Comparison of Experimental and Numerical Studies of Ionizing Flow over a Cylinder

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Introduction

- Testing has provided reliable data up to orbital entry speeds around 8 km/s
- Vibrational excitation and dissociation form the main non-equilibrium chemical processes
- At super orbital speeds, spacecraft generate a high-temperature reacting gas flow that has appreciable ionization
- This study compares a numerical analysis to experimental values for a flow at high speed and temperature

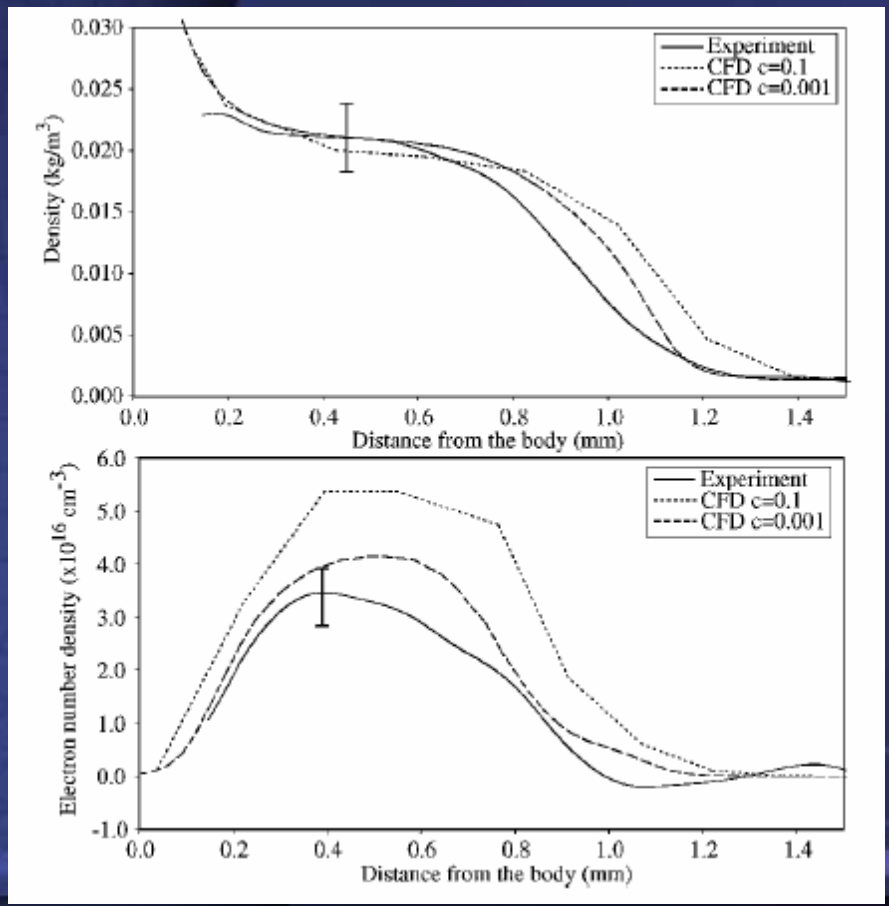
Numerical Analysis

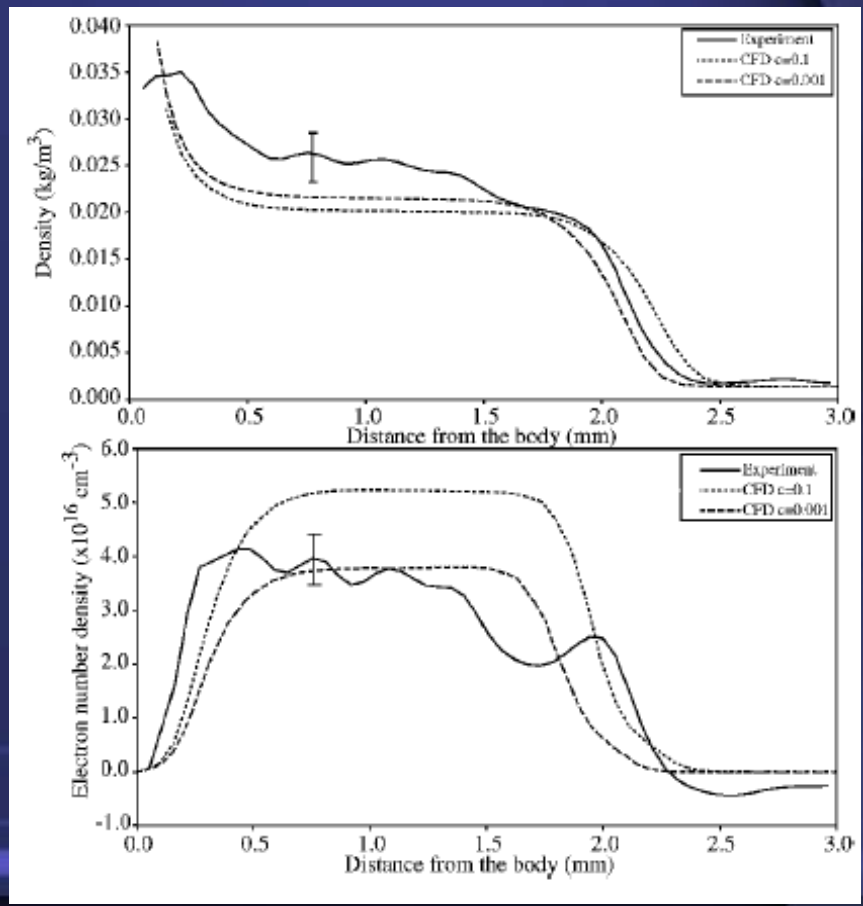
- Input to code taken from free-stream conditions
- Uses the two-temperature Park model to allow for separate heavy particle and electron temperatures

Table 1 Calculated freestream conditions

Parameter	Value
Density	0.0014 kg/m^3
Temperature	3030 K
Velocity	10.3 km/s
Equivalent flight speed	11.3 km/s
Mach number	9.6
Enthalpy	64 MJ/kg
Pressure	1.3 kPa
Pitot pressure	165 kPa

Numerical Analysis (cont.)





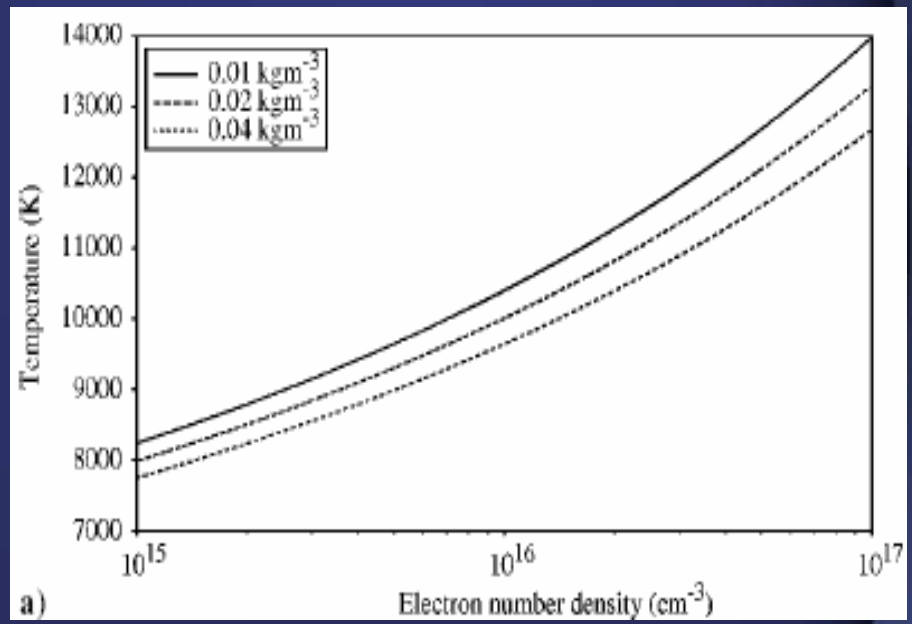
Experiment Set Up

- A super orbital flow was set up for two cylinders of 15 and 30 mm diameters
- The analytical equation governing the electron density is given by the Saha equation,

$$\frac{N_e N_I}{N_a} = \left[\frac{2\left(2\pi mkT\right)^{3/2}}{h^3}\right]\left[\frac{Q_I(T)}{Q_a(T)}\right] e^{\frac{-\chi}{kT}}$$

Experiment Results

- Results indicate that equilibrium is not established behind the bow shock for the 15 mm diameter cylinder
- For the 30 mm diameter cylinder equilibrium is established in the vicinity of the stagnation streamline behind the bow shock



Experiment Results (cont.)

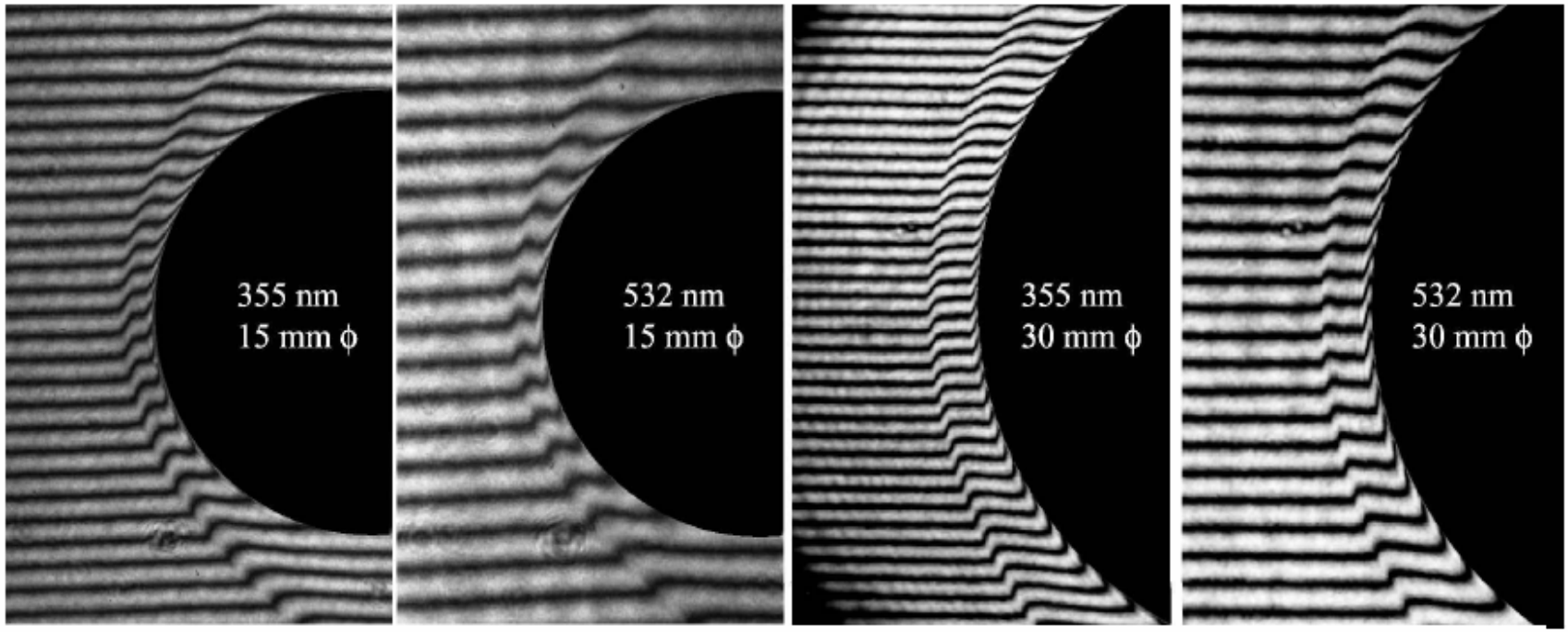


Fig. 1 Holographic interferograms of flow over 15- and 30-mm-diam cylinders; flow left to right.

Conclusions

- Results showed generally good agreement for the following
  - Shock standoff distance
  - Density distribution
  - Electron concentration
  - Temperature