The ISR Asymmetrical Capacitor Thruster; Experimental Results and Improved Designs

40th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit
Fort Lauderdale, Florida  11 - 14 Jul 2004
Dr. Francis X. Canning
FCanning@ISR.us

Research with an EDGE  
320 Adams Street | P.O. Box 2720 | Fairmont, WV 26555-2720
Phone 304.368.9300 | Fax 304.368.9313 | www.isr.us
The Team

AT ISR
• Francis Canning
• Ed Winet
• Bob Ice
• Cory Melcher
• Phil Pesavento
• Alan Holmes
• Carey Butler

AT NASA Marshall
• John Cole
• Jonathan Campbell
ACT Project Background

- Lifters – Internet (J.L. Naudin, Tim Ventura, etc.).
- Still no peer review publications explaining the effect.
- Previous improvements have used intuition.
The TDT's Lifter1 experiment by JL Naudin
New Science or Pseudo-Science

The NASA Two dimensional asymmetrical capacitor thruster simulation
by JL Naudin - Nov 18, 2001 - Email: JNaudin509@aol.com - http://go.to/jlnlabs
Project Goals

- Understand how to optimize the thrust.
- Understand how to use on other atmospheres.
- Understand how the force is produced.

STRATEGY

- Develop several designs.
- Optimize these designs.
- Instrument for data acquisition.
- Develop computer models.
- Compare experiment and models.
Outline

- Test apparatus
- Devices tested
- Circuits used
- Data collected
  - Time averaged
  - Time resolved
- Patterns Observed
- Force Calculation
- Electrostatic Modeling
- Understand it all
Test Apparatus: Design Features

24in

13in
Many ACTs Were Tried
Asymmetry causes a force?

- Word on the street re direction is:
  - Sharp capacitor plate is forward side.
  - Polarity of excitation doesn’t matter.

- Sharp edges cause high electric field:
  - Well known effect.
  - But, why does that matter.
    - Polarizing vacuum?
    - Current flow of ions?
Strong E Field, because...

Electric Field

Charge

Position
Resistors with NO Sharp Edges
Wires on a Screen
An Early Asymmetrical Capacitor
Four Devices Tested

1

2

3

4

Footer
Devices 1 & 2
Device 3
Four Circuits Tested

A

B

C

D
Force Vs Atmospheric Pressure

![Graph showing the relationship between torque (meter-Newton) and pressure (Torr). The x-axis represents pressure in Torr, ranging from 0 to 800, and the y-axis represents torque in meter-Newton, ranging from 0.001 to 0.006. The graph includes various data points and trend lines indicating the increase in torque with increasing pressure.](image-url)
Data Collected

- Current into ACT.
- Current out of ACT.
- Voltage Applied.
- RPM.
- VLF Radiation.

- All time resolved on Oscilloscope / DAQ.
- Current into ACT measurement fluctuated.
- Also measured friction.
Current Vs Trichel Radiation

Top trace is radiation, bottom is current out of ACT
Data Acquisition System

Time scale is several orders of magnitude longer than for oscilloscope.
RPM Vs Time

D2ADryAirR9 Velocity

RPM

Time (sec)

Series 1
Raw Computed Acceleration

D2ADryAirR9 Acceleration

Revolution/sec^2

Time (sec)
Smoothed Acceleration Data

- Smoothed Acceleration Data.
- Acceleration is a 2nd derivative of position.
- Puts noise into the result.
- Performed least squares fit of vel. vs time.
- Used five pairs of time and velocity.
- Took slope of fitted line as acceleration.
- Result still had some jitter- but much less.
- Plotted as Acceleration Vs Velocity.
Spin Down Device 3

D3SpnDnEval

Acceleration (rad/sec^2)

Velocity (RPM)

- D3ComAirSpnDn
- D3DDryAirR1
- D3DDryAirR2
- D3DDryAirR3
- D3DNitR1
Patterns Observed

- Devices 3 and 4 always rotated with the rough side first.

- Devices 1 and 2 always rotated so that the non grounded side was first.

- Changing polarity never changed the direction.

- Devices that moved weakly only moved with one polarity.
Induced Charges???

Accelerating Charges Radiate

Does the radiation cause electrostatic forces?

\[ \vec{J} = \hat{n} \times \vec{H} \]
Electrostatic Explanation

\[ \frac{d}{h} = 0.01 \]

0.05 lbs * \((d/h)^2\) = 0.000005 lbs
Ablation???

- Particles may be ejected due to heating.
- Assume $T=2,600$ Kelvin.
- Assume $KE =$ Thermal Energy & Copper mass.
- Implies 0.005Kg loss in six minutes.

- Doesn’t seem reasonable for sustained op.
- May explain transients.
\[ \nu = \left( \frac{8kT}{\pi m} \right)^{1/2} \]

\[ \nu = \left( \frac{8 \times \left( 1.3807 \times 10^{-23} \frac{J}{\circ K} \right) (2600 \circ K)}{\pi (1.0544 \times 10^{-25} \text{ kg})} \right)^{1/2} = 930 \text{ m/s} \]
\[ \frac{dm}{dt} = \frac{F}{v} \]

\[ \frac{dm}{dt} = \frac{0.014 \, N}{931.1 \, m/s} = 1.5 \times 10^{-5} \, kg/s \]
Polarizing the Vacuum???

- The energy to create an electron-positron pair = 1.0 MeV (from $2mc^2$).
- ACT has 100 keV, but over centimeters.
- Relevant comparison is work done on an atomic length scale (or smaller).
- Over one Angstrom, the available energy is less than $10^{-9}$ of an MeV.

THIS MECHANISM IS NOT PLAUSIBLE
Electrostatic with Ion Drift!!!

- Assume charged ions cross ACT.
- Assume $10^{10}$ collisions/sec with air.
- Assume loss of forward motion on collision.

$$F = 2d \frac{10}{\text{sec}} \frac{m}{l/e}$$

- Note: Collisions cause momentum transfer.
- Note: The voltage causes an increased current, indirectly affecting $F$. 
Electrostatic with...Backup

- $F = qE = qV/d = tIv/d$ (i)
- $d_0 = 0.5at_0^2 = 0.5 a [10^{-10} \text{ sec}]^2$
  - Where $a = F/m = [\text{eV/d}]/m$
- The total time to travel a distance $d$ is
  - $t = 10^{-10} \text{ sec} (d/d) = 2d(10^{10}/\text{sec})/a$
  - $= 2d^2 \times 10^{10} \text{ sec m/(eV)}$ (ii)
- Substituting (ii) into (i) gives:
  - $F = 2d (10^{10}/\text{sec}) m I / e$
- $F = 2(7\text{cm})(4.7E-26 \text{ kg})(0.0035 \text{ Amps})x(10/\text{sec})$
  - $(1.6E-19 \text{ Coulombs}) = 1.44 \text{ Nt.}$
Force and Speed Agree

- Force computed as above is slightly less than that measured.
- Device 4, Circuit A, was most efficient.
- Other Device/Circuit Combos significantly less efficient.
- Believe due to removing ambient ions.
- Found 1% power efficiency, and ratio of velocities was 100:1 also!
Voltage near a Cylinder
Patterns Observed....Repeated

- Devices 3 and 4 always rotated with the rough side first. (3&4 are most asymm.)

- Devices 1 and 2 always rotated so that the non grounded side was first. (least asymm.)

- Changing polarity never changed the direction.

- Changing polarity changed rotation rate.
Working Explanation re Efficiency

- Ions move in both directions.
  - Wrong way ions reduce force produced.
- Ionizing ambient air causes losses.
- Most efficient devices are the most asymmetric devices.
- Device 4 removes ambient ions, due to the rear wires. This improves efficiency.
Working Explanation re Direction

- Ions are created at a rate depending on strength of E field.
- Sharp features cause larger E field.
- Grounding a side reduces its E field.

CAN WE SHOW THIS BY NUMERICAL SIMULATION???
Electrostatic Modeling
Designing more efficient ACTs

- How to increase thrust?
  - Increase hang time for ions.

- Does it work in a vacuum?
  - No!

- How to improve efficiency?
  - Use it on a moving vehicle & decrease ion speed.

- Is there any new physics?
  - NO!
The mechanism of operation for ACTs has been determined.
Their efficiency is determined by the ratio of speeds of ions Vs the ACT.
There is no new physics.
They do not work in a vacuum.
They can be optimized to work at various pressures and in various gasses.