Pulsed Inductive Thruster Using Martian Atmosphere as Propellant

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**Pulsed Inductive Thruster (PIT)**

**Inductive Pulsed Plasma Thrusters Demonstrated**

- High, relatively constant $\eta_t$ over an $I_{sp}$ range
- Operate on arbitrary power level while maintaining constant performance
- Increase pulse rate to process significant levels of power in a single thruster unit
- **Electrodeless, operates on range of propellants:** Ammonia, Hydrazine, Hydrocarbons, Water

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**Other Inductive PPT Variants**

- **Field-Reversed Configuration**
- **Conical Theta-Pinch**

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**Pulsed Inductive Thruster**

**Energy** = 4.6 kJ/pulse

**Impulse** = 0.1 N-s

**$I_{sp}$** = 5,000 s

$\eta$ = 50% (or better)

$\rightarrow$ **Thrust** = 3 N ($f_{rep} = 30$ hz)

$P_{Jet}$ = 75 kW

Performance of PIT on Various Propellants

PIT MK V – 4.5 µF, PIT MK Va – 9 µF

Demonstration of significant advancement in operation capability from MK V to MK Va

- Due to better dynamic impedance matching
- Further advances possible

Expect all other atomic / molecular propellants to follow suit in terms of performance trends and improvements

Performance of PIT

MK V performance
- NH$_3$, N$_2$H$_4$ – $\eta_t$ ~ 20-30%
- Ar, He, CO$_2$ – $\eta_t$ ~ 15-20%
- Dynamic Impedance not optimum

MK Va performance
- NH$_3$, – $\eta_t$ ~ 40-50%
- N$_2$H$_4$ – $\eta_t$ ~ 35-40%
- Dynamic Impedance spans optimum

Takeaways
- PIT will operate on many propellant options
  - Provides consistent performance and flexibility for a mission
  - Variations in efficiency across various propellants, but performance likely better for all options with improved dynamic impedance match
  - Higher efficiency possible with inductive energy recapture
    - Electrical / Power System challenge: Independent of propellant choice

The Martian Atmosphere as Propellant

Propulsion Systems Department

Concept

- If an EP system can operate on CO\(_2\) (as PIT can), Mars atmosphere is a simple ISRU option
- Only need to carry propellant for one way trip (mass and systems advantages)
- Can produce propellant at Mars by compressing atmosphere and filling a COPV tank
- Variation in \(\eta_t\) with propellant (but still fairly close)
  - Analysis of system and mission concept required to quantify effects
  - Testing will be conducted at NASA-MSFC using a PIT thruster on simulated Martian atmosphere.
- Spacecraft could also leave Mars and go to a different destination (other than returning to Earth)
- Potentially permits *in situ* refueling at any other destination where the atmosphere is accessible

<table>
<thead>
<tr>
<th>Chemical Species</th>
<th>Mole fraction</th>
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<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>95.32%</td>
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<tr>
<td>Nitrogen</td>
<td>2.7%</td>
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<tr>
<td>Argon</td>
<td>1.6%</td>
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<tr>
<td>Oxygen</td>
<td>0.13%</td>
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<tr>
<td>Carbon Monoxide</td>
<td>0.07%</td>
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