N93-26930

National Aeronautics and
Space Administration

Lewis Research Center

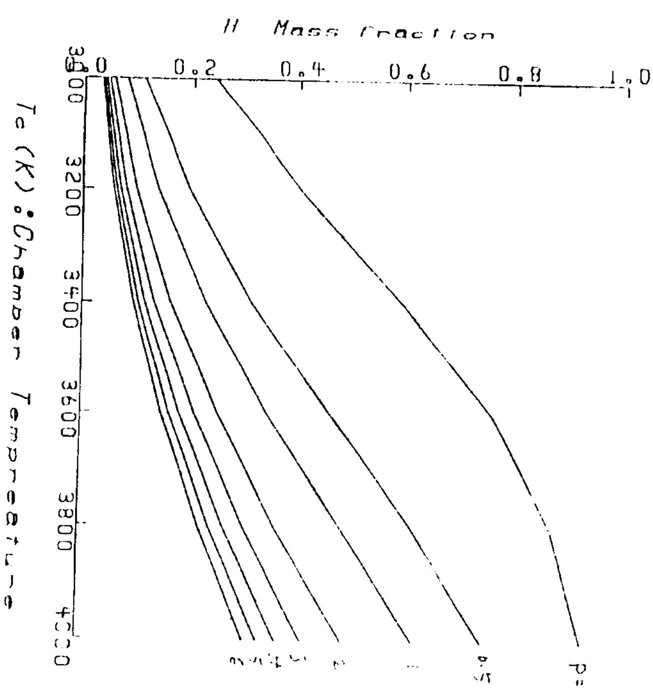
NASA

COMPUTATIONAL FLUID DYNAMICS FOR NUCLEAR THERMAL PROPULSION

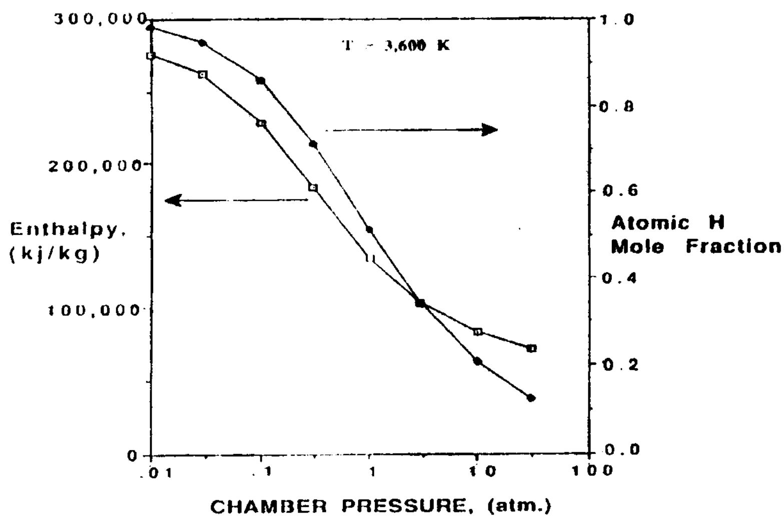
Presented to the
Nuclear Propulsion Technical Interchange Meeting

October 21, 1992

Robert M. Stubbs
Suk C. Kim



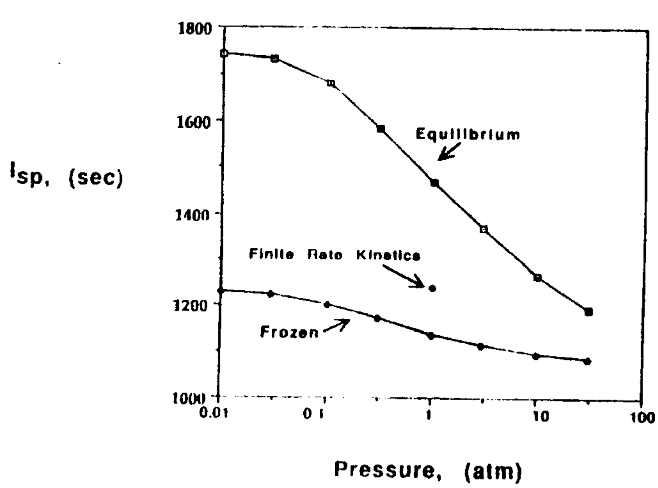
SPECIFIC ENTHALPY OF HYDROGEN AND MOLE FRACTION OF H
AS A FUNCTION OF CHAMBER PRESSURE
AT A CHAMBER TEMPERATURE OF 3,600 K



INTERNAL FLUID MECHANICS DIVISION

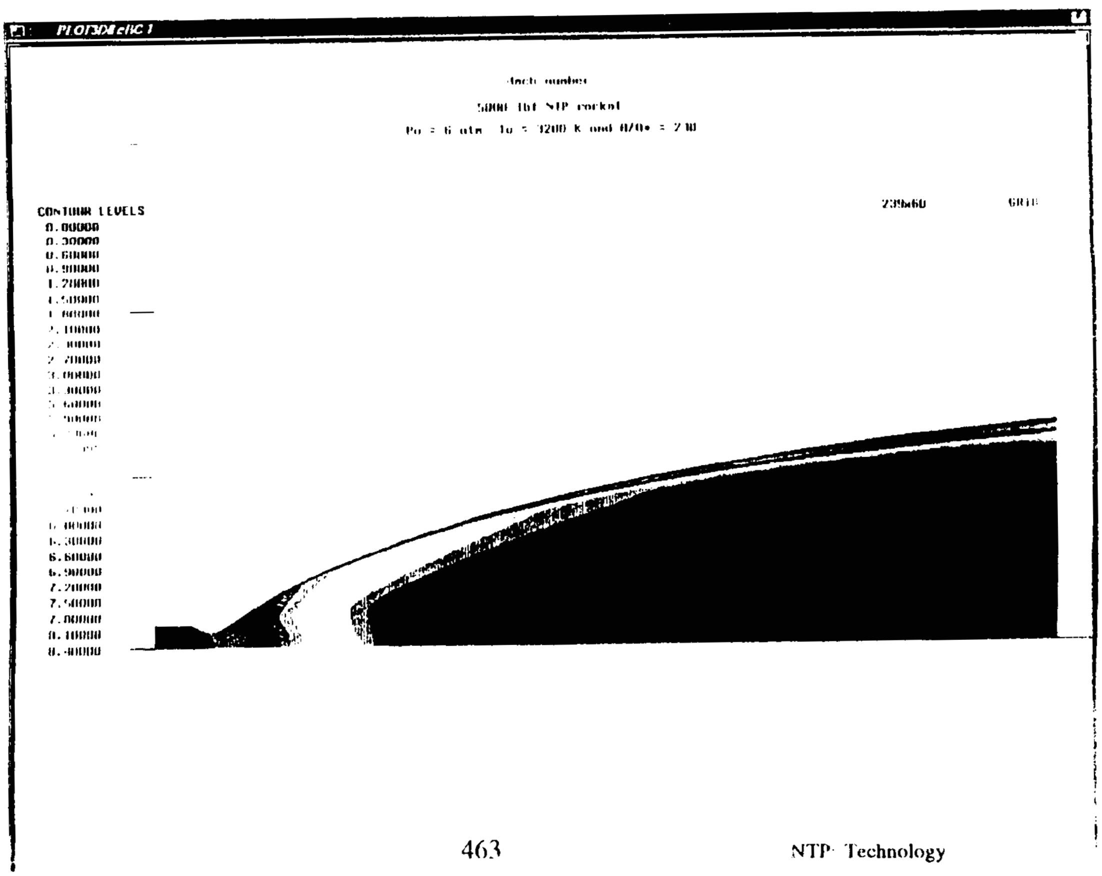
SPECIFIC IMPULSE AS A FUNCTION OF CHAMBER PRESSURE

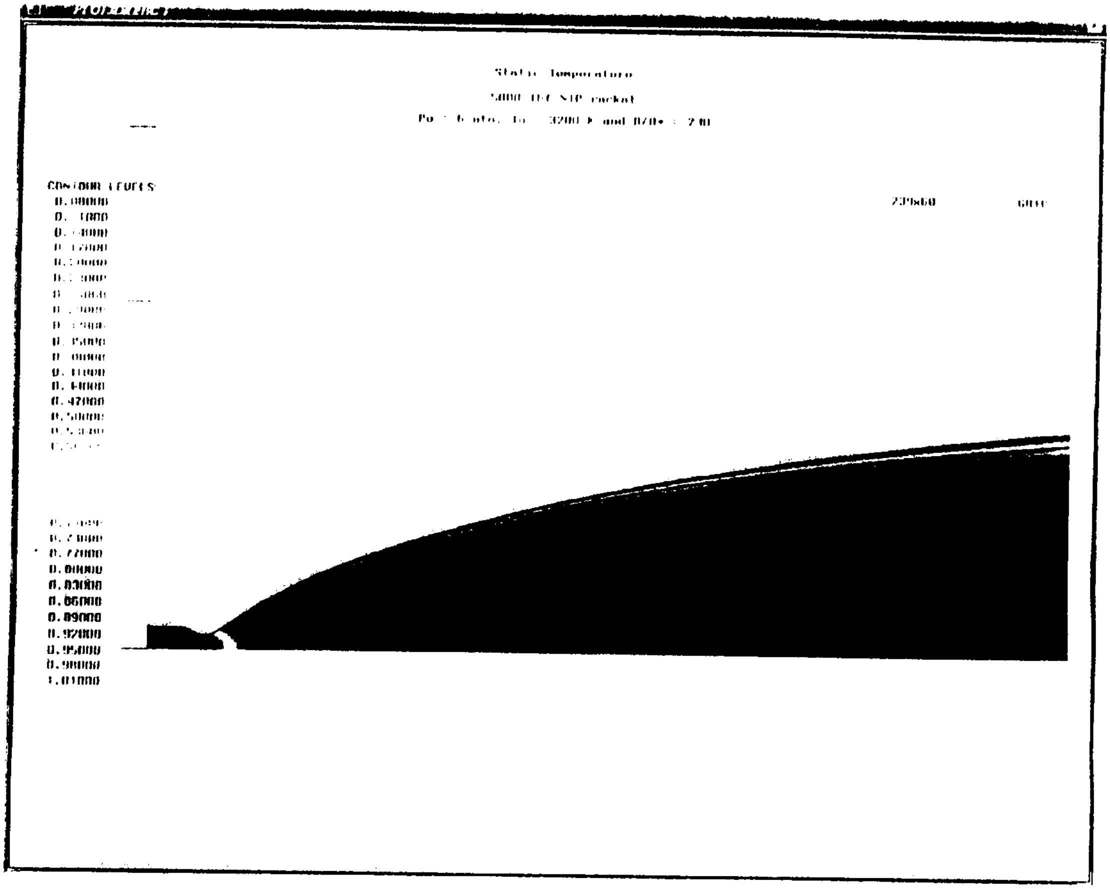
T_C = 3,600 K

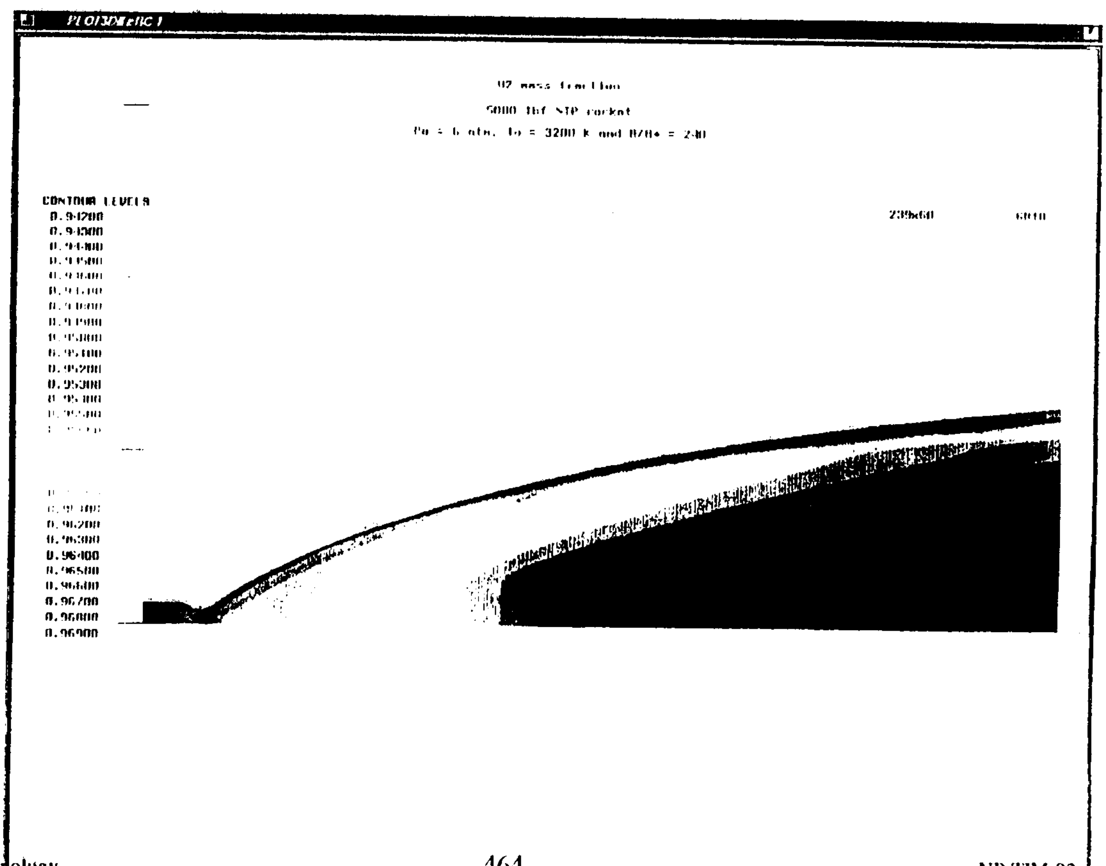


RPLUS

- DEVELOPED AT NASA-LEWIS
- A NAVIER-STOKES CODE WITH FINITE RATE CHEMICAL KINETICS CAPABILITY
  - LU-SSOR
  - 9 SPECIES, 18 REACTIONS, (H_2, O_2 COMBUSTION SYSTEM)
  - 3-D, (ONLY 2-D AXISYMMETRIC REQUIRED HERE)

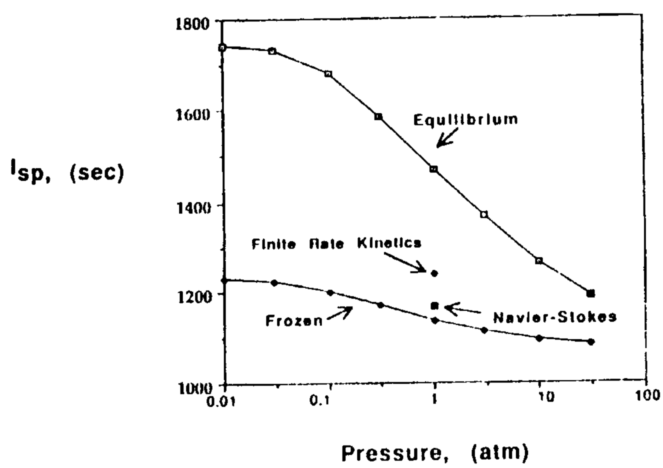



5000 lbf NTP rocket
CONTOUR LEVELS


5000 lbf NTP rocket
CONTOUR LEVELS

SPECIFIC IMPULSE AS A FUNCTION OF CHAMBER PRESSURE

T_C = 3,600 K

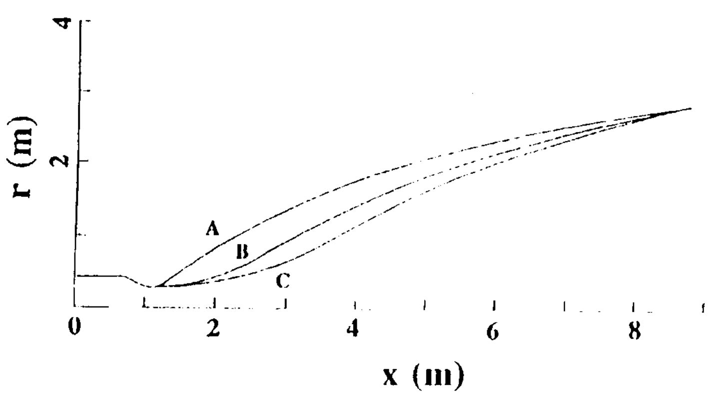


NASA — LEWIS RESEARCH CENTER

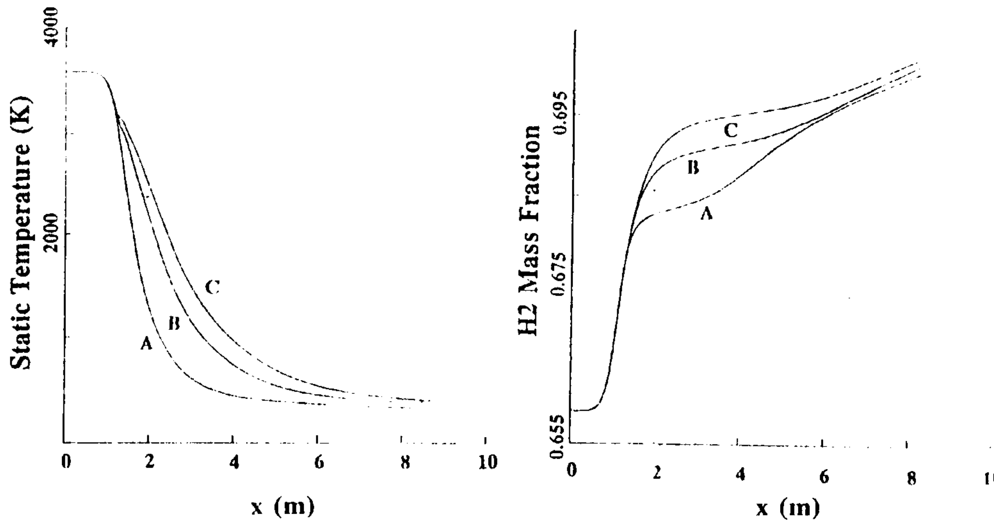
WALL CONFIGURATIONS OF NOZZLES "A", "B", AND "C"

ALL HAVE:

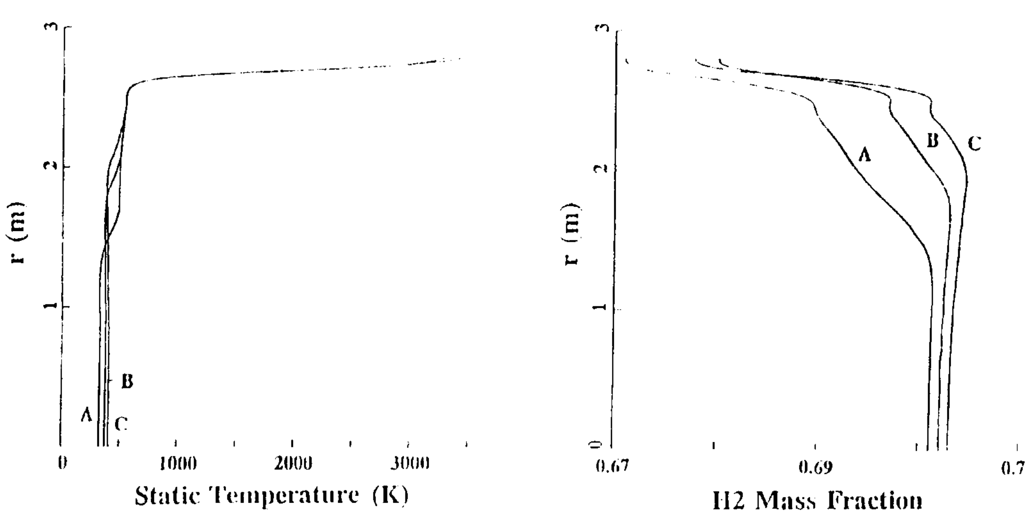
- R_{THROAT} = 0.28 m
- A_E/A_T = 100
- THROAT TO EXIT LENGTH = 7.6 m

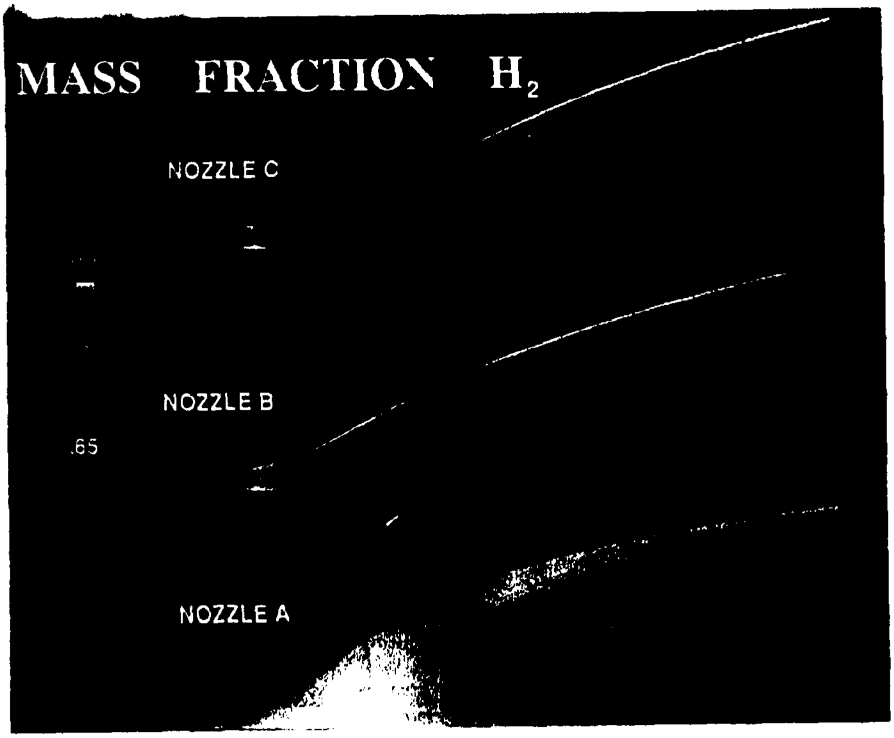


Axial Distributions on the Centerlines



Radial Distributions at the Exit





National Aeronautics and
Space Administration

Lewis Research Center

NASA

TABLE 4. Specific Impulse of NTP Nozzles which have been scaled to produce, at each Temperature, approximately equal Thrust.

	Isp, (lb_f-s/lb_m)		
	P_c=10 atm	P_c=1.0 atm	P_c=0.1 atm
T_c, (K)	r_t=0.28 m	r_t=0.8854 m	r_t=2.8 m
2700	901.61	899.48	903.14
3200	1024.33	1037.21	1072.47
3600	1144.22	1183.39	1223.17

TABLE 5. Specific Impulse for variously sized NTP Nozzles with T_c=3600 K, P_c=1.0 atm.

Isp, (lb_f-s/lb_m)		
r_t =0.28 m	r_t=0.8854	r_t=2.8 m
1151.57	1183.39	1220.41

COMPUTATIONAL FLUID DYNAMICS
FOR
NUCLEAR THERMAL PROPULSION

SUMMARY

- CFD SIMULATIONS PREDICT LOWER SPECIFIC IMPULSE VALUES FOR THE LOW PRESSURE NUCLEAR THERMAL ROCKET THAN ONE-DIMENSIONAL, INVISCID ANALYSES.
- THE LOW PRESSURE CONCEPT SHOWS MORE PROMISE AT HIGHER TEMPERATURES THAN AT LOWER TEMPERATURES, BECAUSE OF THE GREATER AMOUNT OF DISSOCIATION.
- SMALLER NOZZLES SHOW LARGER VISCOUS LOSSES, ESPECIALLY AT LOW PRESSURES; THEREFORE, PERFORMANCE GAINS ARE ASSOCIATED WITH LARGER NOZZLES.
- ADVANCED CFD CODES SUCH AS RPLUS (3D, NAVIER-STOKES, CHEMICAL KINETICS), WITH THEIR ABILITY TO SIMULATE REAL GAS EFFECTS, PROVIDE THE DESIGNER WITH POWERFUL TOOLS TO ANALYZE THE ENTIRE FLOW FIELD AND CALCULATE GLOBAL PERFORMANCE VALUES.