

## Development of an RF-Ion Thruster for Commercial Application

Rainer Killinger, Helmut Bassner, Space Infrastructure  
 Johann Müller, Dornier Satellite Systems

DaimlerChrysler Aerospace AG  
 Postfach 80 11 69  
 D-816633 München, Germany  
 Tel: +49 89 607 23682

### ABSTRACT

Based on the Radiofrequency Ion Thruster (RIT10\_ART) built and successfully qualified for ARTEMIS the DaimlerChrysler Aerospace AG (DASA) started to develop two improved ion thrusters for low to medium thrust (RIT10\_EVolution) and high thrust (RIT\_XT) applications. This paper, after an initial description of the RIT operational principle will provide the results of the already completed RIT10\_EVO development. During the development of the RIT\_XT special emphasis was put on easy manufacturing an thus low cost. The first results of the RIT\_XT are outlined in chapter 3.

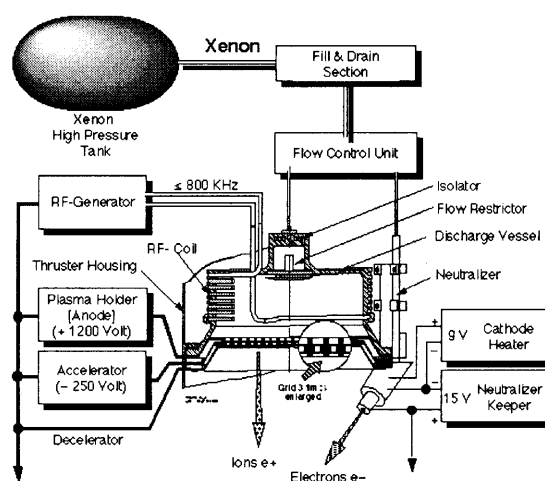


Fig. 1-1: Operating Principle of a Radiofrequency Ion Thruster

## 1. THE RIT TECHNOLOGY

### 1.1 RIT Operating Principle

The RF-Ion Thruster technology ionizes Xenon atoms by collision with electrons which are accelerated by an RF-field. The RF-field is coupled into the inner of a discharge vessel by an RF-coil.

The ions are accelerated in an extraction grid system by an electrostatic field. Electrons for neutralization of the extracted ion beam are produced by a hollow cathode neutralizer, which also generates the electrons for the ignition of the discharge in the thruster. During normal discharge operation an electron source is not necessary.

Fig. 1-1 shows a block diagram explaining the operating principle of a RIT thruster.

### 1.2 Comparison with other technologies

The RF-Ion Thruster (RIT) technology has some advantages compared to other thruster technologies like the Kaufmann-thruster or the Hall Effect Thruster (HET):

- \* The RIT does not need a continuous electron source for the discharge operation. Since the discharge is ignited, it is self-sustaining. Electrons for the ignition of the discharge will be delivered from the neutralizer.
- \* The thrust level is easy and fast to control by the adaptation of the RF-energy for ionization.
- \* RIT has a constant exhaust velocity and a negligible number of double charged ions, therefore no erosion of discharge vessel, gas inlet, and screen grid.

- \* RIT thruster do not need a main hole cathode like Kaufmann or Hall Effect Thrusters, main discharge works electrodeless by RF power coupled into the plasma
- \* There are only 2 Xenon flows to control.
- \* The beam has a very low divergence angle (12°half cone angle for 95% of the beam).
- \* The thruster case and the input control parameters are on ground potential.

Gridded ion thrusters like RIT and the Kaufmann thrusters need about 22 to 30 W/mN overall specific power to produce the thrust level at a specific impulse of around 3000 s. This is higher than for the HET thrusters, which produce the thrust at a specific power of 15 to 19 W/mN, but only at a specific impulse of 1500 to 1900 s.

For each special mission these data have to be compared on system level. Mass saving of up to 50% for gridded ion thrusters in respect to HET against a 30% shorter operation time of the HET thruster at identical input power.

## 2. DEVELOPMENT OF THE RIT10\_EVO(lution)

Due to the market requirement for higher thrust levels, Dasa decided to improve the RIT technology with respect to ion beam density in the grid system to allow for the generation of higher thrust at the same beam diameter and to improve the ionization efficiency in order to decrease the power to thrust ratio. As a first step of this „Evolution Program“ a high performance thruster of the ARTEMIS class, i.e. 10 cm discharge chamber diameter, called RIT10\_EVO, was developed, manufactured, and tested in 1997/98.

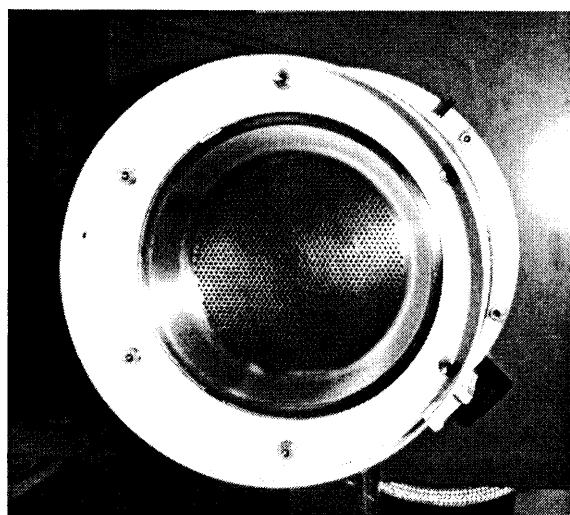


Figure 2-1: RIT10-EVO

In order to minimize cost and time for development and the manufacturing to flight standard, ARTEMIS parts were used where feasible. As a result the new thruster was ready for test within 4 months after start of the development.

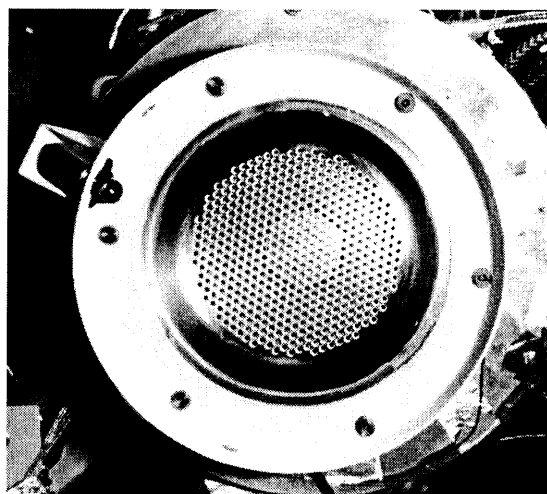


Figure 2-2: RIT10 ARTEMIS (for comparison)

The testing was performed in January/February 1998 at the ESTEC test facility in Noordwijk, The Netherlands. The newly developed grid resulted in a increased performance and a reduced grid erosion..

The following achievements were made:

- Thrust regulation bandwidth  
Demonstrated: 1 to 41 mN
- Increased specific impulse Isp (thruster):  
( at acceleration voltage = 1500V)

Thrust	was	achieved
15 mN	3400 s	> 3700 s
35 mN	n/a	3400 - 3700

- Reduced acceleration grid loss current (Iacc) from 1,5% to approx. 0,7% at ≤ 30 mN, at a vacuum chamber pressure of 5 \*10<sup>-5</sup>, and therefore increased lifetime capability.
- Reduced specific power:

	P <sub>thruster</sub> /F	P <sub>mainbus</sub> /F
ARTEMIS	35 W/mN	37.5 W/mN
RIT10_EVO	25-27 W/mN.	29-31 W/mN

The RIT10\_EVO thruster, shown in figure 2-1, is optimized for N/S-station keeping of geo-synchronous satellites, orbit maintenance of LEO constellation, and other low or medium thrust / power applications. Due to its capability to operate at various thrust levels (<1 mN up to 40 mN), at an

extremely short time scale, it is the first choice for missions requiring drag compensation like, ESA's Gravity and Ocean Circulation Explorer (GOCE). This unique behavior was tested on a RIT engineering model. Figure 2-3 shows the RIT performance at fast throttling application comparison. The figure shows a comparison between commanded and measured thrust. The thruster was operated at a constant mass flow of 0.31 ms/s. During this test the operation bandwidth (ft) of the thrust level was limited due to the use of the ARTEMIS electronics (ft  $\cong$  1 Hz), the bandwidth for the use on GOCE will be improved to ft >10 Hz.

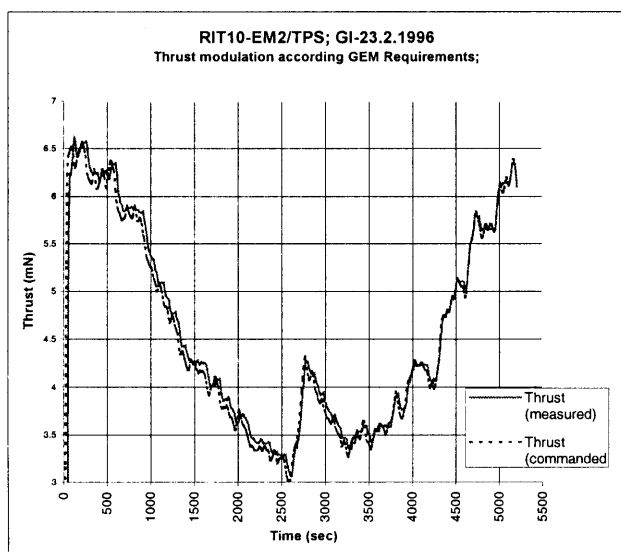


Fig 2-3 RIT10 thrust response test results

The figures below show a set of the results achieved during the development testing:

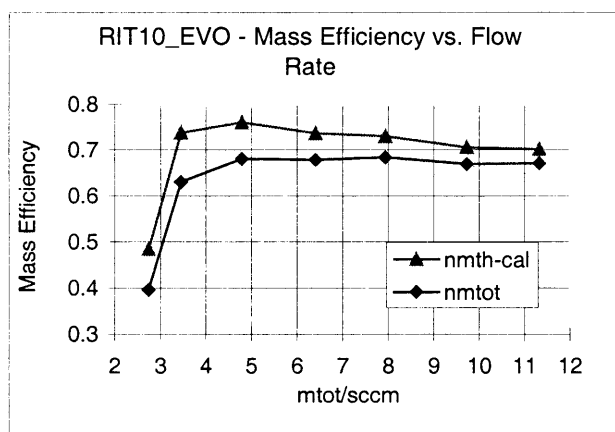


Fig 2-4 RIT10\_EVO Mass Efficiency as a function of Flow Rate

Figure 2-4 shows the mass efficiencies of the thruster (measured) and the total efficiency - thruster and neutralizer - (calculated). For total flow rates above 8 sccm, the mass efficiency is slightly decreasing for increasing flow rates due to increasing neutral gas losses due to the increasing pressure in the thruster vessel.

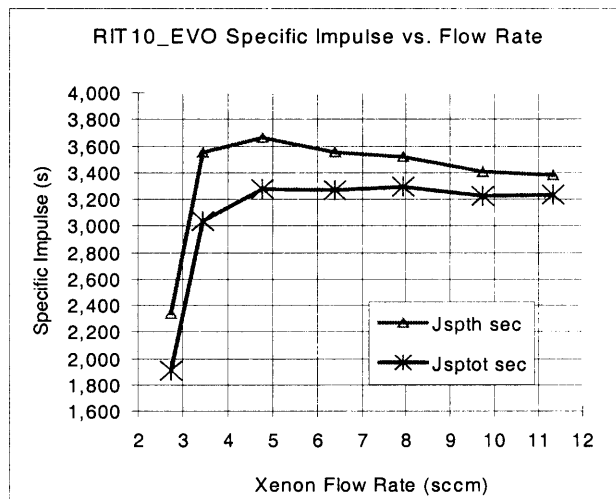


Fig 2-5 RIT10 EVO Specific Impulse as a function of Flow Rate

At low flow rates < 5 sccm the constant neutralizer mass flow causes an increasing mass efficiency, as it has less influence on the flow rate at increasing thruster flow rates. This behavior directly has an effect on the specific impulse, as shown in Fig 2-5.

The specific power in Fig 2-6 is shown for an acceleration voltage of 1500V. At lower acceleration voltages the specific power and thus the main bus power are reduced, as shown in Fig 2-7

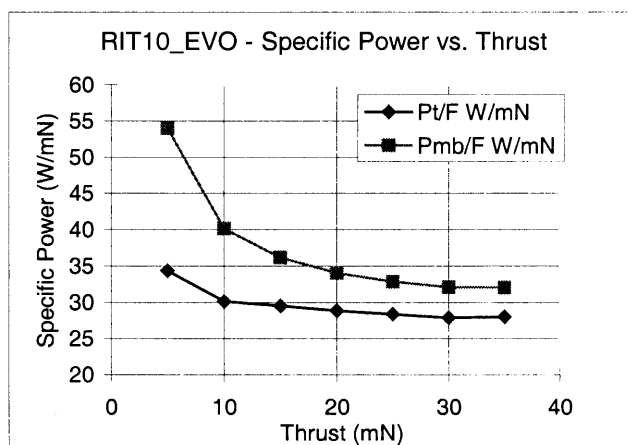


Fig 2-6 RIT10 EVO Specific Power as a function of Thrust

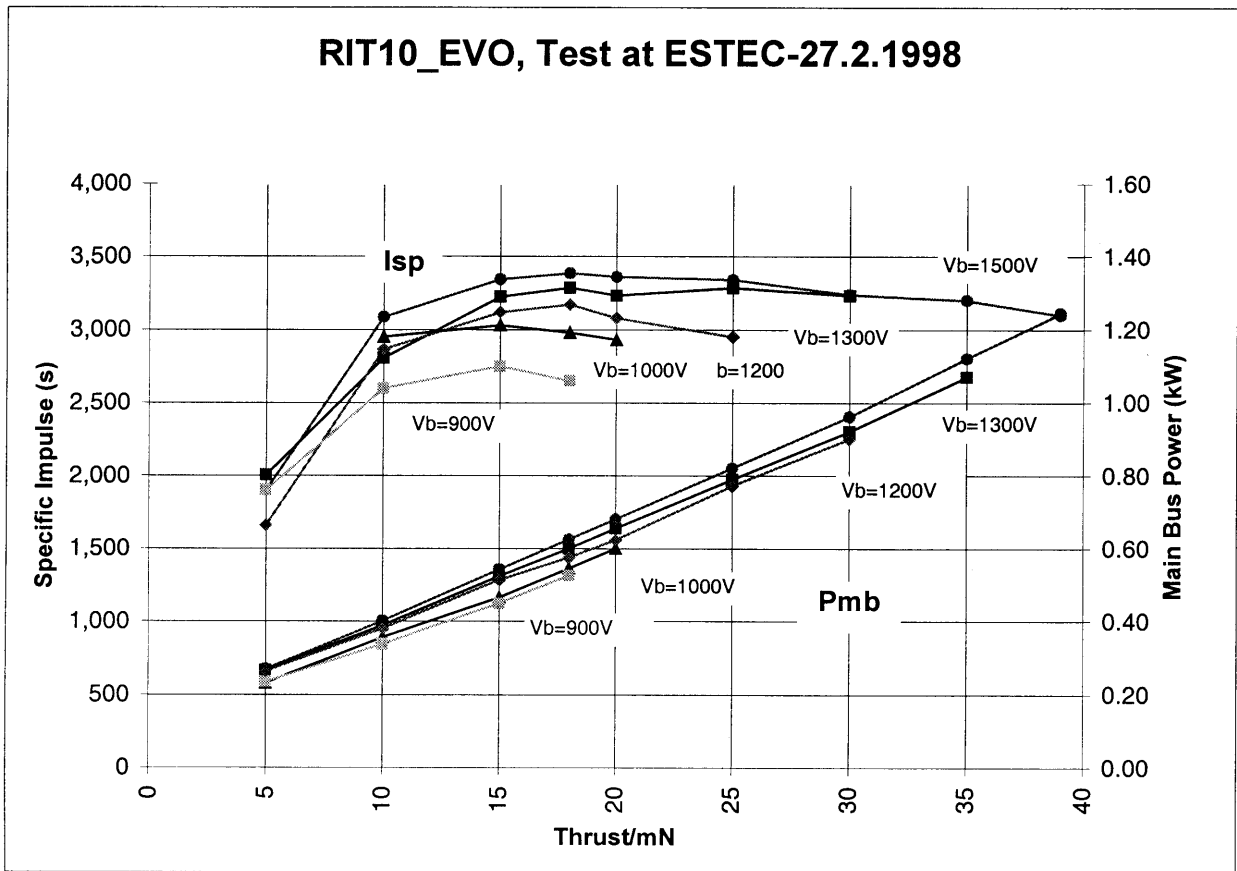


Fig 2-7 RIT10 EVO Main Bus Power vs. Thrust, compared to the ARTEMIS thruster

One major improvement was the reduction of the accel drain current from ARTEMIS to the RIT10\_EVO as shown in Fig 2-8.

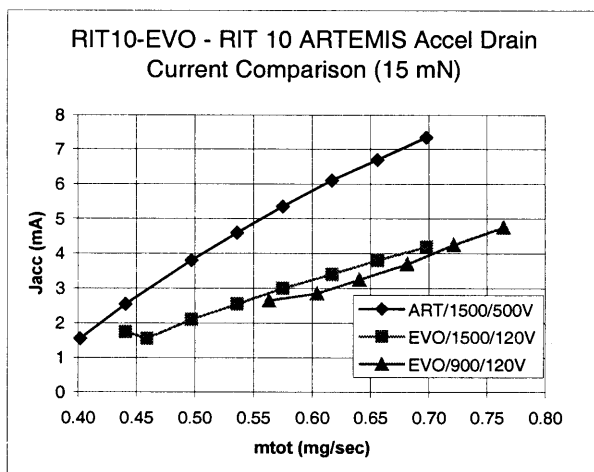


Fig 2-8 Comparison to the Access Drain Current between the ARTEMIS thruster and the RIT10\_EVO

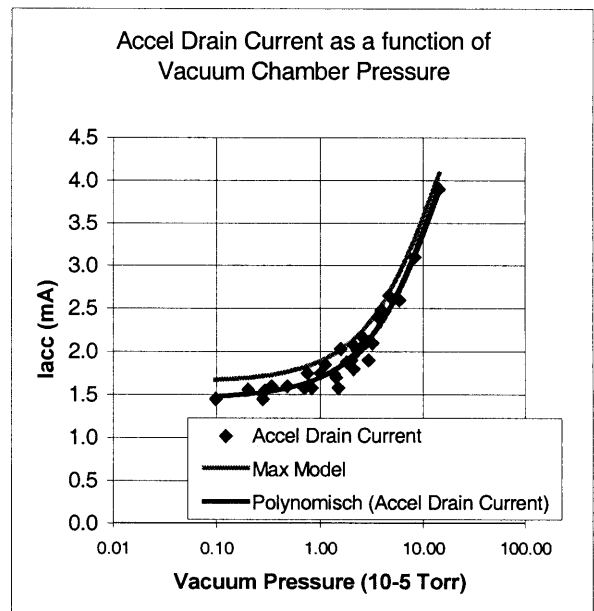


Fig 2-9 Pressure dependence of the Accel Drain Current

These tests were performed at vacuum chamber pressures pressure of  $5 \times 10^{-5}$  mbar. From the results shown in Fig 2-9 it can be concluded that the accel. drain current in space will be about 70% of the values tested.

### 3. DEVELOPMENT OF THE RIT\_XT HIGH POWER THRUSTER

In order to cover the high thrust requirements for orbit raising of LEO-constellations, transfer from GTO to GEO, and interplanetary missions for the beginning new millennium, Dasa currently is developing an 100-mN class thruster called RIT\_XT. Design and specific performance of this thruster is based on the achievements of the RIT10\_EVO. The performance requirements achieved on the EVO thruster, e.g. current density in the grid, were reduced for the large thruster in order to allow a design to cost. In addition this approach provides a growth potential for the thrust above the 100mN which is the current design goal for this thruster.



Fig.: 3-1: RIT\_XT in Test Chamber

A comparison of the evolution thruster family with EURECA and ARTEMIS is shown in table 4.1.

Together with the RIT\_XT thruster an advanced Power Processing Unit - PPU is under development at Dasa.

The key technical data are listed below:

- Primary power demand 2,800 W (per thruster)
- Mechanical I/F 360 \* 420 \* 140 mm
- Dissipated power 252 W
- Max. heat flux 0.17 W/cm<sup>2</sup>
- Mass 12kg

The testing of the RIT\_XT was started in February 1999. First results at low thrust levels up to 50 mN (Fig 3-3) show an excellent performance.

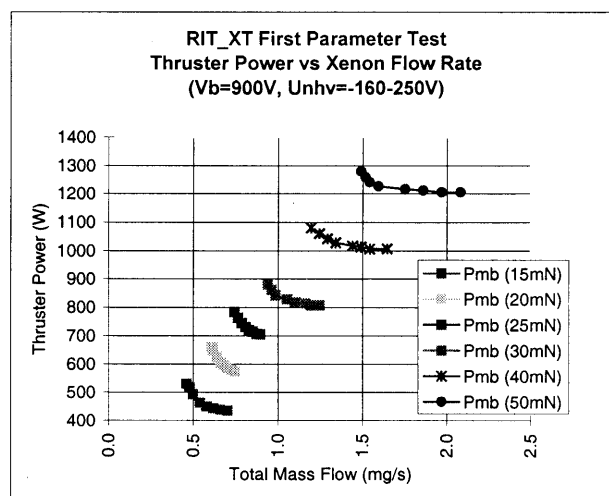


Fig 3-3 Thruster Power as a function of Flow Rate for different Thrust Levels

In addition the first results show a trend to excellent low specific power values for the RIT\_XT thruster, as shown in Fig. 3-4.

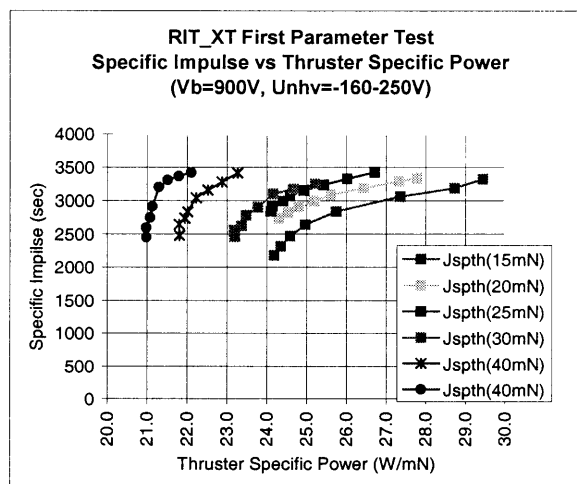


Fig 3-4 Main Bus Power as a function of Flow Rate for different Thrust Levels

A combination of the figure 3-3 and 3-4 is shown in Fig.3-5.

Currently the test is interrupted awaiting the delivery of a power supply for higher thrust levels

Parameter	EURECA	RIT10_ART	RIT10_EVO	RIT_XT
Thrust level	10 mN	15 mN	1 to 35 mN	15 to 150 mN
Thruster Diameter	16 cm	16 cm	16 cm	28,9 cm
Discharge Chamber Ø	10 cm	10 cm	10 cm	22 cm
Beam Diameter	85 mm	87 mm	89 mm	208 mm
No. of Holes	253	499	1483	8160
Beam voltage	1500 V	1500 V	1300 V	1200 V
Main Bus Power	440 W	560 W	100 W to 1050W	2600 W at 100 mN
Optimum Specific Impulse	3200 s	3350 s	3000-3200 s	3000-3300 s
Thruster Specific Power	41 W/mN	35 W/mN	25W/mN-27/mN	22W/mN-24W/mN
Specific Power Pmain_bus/F	44 W/mN	37,5 W/mN	29W/mN-31/mN	26W/mN-28W/mN

Table 4-1: Dasa Radio Frequency Thruster Performance Comparison

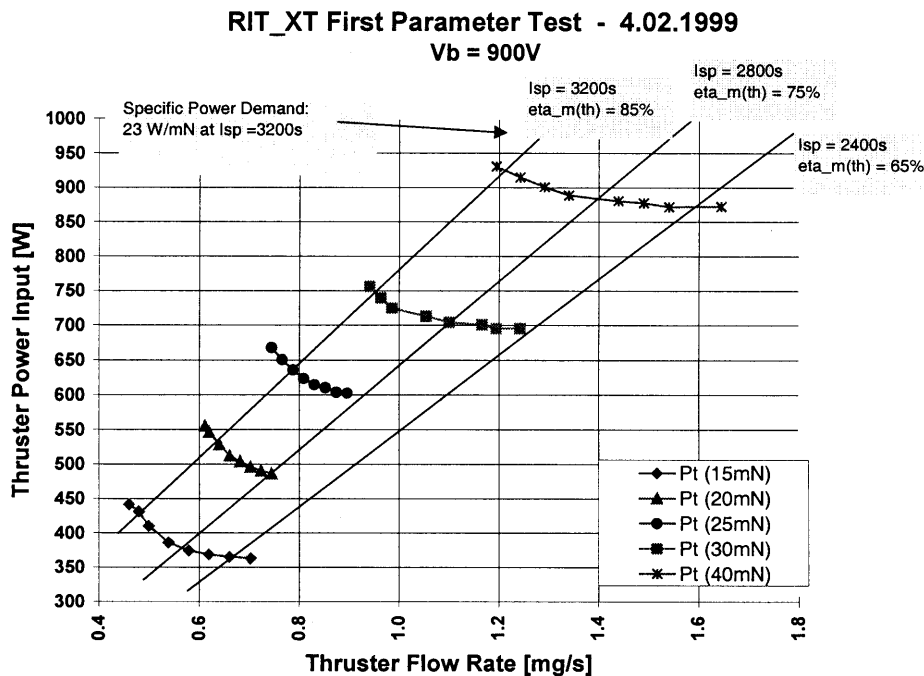


Fig 3-4 Thruster Power Input as a function of Flow Rate for different Thrust Levels

**6. CONCLUSIONS**

The RF-Ion Thruster technology has great advantages with respect to other gridded ion thrusters and to the Hall Effect Thruster (HET). For commercial applications on GEO communication satellites and LEO constellations the thruster technology has been improved in general. The specific power drawn from the main bus has been reduced to 26-28 W/mN at specific impulses in the range of 3000 to 3200s.

Dasa started a program to qualify such a thruster for 100mN thrust level which can be used for commercial applications in 2001. It will be designed for serial fabrication to allow the production of the thruster system at reasonable prices.

**REFERENCES**

AIAA 99-2271, Electric Propulsion System RITA of ARTEMIS; R. Killinger, H. Bassner, G. Kienlein