

## Case name: HyRoE project F

Description: F=7

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**Table 1. Propellant Specification**

Component	Temperature, K	Pressure, MPa	Enthalpy, kJ/mol	Enthalpy, kJ/kg	Mass fraction
C32H66(a)	298.1	0.1013	-967.8000	-2146.534	0.1250000
N2O(L), 184.67K	184.7	0.1013	61.0240	1386.506	0.8750000
Total			46.8739	944.870	

Propellant exploded formula:

$C_{0.440117} H_{0.907742} N_{1.972493} O_{0.986246}$  (based on 1 mole)  
 $C_{10.219605} H_{21.077935} N_{45.801640} O_{22.900820}$  (by mass %)  
 $\alpha$ : 0.7392499 (oxidizer excess coefficient)  
O/F: 7.0000000  
O/F<sub>0</sub>: 9.4690572 (stoichiometric)  
 $\rho$ : kg/m<sup>3</sup>

**Table 2. Combustion Properties**

Parameter	Injector	Nozzle inlet	Nozzle throat	Nozzle exit Unit
Pressure	13.0000	12.7838	7.2916	0.5277 MPa
Temperature	3273.7375	3269.4061	3013.3571	1866.2988 K
Enthalpy	24591.7370	24363.7045	9808.8553	-43042.5890 J/mol
	944.8677	936.0372	374.4646	-1631.4315 kJ/kg
Entropy	248.5234	248.6110	250.1944	251.9995 J/(mol·K)
	9.5488	9.5515	9.5515	9.5515 kJ/(kg·K)
Internal energy	-2627.6620	-2819.6810	-15245.6181	-58559.8782 J/mol
	-100.9605	-108.3303	-582.0194	-2219.5790 kJ/kg
Specific heat (p=const)	2.6395	2.6369	2.2638	1.5839 kJ/(kg·K)
Specific heat (V=const)	2.2213	2.2190	1.8906	1.2684 kJ/(kg·K)
Gamma	1.1883	1.1883	1.1974	1.2488
Isentropic exponent	1.1797	1.1797	1.1927	1.2487
Gas constant	0.3195	0.3194	0.3174	0.3151 kJ/(kg·K)
Molecular weight	26.0266	26.0286	26.1943	26.3833
Density	12.4303	12.2406	7.6233	0.8972 kg/m <sup>3</sup>
Sonic velocity	1110.7332	1109.9785	1068.0836	856.9983 m/s
Mach number	0.0000	0.1197	1.0000	2.6487
Area ratio	5.0000	5.0000	1.0000	4.0000 A/At
Mass flux	1626.7120	1626.7120	8142.3409	2036.5134 kg/(m <sup>2</sup> ·s)
Viscosity	0.9858	0.9849	0.9305	0.6674 x 10 <sup>-4</sup> kg/(m·s)
Conductivity, frozen	0.2434	0.2432	0.2263	0.1490 W/(m·K)
Specific heat (p=const), frozen	1.6514	1.6512	1.6407	1.5533 kJ/(kg·K)
Prandtl number, frozen	0.6688	0.6689	0.6745	0.6956
Conductivity, effective	0.4802	0.4793	0.3744	0.1536 W/(m·K)
Specific heat (p=const), effective	2.6395	2.6369	2.2638	1.6345 kJ/(kg·K)
Prandtl number, effective	0.5419	0.5419	0.5625	0.7103

**Table 3. Combustion Products**

Product	Injector mass fraction	Injector mole fraction	Nozzle inlet mass fraction	Nozzle inlet mole fraction	Nozzle throat mass fraction	Nozzle throat mole fraction	Nozzle exit mass fraction	Nozzle exit mole fraction
CO	0.1614662	0.1500316	0.1613866	0.1499686	0.1555144	0.1454323	0.1370330	0.1290737
CO2	0.1367178	0.0808527	0.1368434	0.0809329	0.1460854	0.0869491	0.1751370	0.1049925
COOH	0.0000095	0.0000055	0.0000093	0.0000054	0.0000043	0.0000025		
H	0.0002423	0.0062572	0.0002416	0.0062391	0.0001541	0.0040043	0.0000024	0.0000632
H2	0.0033704	0.0435140	0.0033697	0.0435082	0.0033152	0.0430778	0.0042715	0.0559040
H2O	0.1285138	0.1856625	0.1285474	0.1857248	0.1315868	0.1913270	0.1266204	0.1854342
H2O2	0.0000027	0.0000021	0.0000027	0.0000021	0.0000009	0.0000007		
HCHO,form aldehy	0.0000004	0.0000004	0.0000004	0.0000003	0.0000002	0.0000002		
HCN	0.0000014	0.0000013	0.0000013	0.0000013	0.0000007	0.0000007		
HCO	0.0000080	0.0000072	0.0000079	0.0000071	0.0000035	0.0000032		
HCOOH	0.0000024	0.0000014	0.0000024	0.0000014	0.0000013	0.0000008		
HNC	0.0000003	0.0000003	0.0000003	0.0000003	0.0000001	0.0000001		
HNCO	0.0000026	0.0000016	0.0000026	0.0000016	0.0000014	0.0000009	0.0000001	0.0000001
HNO	0.0000063	0.0000053	0.0000062	0.0000052	0.0000020	0.0000017		
HNO2	0.0000011	0.0000006	0.0000011	0.0000006	0.0000003	0.0000002		
HO2	0.0000099	0.0000078	0.0000098	0.0000077	0.0000028	0.0000022		
N	0.0000024	0.0000044	0.0000023	0.0000044	0.0000007	0.0000013		
N2	0.5545102	0.5151804	0.5545292	0.5152361	0.5557967	0.5197029	0.5569212	0.5245114
N2O	0.0000040	0.0000024	0.0000039	0.0000023	0.0000014	0.0000008		
NCO	0.0000003	0.0000002	0.0000003	0.0000002	0.0000001	0.0000001		
NH	0.0000019	0.0000034	0.0000019	0.0000033	0.0000006	0.0000011		
NH2	0.0000019	0.0000032	0.0000019	0.0000031	0.0000008	0.0000013		
NH3	0.0000032	0.0000049	0.0000032	0.0000048	0.0000021	0.0000032	0.0000008	0.0000013
NO	0.0051311	0.0044506	0.0050911	0.0044162	0.0023976	0.0020930	0.0000015	0.0000013
NO2	0.0000037	0.0000021	0.0000037	0.0000021	0.0000010	0.0000005		
O	0.0005623	0.0009148	0.0005581	0.0009079	0.0002062	0.0003376		
O2	0.0018673	0.0015187	0.0018544	0.0015084	0.0007237	0.0005924		
OH	0.0075563	0.0115635	0.0075173	0.0115047	0.0041957	0.0064621	0.0000118	0.0000183
Gaseous fraction:	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000
Condensed fraction:	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000

**Table 4. Ideal Performance**

Parameter	Sea level	Optimum expansion	Vacuum Units
Characteristic velocity		1583.3621	m/s
Effective exhaust velocity	2479.2843	2269.9335	2529.0385 m/s
Specific impulse (by mass)	2479.2843	2269.9335	2529.0385 N-s/kg
Specific impulse (by weight)	252.8166	231.4688	257.8902 s
Thrust coefficient	1.5658	1.4336	1.5973
Thrust	4.6249	4.2343	4.7177 kN
Altitude	0.0000	0.0000	km
Ambient pressure	1.0000	5.2077	0.0000 atm

**Table 5. Estimated Delivered Performance**

Parameter	Sea level	Optimum expansion	Vacuum Units
Characteristic velocity		1568.7148	m/s
Effective exhaust velocity	2447.6228	2240.2087	2496.9167 m/s
Specific impulse (by mass)	2447.6228	2240.2087	2496.9167 N·s/kg
Specific impulse (by weight)	249.5881	228.4377	254.6146 s
Thrust coefficient	1.5603	1.4281	1.5917
Thrust	4.5658	4.1789	4.6578 kN
Altitude	0.0000	0.0000	km
Ambient pressure	1.0000	5.2077	0.0000 atm

**Table 6. Altitude Performance**

Altitude, km	Pressure, atm	Specific impulse, N·s/kg	Specific impulse, s	Thrust coefficient	Thrust, kN
0.0000	1.0000	2447.6228	249.5881	1.5603	4.5658

**Table 7. Throttled Performance (delivered)**

Throttle value	Mass flow rate, kg/s	Pressure, MPa	Specific impulse, N·s/kg Sea level	Specific impulse, s Sea level	Thrust, kN Sea level	Specific impulse, N·s/kg Optimum expansion	Specific impulse, s Optimum expansion	Thrust, kN Optimum expansion	Specific impulse, N·s/kg Vacuum	Specific impulse, s Vacuum	Thrust, kN Vacuum
1.0000	1.8654	13.0000	2447.6228	249.5881	4.5658	2240.2087	228.4377	4.1789	2496.9167	254.6146	4.6578

**Table 8. Chamber Size**

Combustion chamber size				Nozzle size	
Dc	38.01	mm	Type	TIC nozzle	
Dt	17.00	mm	Rn	3.25	mm
Lcyl	254.65	mm	Tn	18.02	deg
Lc	300.00	mm	Te	8.61	deg
L*	1420.16	mm	De	34.00	mm
R1	12.75	mm	Le	34.00	mm
R2	80.73	mm	Le/Dt	2.00	
b	20.00	deg	Le/Lc15	107.17	%
Ac/At	5.00		Ae/At	4.00	

Parameter	Engine		Chamber	
Thrust	sea level	4.5658	4.5658	kN
	opt exp	4.1789	4.1789	kN
	vacuum	4.6578	4.6578	kN
Specific Impulse	sea level	2447.6228	2447.6228	N·s/kg
	opt exp	2240.2087	2240.2087	N·s/kg
	vacuum	2496.9167	2496.9167	N·s/kg
Mass flow rate	total	1.8654	1.8654	kg/s

	oxidizer	1.6322	1.6322 kg/s
	fuel	0.2332	0.2332 kg/s
<b>Number of chambers</b>		1	

**Table 10. Thermal Analysis**