Triple Vortex Plasma Assisted Combustor

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Applied Plasma Technologies (APT) demonstrates a comprehensive approach to a new combustion technology development. Named a Triple Vortex Plasma Assisted Combustor it combines innovative and a recently patented reverse vortex combustor [1-4] with a non-thermal multi-mode plasma pilot burner[5] or spatial arc for ignition and flame control. At the same time we recognize that the reverse vortex technology is already known and was applied for combustion purposes in the turbine combustors and rocket engines by Alfa Romeo Avio S.A.p.A. (Italy) and ORBITEC, Inc. (USA.) [6-10], and Dr. Gutsol et al for high temperature streams insulation[11].

Aerodynamic schemes of the combustor prototypes are shown in Fig. 1. Scheme I presents the simplest double-vortex combustor with the top air inlet, plasma pilot and fuel nozzles placed at the bottom. Scheme II shows a triple vortex combustor with top feeding of the main air supply and bottom feeding of fuel or fuel/air mixture. Scheme III shows the most advanced triple vortex combustor with spatial arc. In this case fuel is injected through the circular gap between the bottom swirler and a flat cathode. Burning in this gap and orbiting high voltage and low current arc provides reliable ignition and optionally continuous flame control.

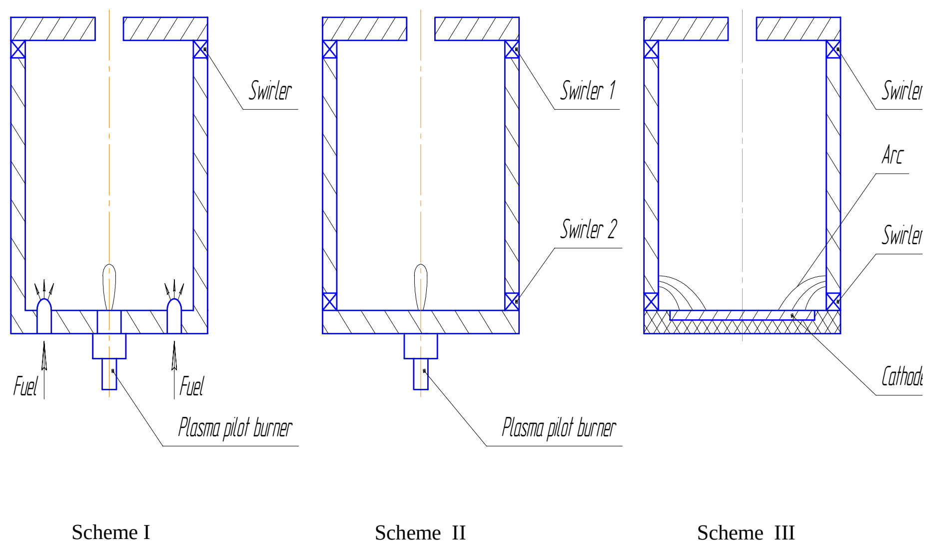
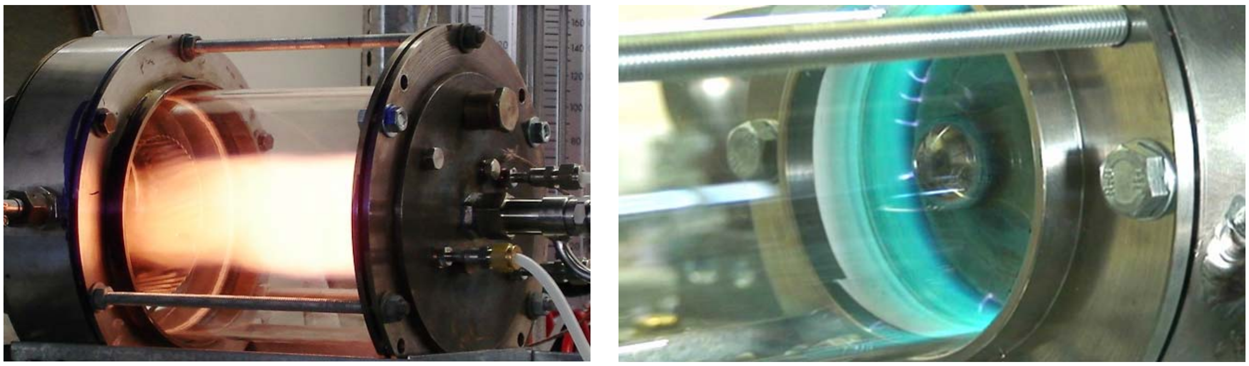


Fig. 1. Plasma Assisted Combustor schemes

All of these schemes have been realized in the atmospheric pressure prototypes shown in Fig. 2a and 2b. Fig. 2a presents a general view of scheme I combustor with ID = 145 mm named PATC-1. Fig. 2b represents the scheme II combustor with ID = 73 mm named PATC-2.
In contrast to these schemes[11] the proposed triple vortex combustor has a third vortex which forms a higher concentration of fuel (gaseous, liquid or coal) and oxidizer in a mixing region

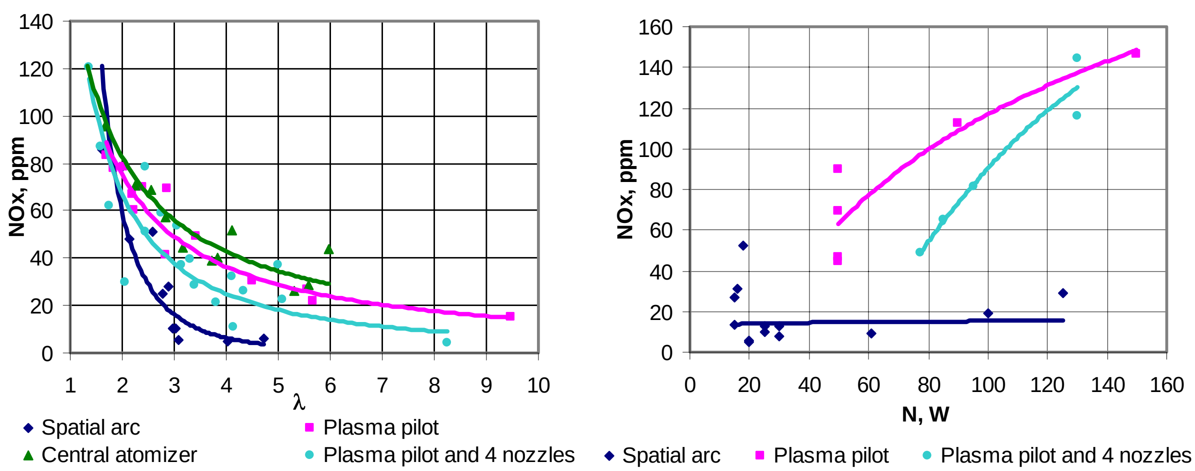
adjacent to the fuel inlet which serves as a means to create a high level of turbulence in the mixing area to improve the combustor's performance. In addition, possibilities for the triple vortex combustor regulation are significantly increased as a consequence of the ability to adjust the location of the direct and reverse vortex contact zone by the changing the flow rates.



a) *b)*

Fig. 2. Plasma Assisted Combustor prototypes: a) PATC-1, b) PATC-2.

Prior full-scale atmospheric pressure PATC tests proved the concept's advantages as follows[2]: High efficient internal mixing of fuel and oxidizer, stable combustion with dramatically extended flammability limits, simple air swirler and fuel injectors, no heating of the combustor walls, simple combustor design, cheaper materials for combustor fabrication, and simple conversion into the multi-fuel and multi-zone combustor. A laser Doppler velocimetry system was used to measure the mean axial and swirl velocity components and their respective fluctuations in the "Tornado" combustor under cold, non-reacting, isothermal conditions[3].



a) b)

Fig 3. Dependences of NO_x emissions

Fig. 3 shows generalized dependences of the nitrogen oxide emission on the combustor operation modes characterized by the air excess coefficient λ for four basic fuel injection methods without electric discharge initiation (Fig. 3a), and with plasma device operation (Fig.

3b). NO_x emission did not exceed 150 ppm for λ varying from 1.5 to 9.5 and the tendency for its increase occurs with discharge power growth.

The PATC-2 preliminary tests confirmed the idea of the spatial electrical arc integration into the reverse vortex combustor for direct ignition and flame control with minimal power consumption. Several power sources for the arc feeding were tested, including a conventional automotive ignition coil, a nano-second pulse power generator and a high voltage DC power supply. For all cases no visible electrode erosion was observed after tens of hours of operation. The combustor with sustained arc had no lean flame-outs. This provides a simple and economically affordable alternative for high altitude engine re-starts, flame control of super lean and low Btu air/fuel mixtures.

Conclusions

Several modifications of the plasma assisted triple vortex combustors have been engineered, manufactured and tested by Applied Plasma Technologies. The test results proved that the triple vortex combustor concept with plasma assistance selected for further development and marketing of the can provide: (1) cold walls operation, which leads to higher turbine efficiency due to the elimination of a need in the combustor cooling, simpler design, lower cost materials, lower manufacturing costs, lighter weight combustor; (2) higher performance due to better fuel and oxidizer mixing, much wider turn down ratios – no lean flame outs with plasma on; (3) simple, reliable, highly effective and economically affordable ignition and continuous flame control by different non-thermal plasma sources, including spatial arc with power from 10 W to 1 kW to ensure the engine's operation at any environment conditions, including low temperature and pressure; (3) fuel flexibility and possible multi-fuel operation; (4) simple combustor integration into existing engines, including tubular and annular configurations; (5) possibility to employ swirling input flows; (6) possible operation as a fuel reformer; (7) satisfactory gravimetric and volumetric parameters.

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Igor B. Matveev was born on February 11, 1954 in Russia. He received his Master of Science degree in mechanical engineering from the Nikolaev Shipbuilding Institute in 1977 and earned his Ph.D. degree in 1984. The Ph.D. theses were entitled “Development and Implementation of The Plasma Ignition Systems for Naval Gas Turbines”. From 1977 to 1990 he was a researcher, teacher and associate professor of the Nikolaev Shipbuilding Institute. In 1990 established a privately owned company Plasmatechnika (Ukraine) for development and mass production of the plasma systems. From 2003 is with Applied Plasma Technologies (USA) as President & CEO. Over 1,200 plasma ignition and flame control systems, developed under his supervision are in operation worldwide.

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