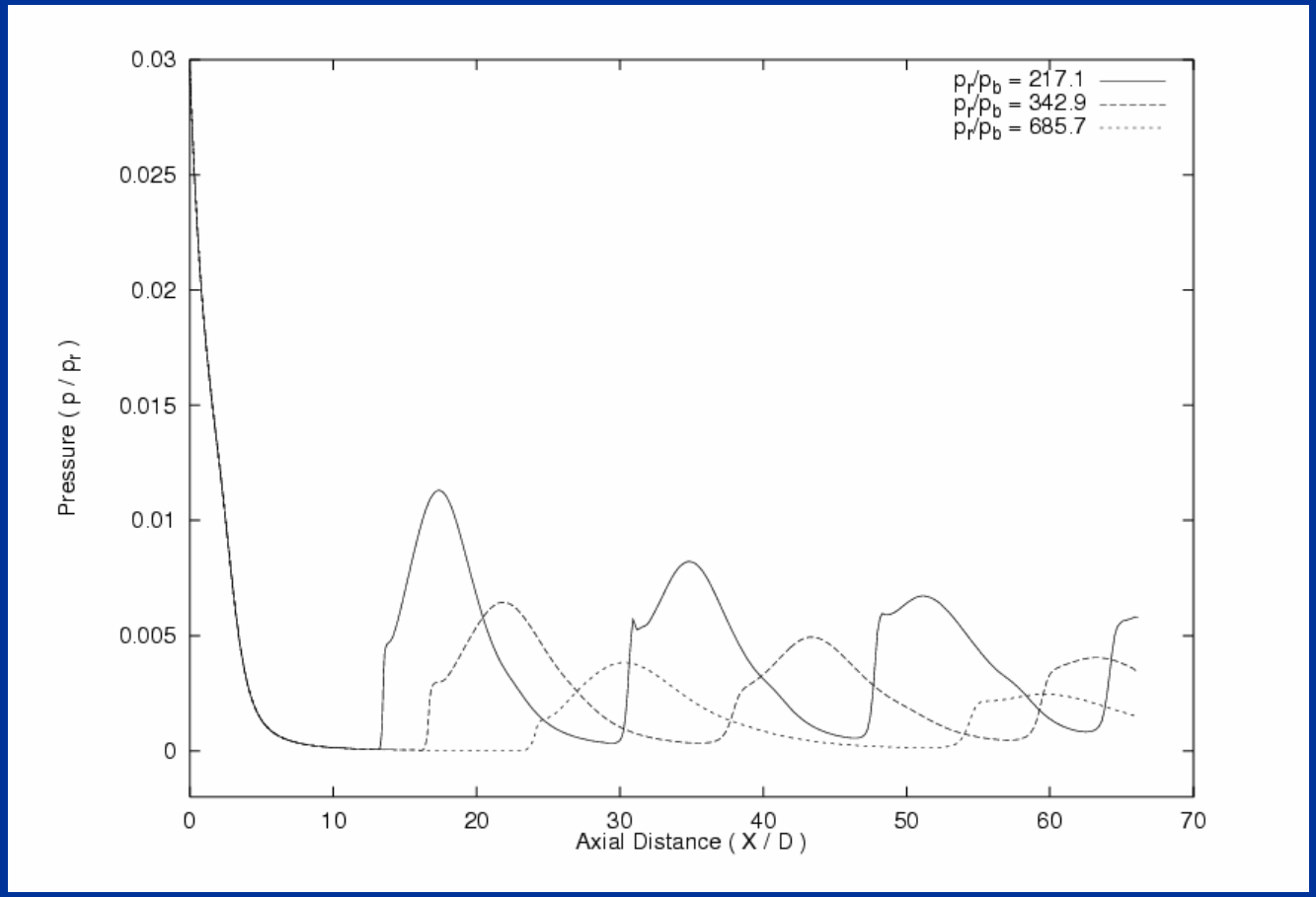
Results 5 : Apparent RR



Results 6 : Mach Disc



Results 7 :
Compression behind Mach Disc



Conclusion

- SRH in an underexpanded jey plume predicted using CFD
- Confidence in results from good agreement
- Detail of numerical results promoted understanding of plume structure