REVERSE VORTEX PLASMA GENERATOR FOR IGNITION & COMBUSTION STABILIZATION IN GAS TURBINE ENGINES

Presented by
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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 technologies
CONTENT

- Chronology
- Technical Discussion
- Perspective Technologies
- Summary
PLASMA SYSTEMS CHRONOLOGY

- 1979 - Began plasma technology R&D
- 1981 - Tested first plasma fuel nozzle
- 1983 - Started 1st gas turbine engine (10 MW)
- 1985 - Began industrial application
- 1987 - Provided direct plasma ignition system for new Soviet Navy gas turbine generators
- 1989 - Conducted 1st (simulated) high altitude test on aircraft engine for MIG
- 1990 - Established privately owned company - Plasma-Technika-Consult
2000 – Presented technology to Pratt & Whitney, Unison, DOE (NETL, BNL, LANL), etc.
2000 – Established Plasma Flame Systems, Inc., USA
2002 – CRDF, USA grant for Plasma-Fuel Nozzle tests
2002 – The first plasma system sold in USA (NETL)
2003 – US patent application on Reverse Vortex Plasmatron, Plasma Ignition System for Suhoi-30/33/37
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 from 1990
- Associate Professor, Nikolaev SBI 1982 - 1990
- Research Professor, Drexel University from 2003
- President Applied Plasma Technologies, USA
- R&D in plasma assisted combustion from 1979
- R&D in fuels for marine propulsion 1977 - 1982
- Inventions 12 patents
- Publications 6 books, 23 articles, 3 textbooks
- Consultant to UN in energy efficiency projects

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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 AND MARINE PLASMA IGNITION SYSTEM

Over 1200 systems are installed and operating all over the world

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PLASMA IGNITER

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PLASMA TORCH

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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 (°C) 2,000 - 3,000
- Air Pressure
  - turbulent igniter (Bar) 0.1 - 0.6
  - laminar igniter (mm H₂O) 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 fixed arc systems  500 – 4,000
  - for gliding 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
PLASMA STABILIZATION SYSTEMS

PLASMA FUEL NOZZLE

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PLASMA CHEMICAL REACTOR

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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 H₂O): 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 FLOW

First gas in

Reverse Vortex flow

Circumferential Velocity component

Nozzle For reverse Vortex flow

Axial velocity component

Reverse Vortex flow

Second gas in

Gas out

Gas out
RVPG PARAMETERS

- **Power (kW)**: 0.01 - 3
- **Dimensions (mm)**
  - length: 80
  - diameter: 30
- **Plasma torch velocity (m/sec)**: 50 - 300
- **Plasma torch temperature (°C)**: 500 - 3,000
- **Air Pressure (mm H₂O)**: 50 - 6,000
- **Air Flow Rate (g/sec)**: 0.01 - 0.6

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RVPG ADVANTAGES

- New quality - generate 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)
- No rare materials
- Flexible design
- Simple and reliable
PERSPECTIVE RVPG APPLICATIONS

- Waste destruction

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PERSPECTIVE RVPG APPLICATIONS

- Tools (metal cutting, soldering, etc.)
PERSPECTIVE RVPG APPLICATIONS

- Environment sterilization (air, water)

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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.