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National Aeronautics and Space Administration

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COMPUTATIONAL FLUID DYNAMICS FOR NUCLEAR THERMAL PROPULSION

Presented to the
Nuclear Propulsion Technical Interchange Meeting

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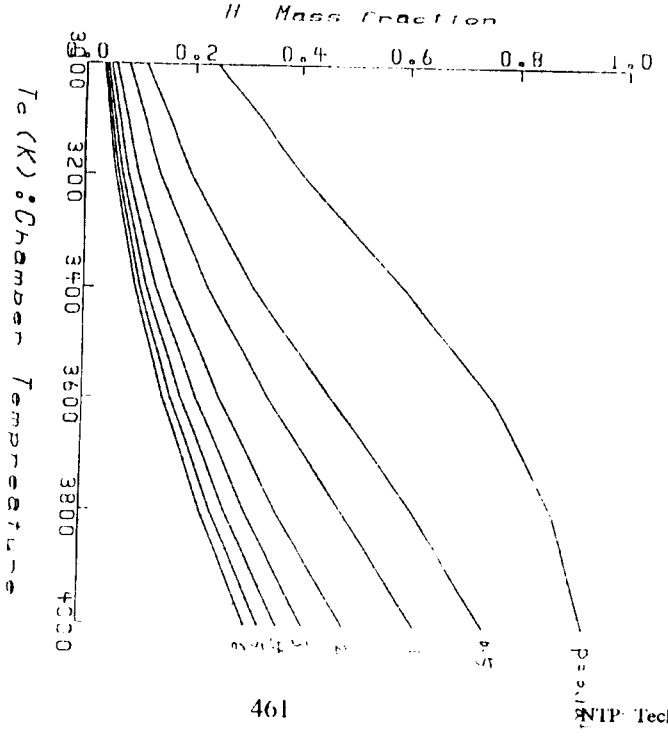

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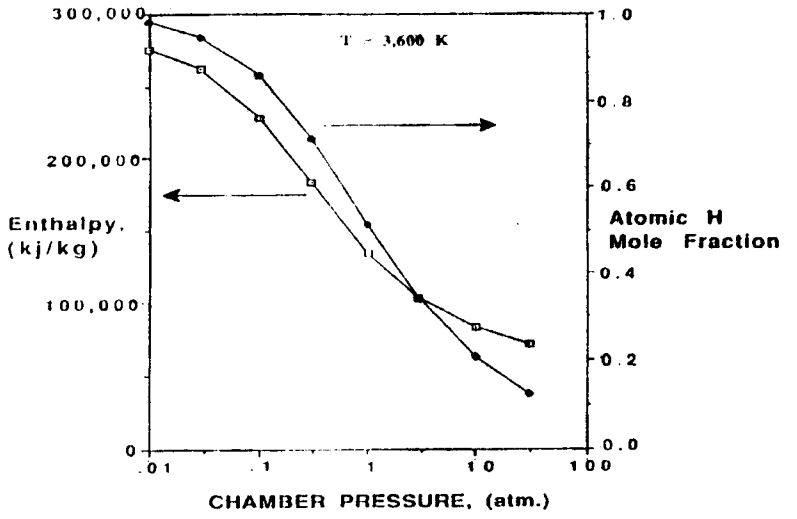
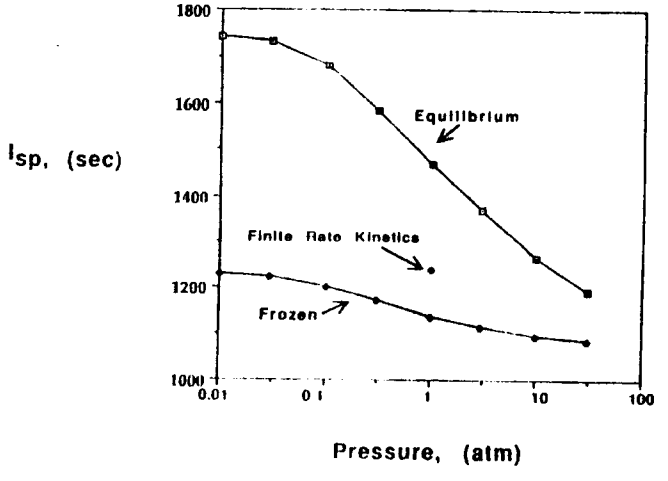
SPECIFIC ENTHALPY OF HYDROGEN AND MOLE FRACTION OF H
AS A FUNCTION OF CHAMBER PRESSURE
AT A CHAMBER TEMPERATURE OF 3,600 K



INTERNAL FLUID MECHANICS DIVISION

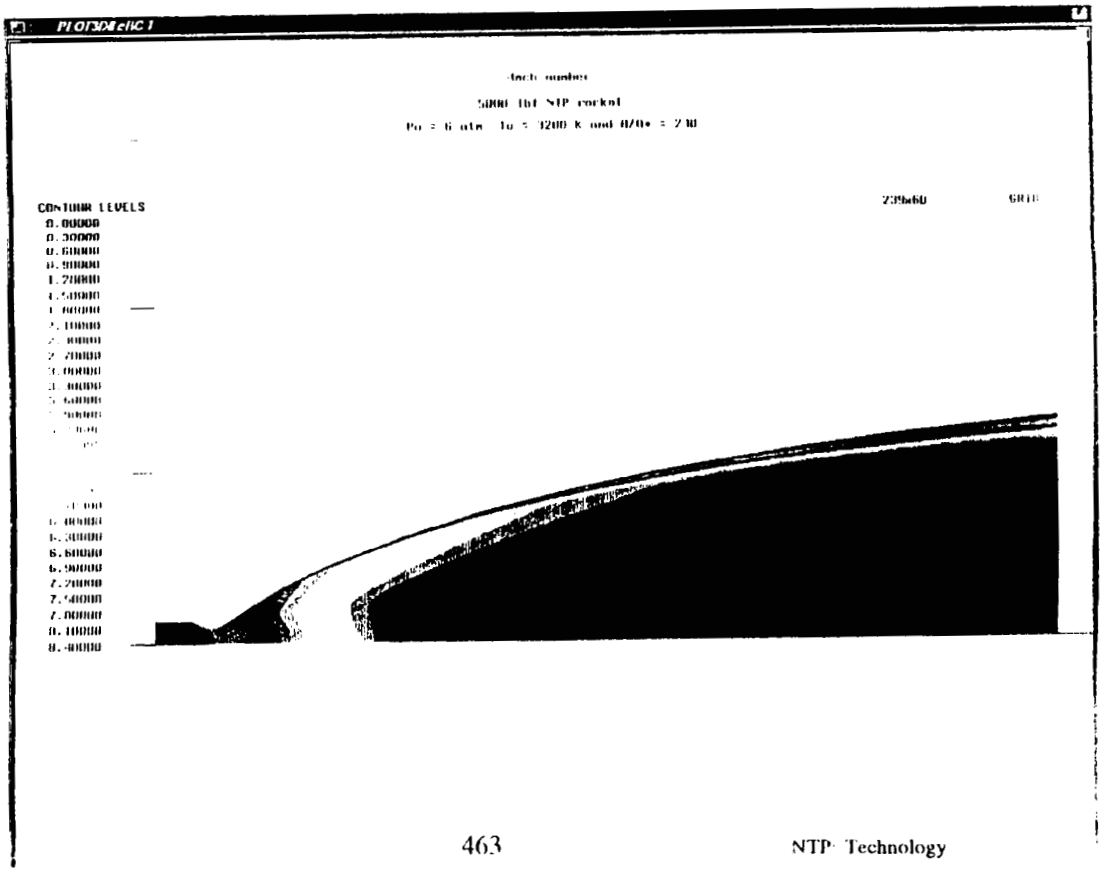
SPECIFIC IMPULSE AS A FUNCTION OF CHAMBER PRESSURE

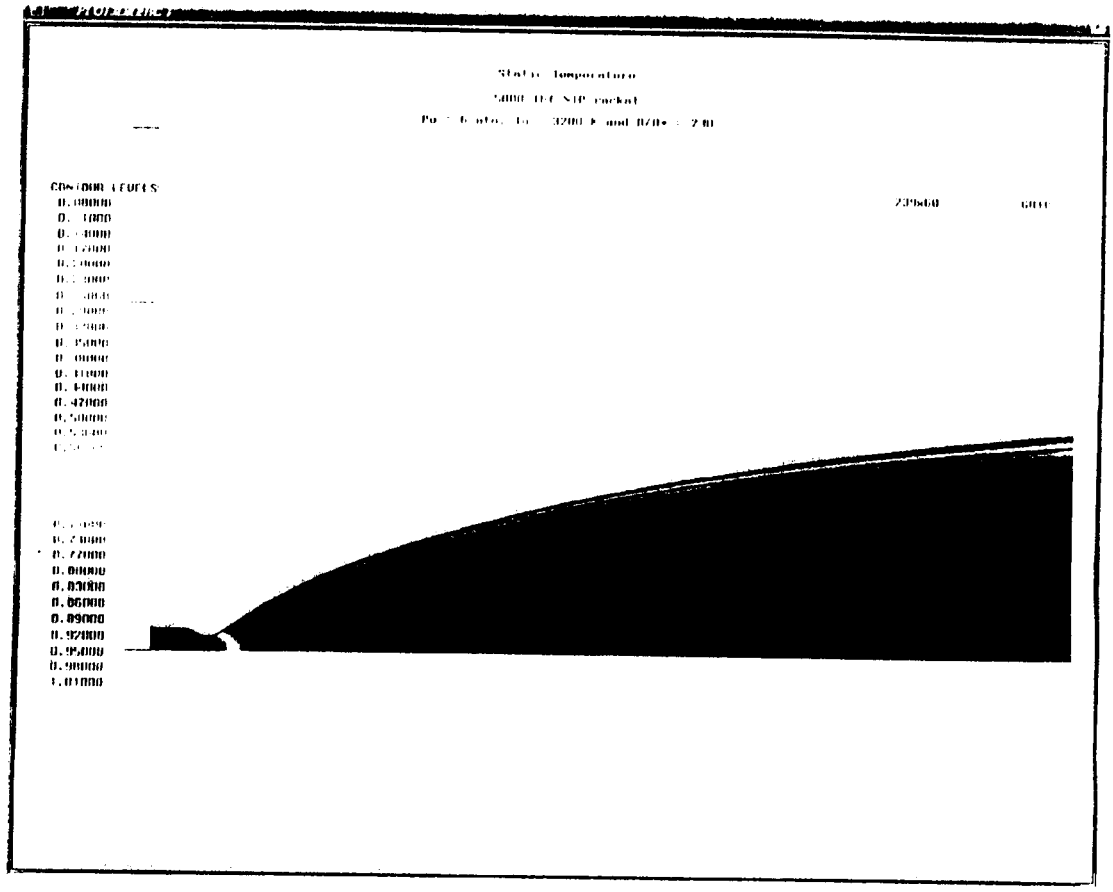
T_C = 3,600 K

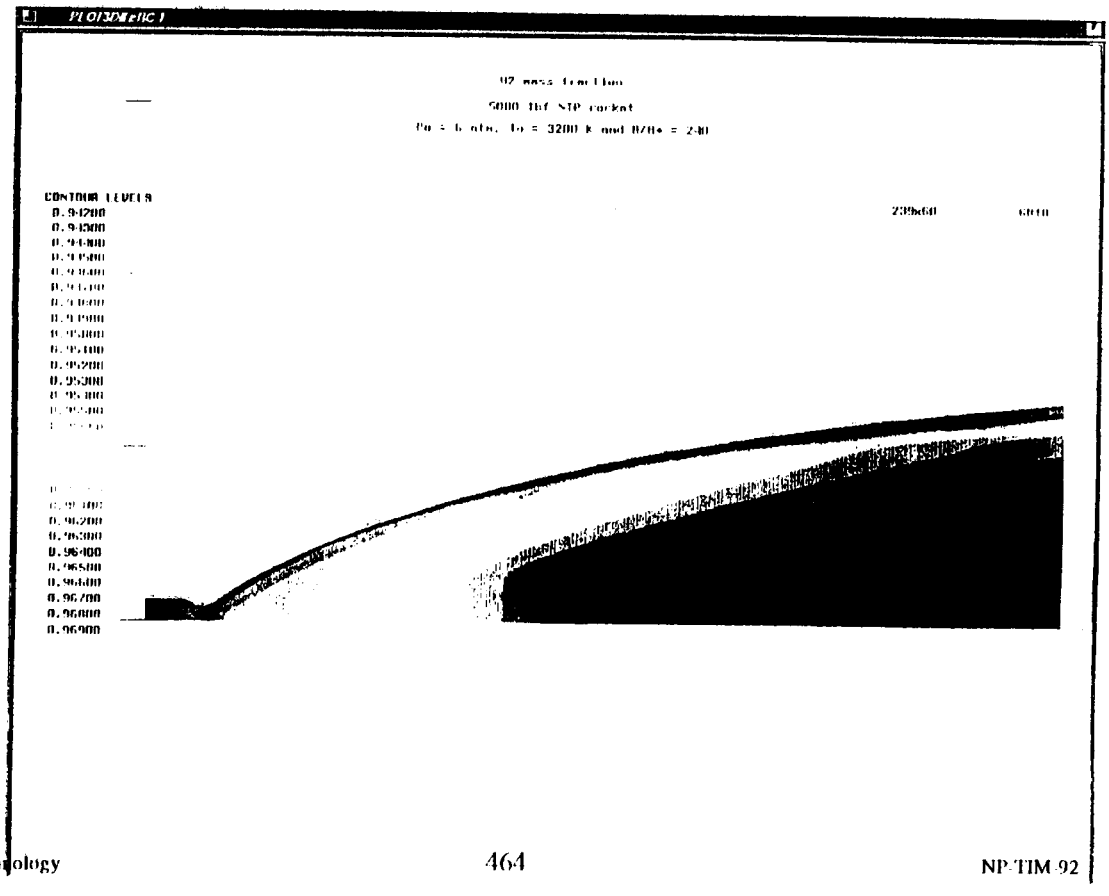


RPLUS

- 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)

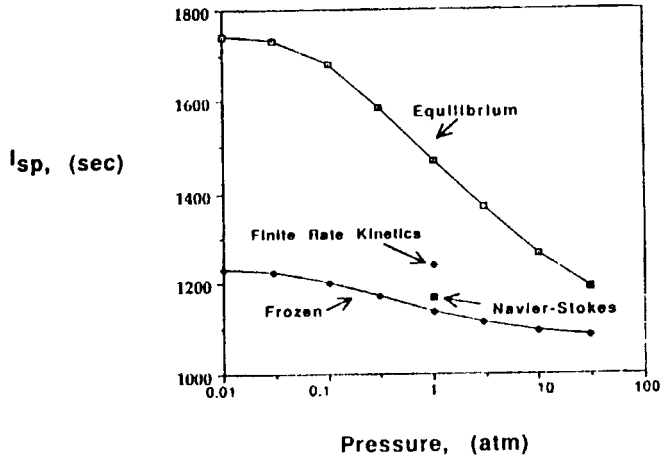






SPECIFIC IMPULSE AS A FUNCTION OF CHAMBER PRESSURE

T_C = 3,600 K



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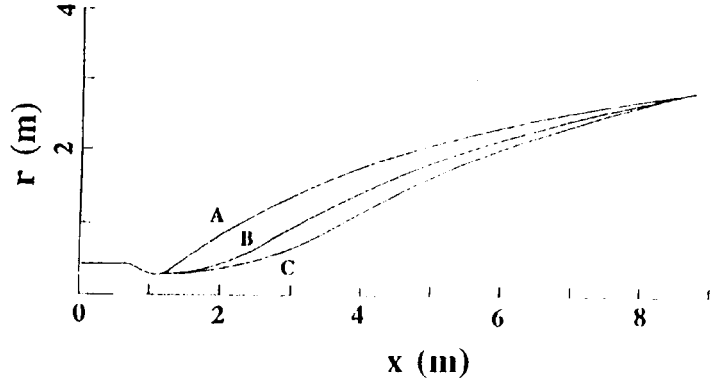
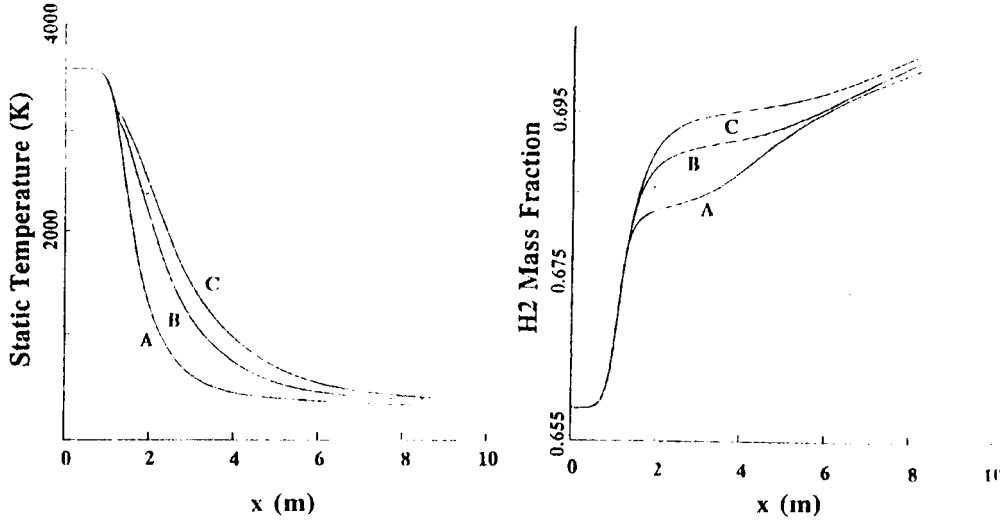
WALL CONFIGURATIONS OF NOZZLES "A", "B", AND "C"

ALL HAVE:

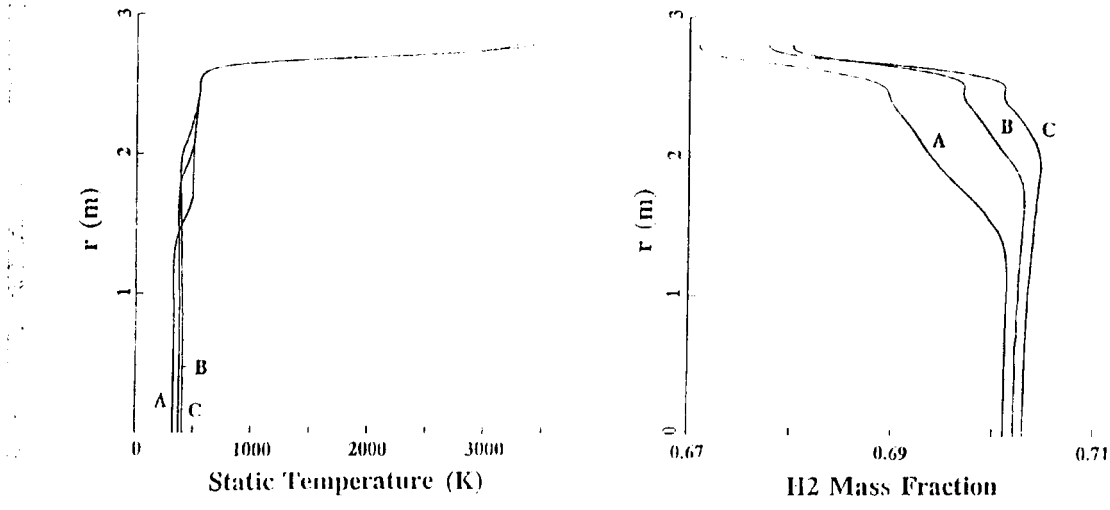
- R_{THROAT} = 0.28 m
- A_E/A_T = 100
- THROAT TO EXIT LENGTH = 7.6 m



Axial Distributions on the Centerlines



Radial Distributions at the Exit



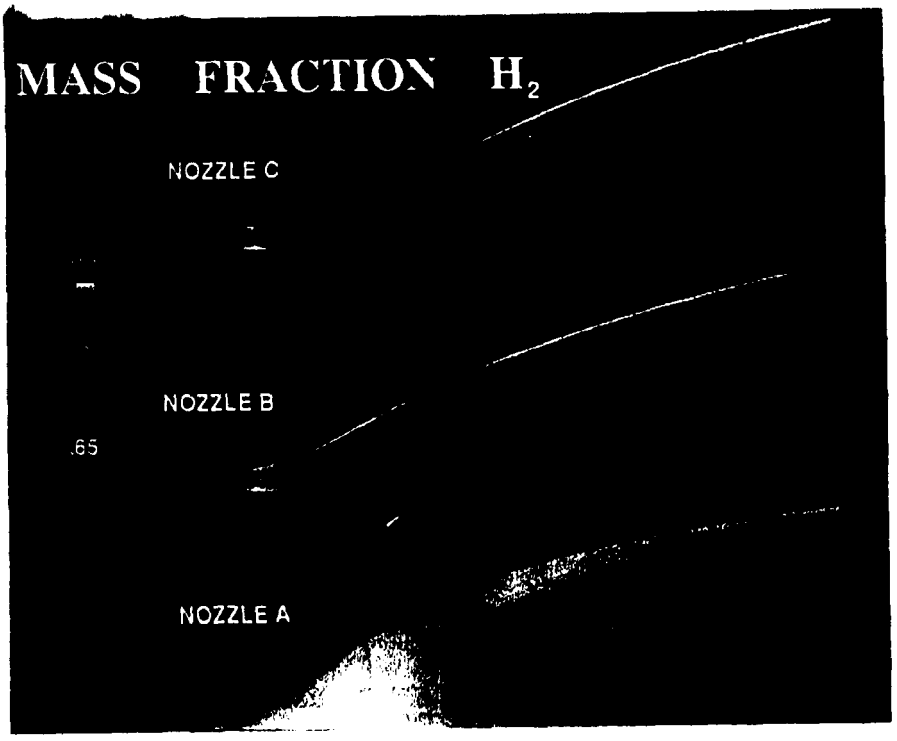


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TABLE 4. Specific Impulse of NTP Nozzles which have been scaled to produce, at each Temperature, approximately equal Thrust.

	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

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.