PLASMA TECHNOLOGIES
FOR
IGNITION & COMBUSTION STABILIZATION
IN GAS TURBINES

Presented

by

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Applied Plasma Technologies (USA)

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PRESENTATION OBJECTIVES

- ☞ Describe existing plasma ignition and combustion stabilization systems and their requirements to plasma generators
- ☞ Demonstrate innovative reverse vortex plasma generator parameters
- ☞ Indicate perspective plasma and combustion technologies

CONTENT

- Chronology
- Technical Discussion
- Perspective Technologies
- Summary

PLASMA SYSTEMS CHRONOLOGY

- 1979 - Began plasma technology R&D
- 1981 - Developed and tested first plasma fuel nozzle
- 1983 - Started 1st gas turbine engine (10 MW)
- 1985 - Began serial manufacturing of plasma ignition systems
- 1987 - Developed direct plasma ignition system for new Soviet Navy gas turbine generator (1.6 MW)
- 1989 - Conducted 1st high altitude tests on aircraft turbine for MIG interceptor
- 1990 - Established privately owned company – Plasma-Technika-Consult
- 2000 – Presented technology to Pratt & Whitney, Unison, DOE (NETL, BNL, LANL), etc.

CHRONOLOGY (cont.)

- 2002 – CRDF, USA grant for Plasma-Fuel Nozzle tests
- 2002 – The first plasma system sold in USA (NETL)
- 2003 – International Patent Application on Reverse Vortex Plasmatron; Plasma Ignition System high altitude tests for Suhoi-30/33/37 interceptor; established Applied Plasma Technologies (USA)
- 2004 - US patent application on Reverse Vortex Combustor, technology validation tests for Siemens turbines
- To Date - Over 1,200 plasma ignition systems operating all over the former Soviet Union and USA

DR. IGOR MATVEEV

- Ph.D. in Mechanical Engineering 1984
- President Plasma-Technika-Consult (UA) 1990 - 2003
- Associate Professor, Nikolaev SBI (UA) 1982 - 1990
- President Applied Plasma Technologies (USA) 2003
- R&D in plasma assisted combustion from 1979
- R&D in fuels for marine propulsion 1977 - 1982
- Inventions 15 patents
- Publications 6 books, 25 articles, 3 textbooks
- Consultant to UN in energy efficiency projects

TECHNICAL DISCUSSION

- Background
- Plasma Ignition Systems
- Plasma Torch Parameters
- Plasma Stabilization Systems
- Plasma Fuel Nozzle Parameters
- Reverse Vortex Plasmatron Parameters
- Reverse Vortex Plasmatron Advantages
- Perspective Reverse Vortex Plasmatron applications

INDUSTRIAL PLASMA IGNITION SYSTEM SAMPLES

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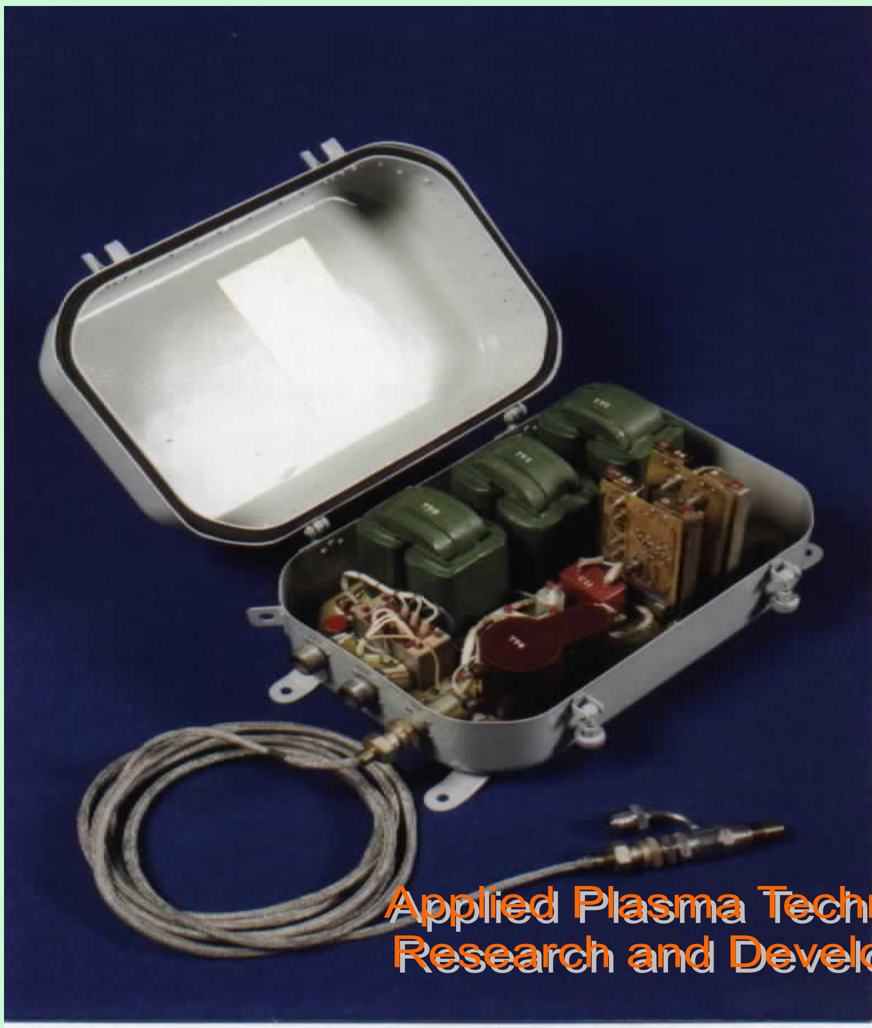
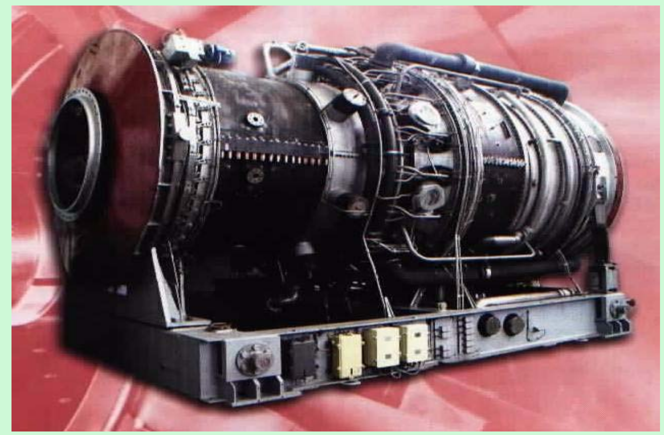
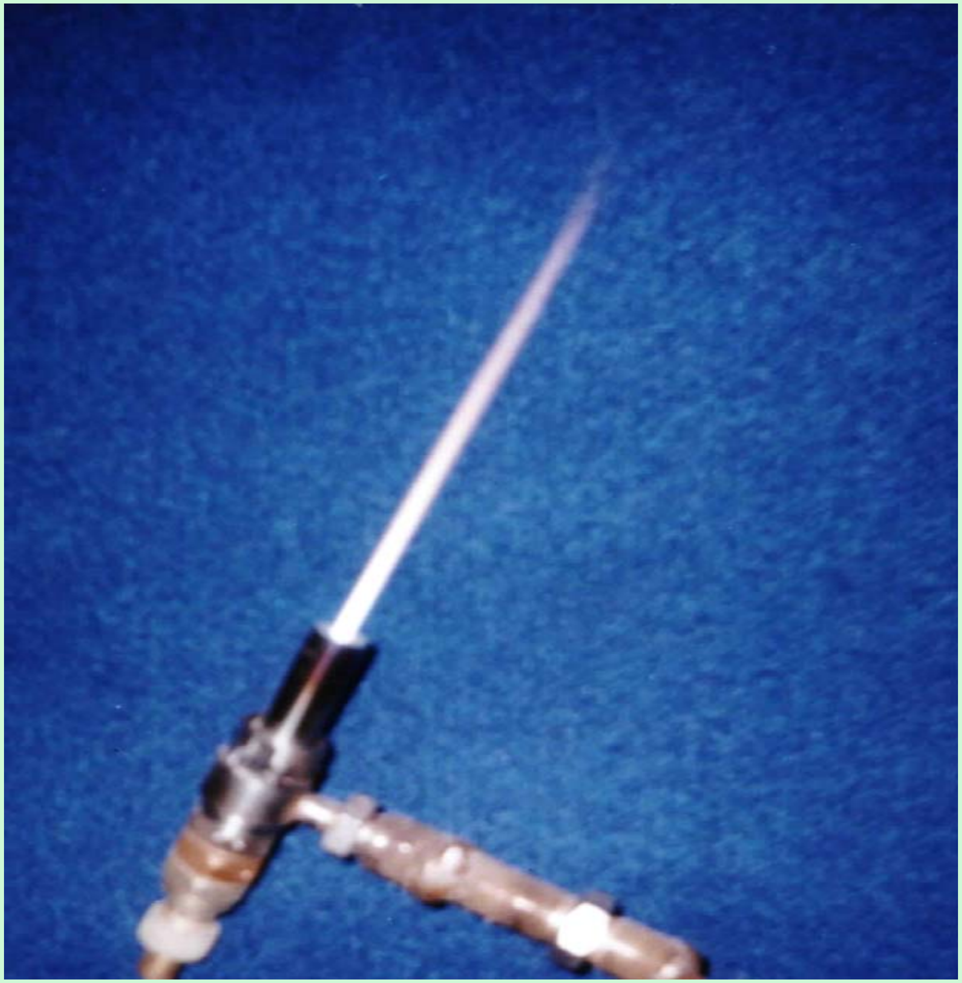
INDUSTRIAL AND MARINE PLASMA IGNITION SYSTEM

Over 1200 systems are installed and operating all over the world





PLASMA IGNITER
(laminar mode)



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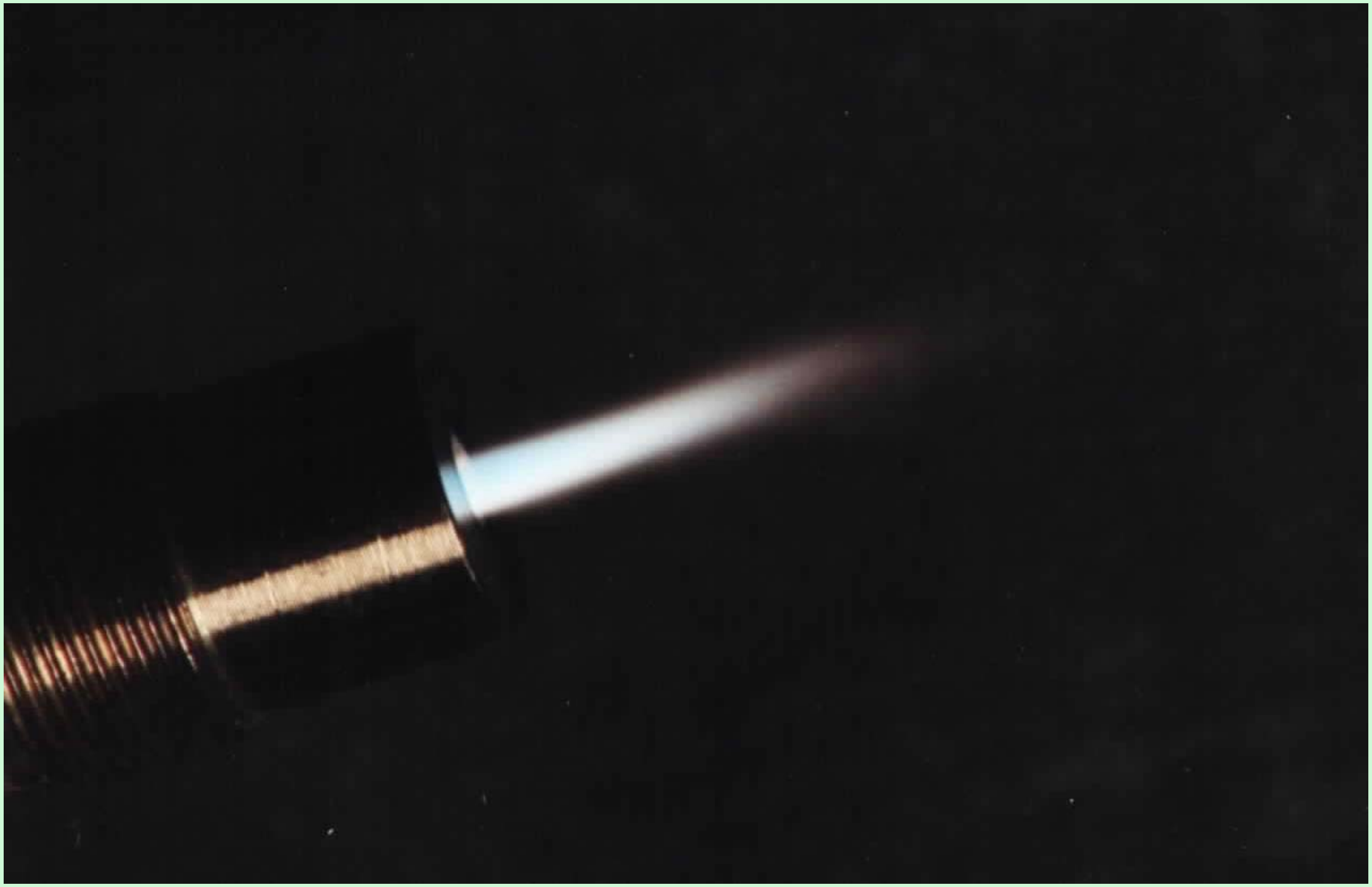
PLASMA TORCH
(turbulent mode)



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PLASMA TORCH PARAMETERS

◆ Power (kW)	0.3 - 3
◆ Dimensions (mm)	
– length	20 - 50
– diameter	10 -15
◆ Velocity (m/sec)	50 - 300
◆ Temperature (^{o} C)	2,000 - 3,000
◆ Air Pressure	
– turbulent igniter (Bar)	0.1 - 0.6
– laminar igniter (mm H_2O)	20 – 3,000
◆ Air Flow Rate (g/sec)	0.01 – 1.0

PLASMA IGNITION SYSTEM PARAMETERS

◆ Coefficient of Performance (COP)	0.3 - 0.75
◆ Cathode Life (cycles, 45 sec. each)	
- for thermal arc systems	500 – 4,000
- for non-thermal arc systems	no limits
◆ Weight (kg)	
– 3X240V, 60 Hz or 3X380V, 50 Hz	6 - 21
– 1X115V 400 Hz network	3 – 5
– 24-27V DC	1.5 - 2.5

CONTEMPORARY POWER SUPPLY

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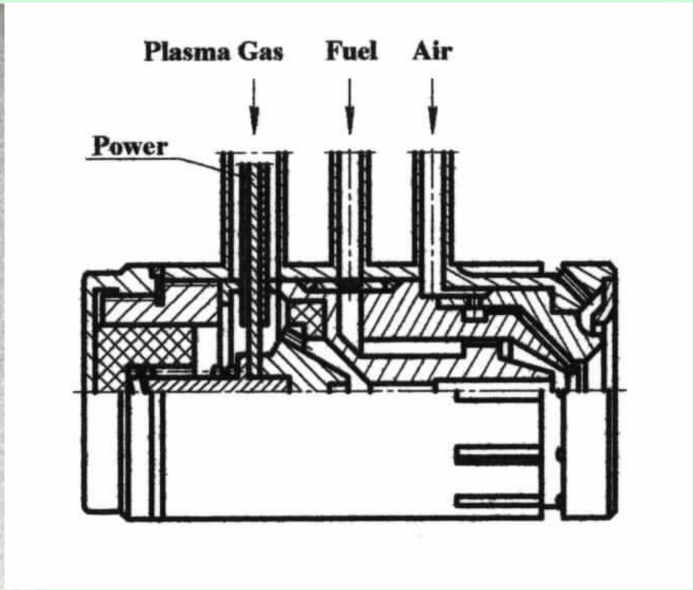
PLASMA STABILIZATION SYSTEMS
PLASMA FUEL NOZZLE



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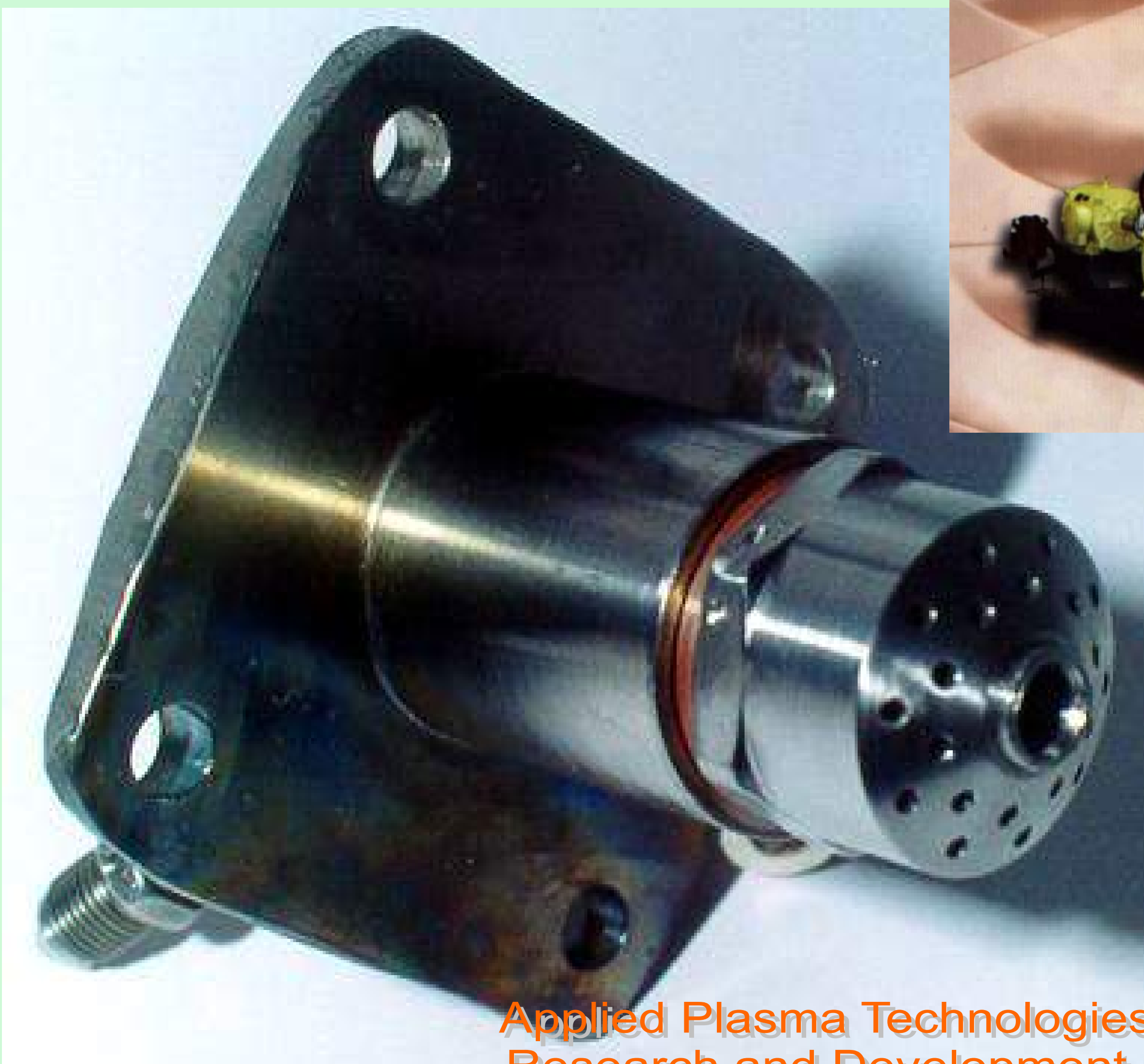
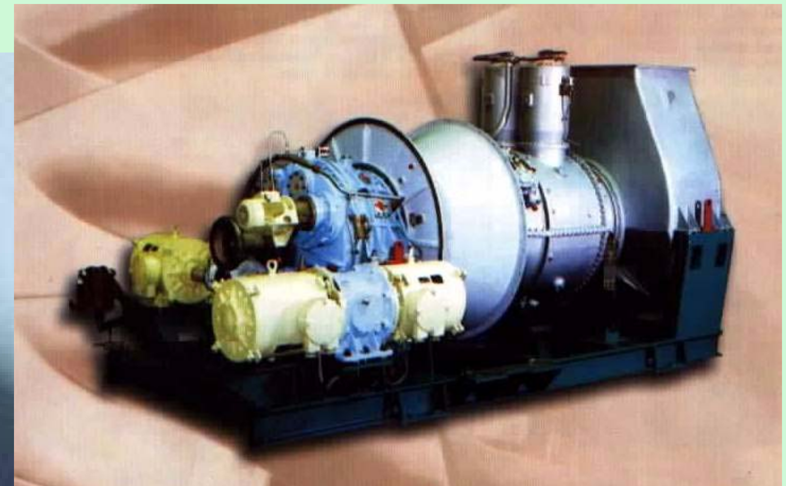
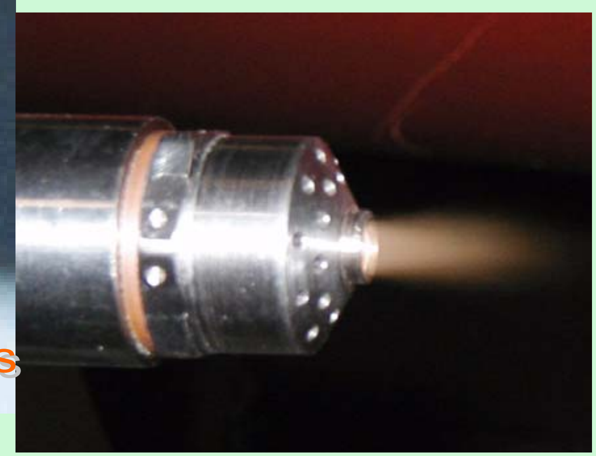
PLASMA NATURAL GAS NOZZLE







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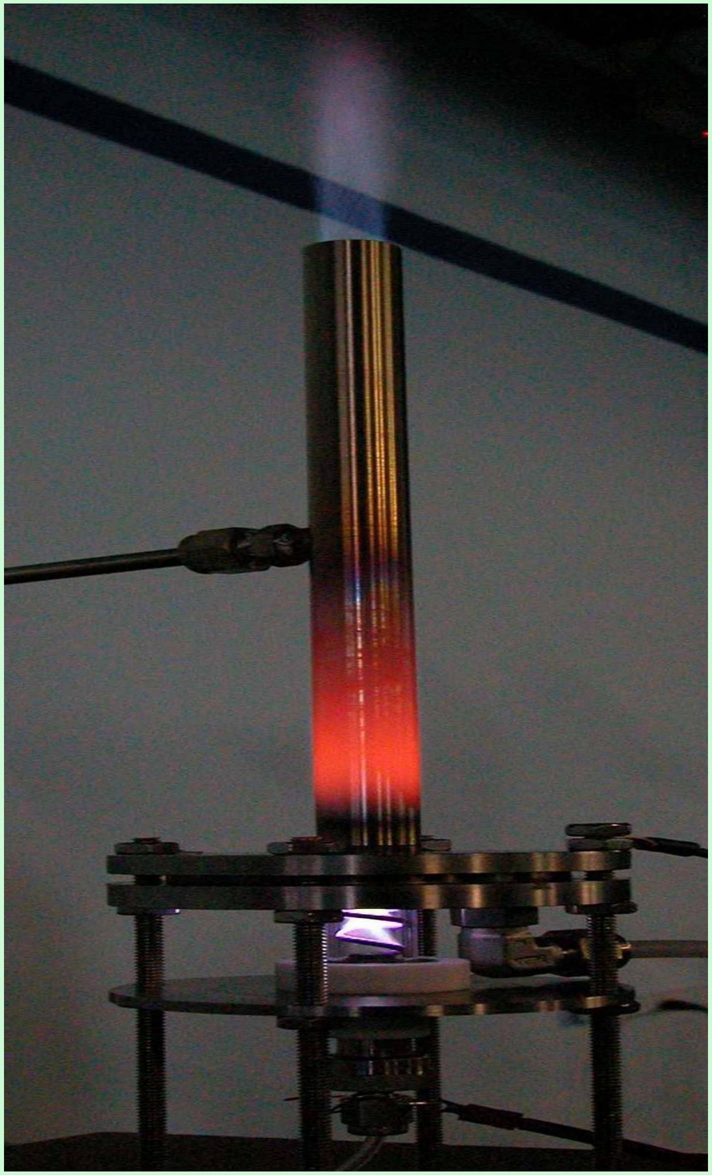
PLASMA CHEMICAL REACTOR
(aircraft afterburner igniter prototype)



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PLASMA FUEL NOZZLE PARAMETERS

◆ Power (kW)	1 - 10
◆ Dimensions (mm)	
– length	100
– diameter	30
◆ Air Pressure for Plasma Formation (PF)	
– turbulent plasmatron (Bar)	0.1 - 0.6
– laminar plasmatron (mm H_2O)	20 – 3,000
◆ Air Flow Rate for PF (g/sec)	0.01 - 0.5
◆ Liquid Fuel Flow Rate (g/sec)	10 and up
◆ Channels for Various Fuels	2 and up

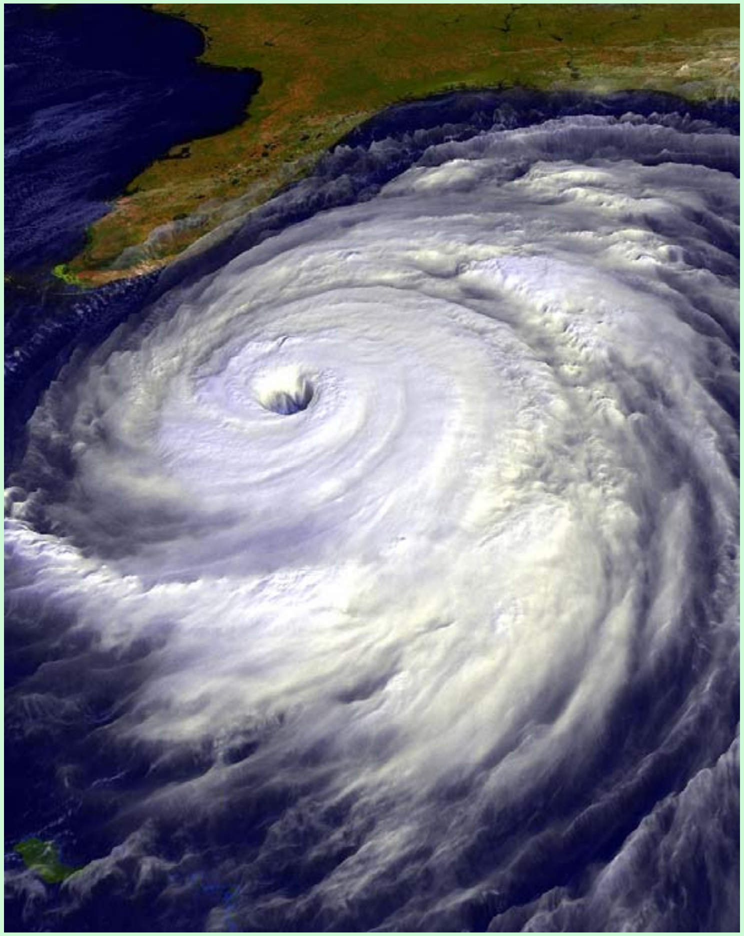
PLASMA FUEL NOZZLE ADVANTAGES

- Increased reliability
- Wider range of stable combustion for fuel-air mixture rate
- Significant decrease in T_3 (RIT) jump at the point of fuel ignition
- Utilization as pilot burner
- Utilization as fuel reformer
- Utilization for hydrogen enriched gas generation

PLASMA FUEL NOZZLE ADVANTAGES (cont)

- Reduction of combustion zone geometry
- Reduction of combustion chamber walls temperature
- Increase of combustion efficiency (COP)
- Reduction of exhaust gases toxicity and achieving smokeless operation
- Simultaneous burning of several fuels
- Smooth regulation in wider range of engine power

REVERSE VORTEX PLASMA GENERATOR (RVPG)



Hurricane Frances

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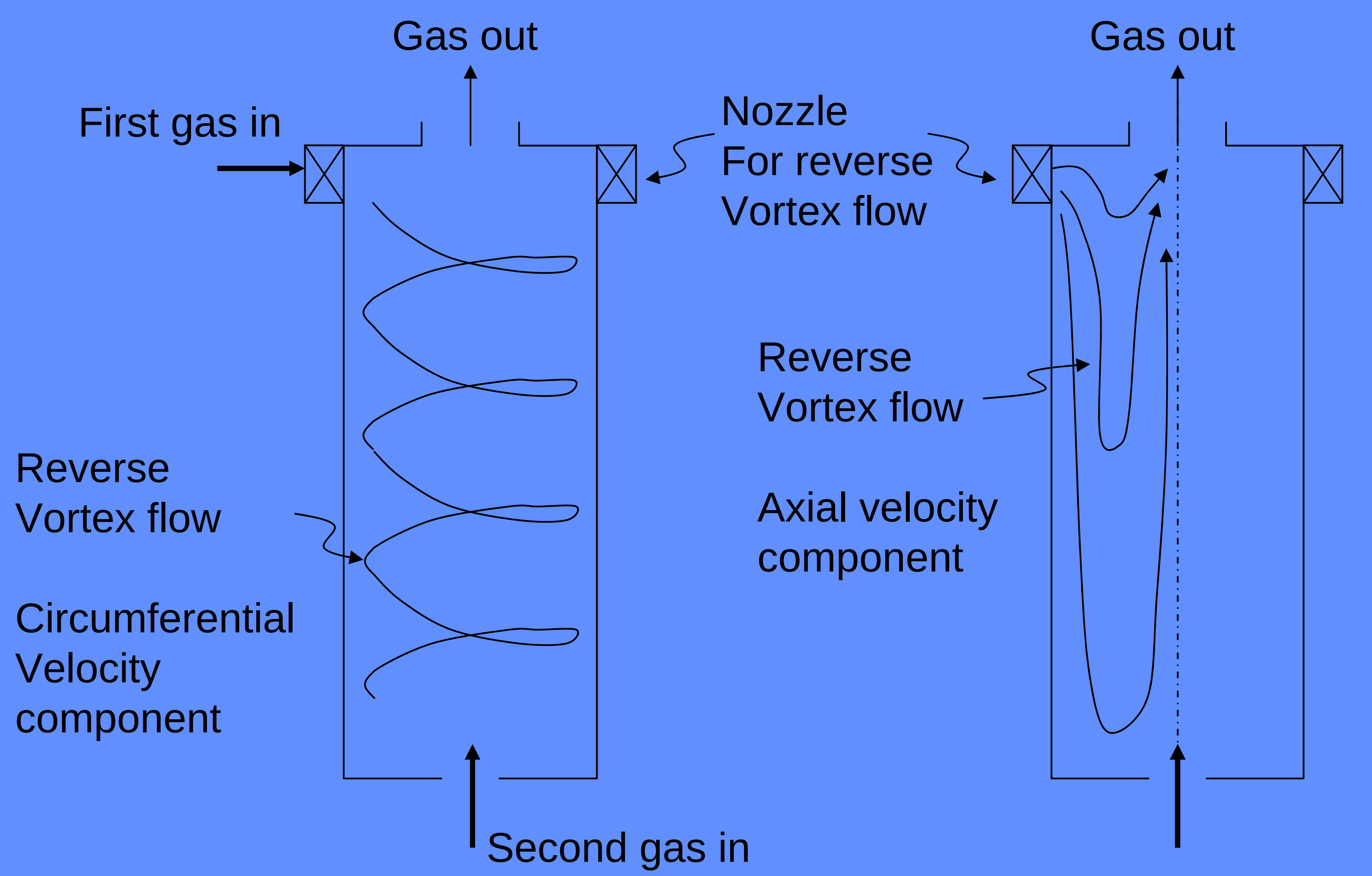
REVERSE VORTEX FLOW



RVPG PARAMETERS

◆ Power (kW)	0.01 - 5
◆ Dimensions (mm)	
– length	50
– diameter	30
◆ Plasma torch velocity (m/sec)	50 – 900 (up to M3)
◆ Plasma torch temperature (^{o} C)	500 - 3,000
◆ Air Pressure (mm H_2O)	50 – 10,000
◆ Air Flow Rate (g/sec)	0.01 – 0.6

RVPG ADVANTAGES

- New quality - generates non-equilibrium plasma
- Dramatically increased life time of both electrodes
- Does not need cooling of electrodes and nozzle
- Wider range of power regulation (from a few W to several kW)
- Utilizes different plasma gases and blends: air, O_2, N_2, Ar, He, water steam, air/methane and steam/methane blends, etc.
- No rare materials
- Flexible design
- Simple and reliable

SUMMARY

- Energy, environmental and security challenges open new markets for advanced plasma technologies
- New plasma generators can assist in capturing new markets: gas turbines and boilers, tools, residential appliances, environment security systems, etc.
- Acceleration of new technologies development could be reached by combining research, development and marketing efforts