# Advertisement for Incubation of Technology

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| **Title of the technology** | Development of Plasma Pyrolysis Plant for Low-carbon Hydrogen Production |

**Current state of Technology**

A non-transferred arc argon plasma torch operating in the range of 5-50 kW power has been successfully developed. A non-transferred arc argon plasma torch provides a high temperature (~8000K-20000K) high-velocity thermal plasma jet to facilitate an inert environment for high-temperature chemical processing. One of the most impactful and fascinating applications include its use as a high-temperature processing medium to crack Methane to produce hydrogen toward sustainable energy transition. Methane, when cracked, produces solid carbon and hydrogen. Potential incubatees are invited to develop a "Plasma Pyrolysis Plant for Low-carbon Hydrogen Production" using the already developed Argon Plasma Torch and contribute to accelerating the energy transition.

The current state of Argon Plasma Torch technology is as follows,

- ✓ Basic principles observed
- ✓ Technology concept formulated
- ✓ Experimental proof of concept
- ✓ Technology validated in lab
- ✓ Technology validated in an industrially relevant environment.
- ✓ Technology demonstrated in an industrially relevant environment
- ✓ System prototype demonstration in an operational environment System
- ✓ Actual system proven in an operational environment
- ✓ Demo system available

**General Information**

The Developed non-transferred arc argon plasma torch generates a thermal plasma jet from atmospheric argon at a moderate power level (up to 50 kW). The present argon plasma torch includes a tungsten-based cathode selectively disposed with respect to a nozzle having a uniform gap between floating segments operatively connected to the plasma source to streamline the plasma jet. The torch incorporates a flexible design that can generate the desired voltage in the plasma column for operation at a desired power level through appropriate alteration in the number of floating segments used. The anode is connected as the last segment to finally terminate the arc after the floating segments. In-between contacts are provided with the floating segments, and the power supply has electrical connectors for switchable connection with the cathode, the nozzle, the floating segments, and the anode. The torch is configured to heat atmospheric pressure argon entering the plasma source, forming a very high temperature (>10,000K) plasma jet exiting from the anode.

**Features/Specification of the Current System**

The novel technology offers a compact device that takes commercial argon from an argon cylinder and converts it into a controlled, well-defined jet of argon plasma at an electrical power level of several tens of kW with an efficiency greater than 50%. Low device cost, low operational cost, simple modular design, use of cheaper gas (argon, instead of costly Helium), high efficiency (>50%), high temperature (~12000 K at the anode exit), and ease of control are some of the key features of the technology.

**Table-1. Features & Advantages**

| ***Sr. No.*** | ***Features*** | ***Advantages*** |
|---|---|---|
| 1 | Low device and peripheral cost | Reduced installation cost |
| 2 | Use of argon as plasma gas | Low operational cost |
| 3 | Lightweight, portable, and compact device: | Easier handling |
| 4 | Simple modular design, easier maintenance | Easy customization, Low maintenance cost |
| 5 | High efficiency (>50% in non-transferred Mode) | Better performance |
| 6 | Extremely low cathode erosion | Long electrode life and low operational cost |
| 7 | Very high plasma temperature (at the exit >12000K) | More efficient heat transfer |
| 8 | Low gas flow requirement (~20 slpm) | Reduced cost of gas delivery and post-treatment section |

**Features/Specification of System to be developed**

The plasma pyrolysis plant for low-carbon hydrogen to be developed will have the following specifications.

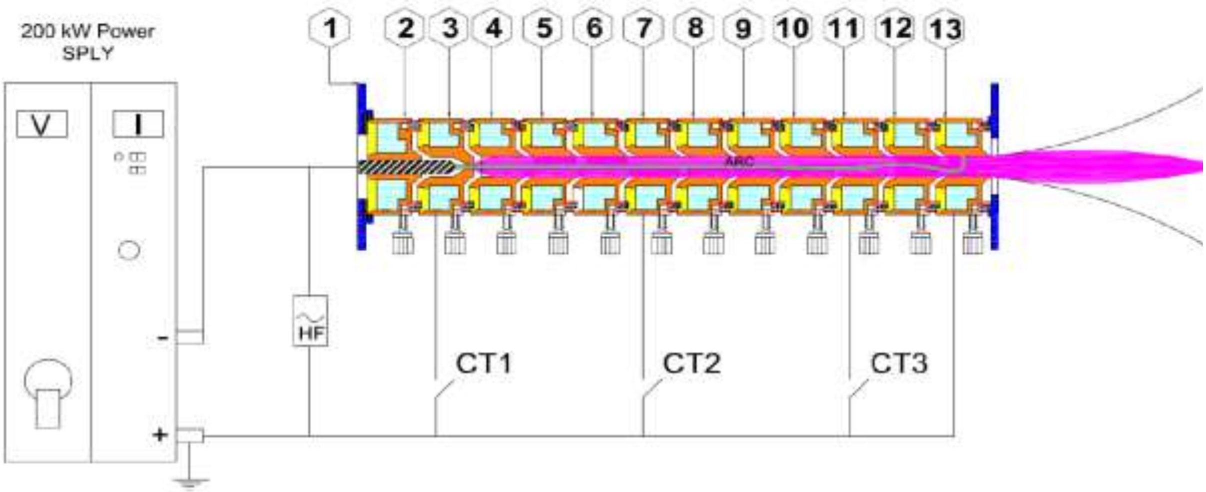
Specifications

- Production capacity: Hydrogen 2 to 10 kg/hr and Solid carbon 6 to 30 kg/hr
- Feed gas: Methane: 8 to 40 kg/hr
- Thermal Energy: Argon Plasma Torch 5 to 50 kW; Nitrogen as a coolant gas
- Other features: Scalable

**Working of the Current System (with schematic block diagram)**

The plasma torch has the following main components: the cathode, the plasma-forming gas injection stage, floating segments and the anode. The anode usually acts as the segment where an arc finally terminates. Non-transferred arc torches are typically used in applications that rely on the formation of a plasma jet with moderate to very high velocity and its use as a heat source, high-temperature processing medium, or source of specific reactive species. Inside the torch, the working gas flows around the cathode and through a constricting tube or nozzle. The plasma is usually initiated by a high-voltage (~kV) and high frequency (~3MHz) pulse, which creates a conductive path for an electric arc to form between the cathode and the torch nozzle. The electric heating produced by the arc causes the gas to reach very high temperatures (e.g.,>10,000 K), thus to dissociate and ionize. The cold gas around the surface of the water-cooled nozzle being electrically nonconductive, constricts the plasma, raising its temperature and velocity. The cold boundary layer so formed protects the electrodes from melting. The plasma torch operates at atmospheric pressure with electric power levels ranging between 5 and 50 kW, arc currents between 50 and 500 A, arc voltages between 30 and 100 V, and the flow rates between 20 and 150 slpm (standard liters per minute).

Schematic diagram of the system:




**Working of the System to be developed (with schematic block diagram)**

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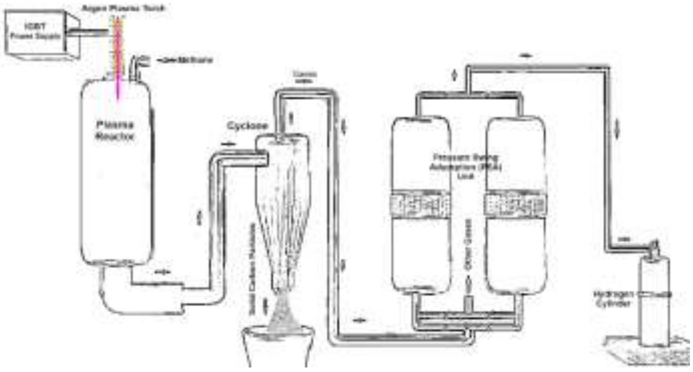
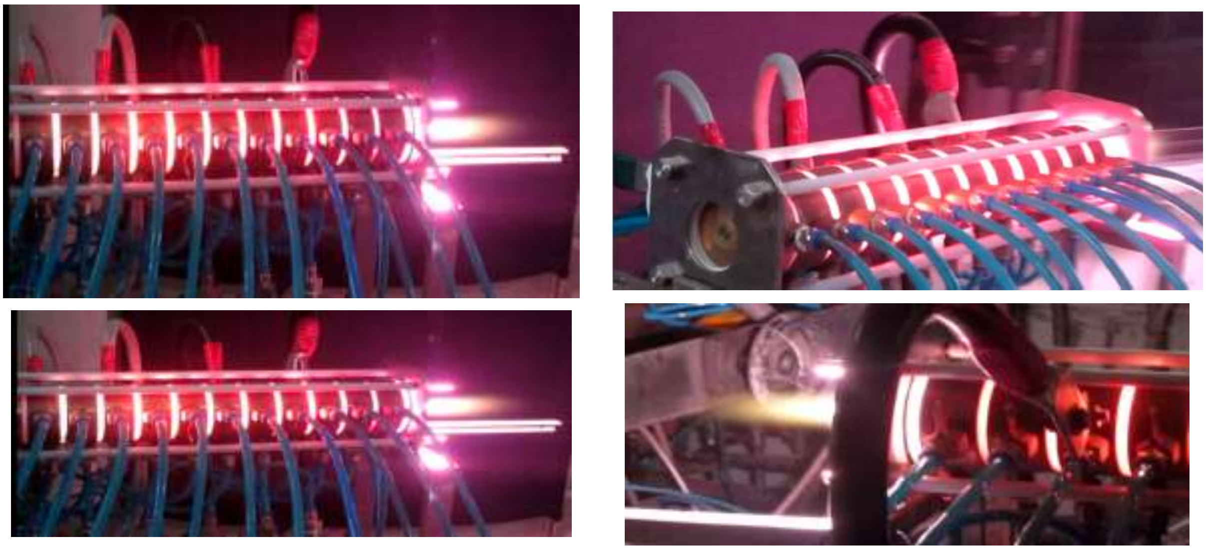
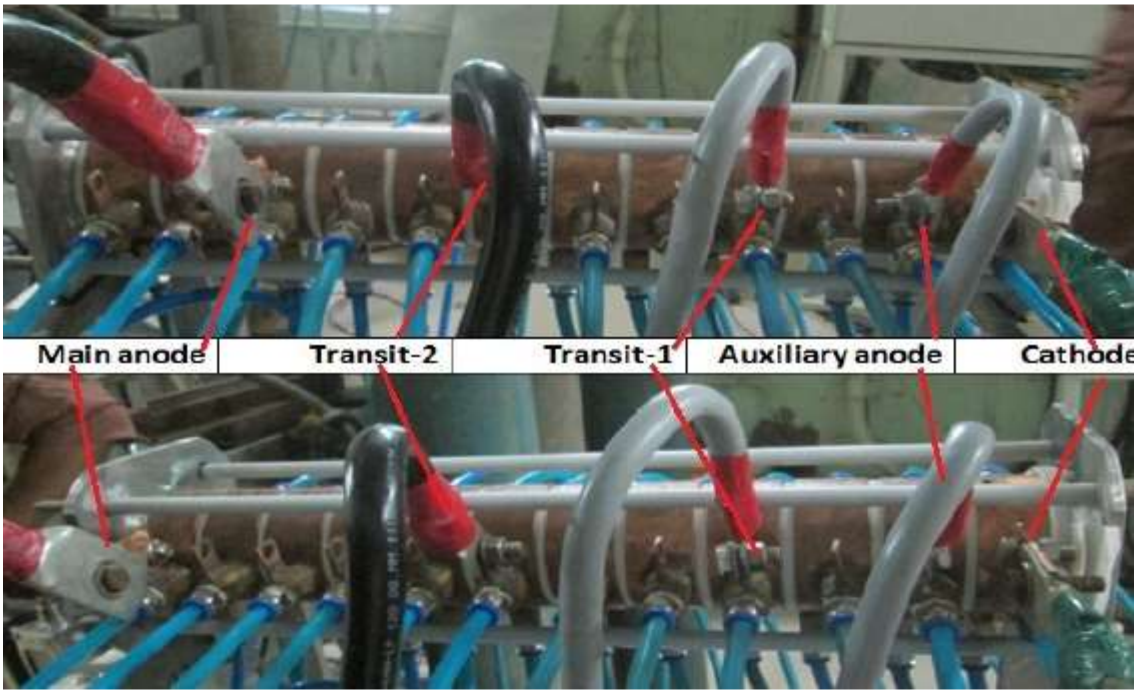
| 1 Plasma Reactor: Methane is cracked to form granular carbon and hydrogen in the argon plasma flame.<br><br>2 Cyclone: Solid carbon and hydrogen with residual gases are separated in a cyclone separator. Granular carbon is collected at the bottom.<br><br>3. PSA: Pure hydrogen and residual gases are separated in the PSA (Pressure Swing and Adsorption) unit.<br><br>4. Pure hydrogen is collected in a cylinder. |  |

**Applications of the System to be developed**

Distributed production of low-carbon hydrogen

**Picture/Photo of the current System –**







**Whether the parent product/ technology/ process is patented: Yes/No**

**If yes, provide the details –** NO

**Deliverables –**

a. Continuous production of hydrogen as per specifications 2 to 10 kg/hr

b. Hydrogen purity as per the customer requirement (Three 9s or Five 9s)

c. Solid carbon production as per specifications 6 to 30 kg/hr

d. Structure of carbon as per customer requirement (carbon black or granular carbon)

e. Safety controls and automation tests

f. Zero-Leakage tolerance

g. Cloud connectivity and remote monitoring test

h. Energy Efficiency (Energy equivalent of hydrogen/input energy)

i. Conversion Efficiency (> than 90% methane conversion to hydrogen)

**Justification for Incubation –**

Out of all the applications of plasma torch, one of the most fascinating and impactful applications may be its use as a high-temperature processing medium to crack Methane. Methane, when cracked, produces solid carbon and hydrogen. The hydrogen produced is categorized as low-carbon hydrogen. It is zero-emission technology, as no carbon dioxide is released into the atmosphere. This technology will play a significant role in achieving the net-zero goal. To mitigate climate change and accelerate the energy transition, the development of this technology should be made a priority.

**Facility and Infrastructure requirements:**

**Facility and Infrastructure to be provided by Incubatee/BARC:**

| Manpower/ expertise / Responsibility | |
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| BARC | Incubatee |
| ***The responsibility of BARC is to help the Incubatee for a collaborative activity of conducting the following laboratory-scale experiments inside BARC with the base technology available to take the technology to TRL9***<br>1) Technical help and consultancy to perform experiments to perform methane cracking with the lab-scale plasma reactor developed by incubatee using the existing plasma torch, power | ***The responsibility of Incubatee is to take the technology from TRL4 to TRL9***<br>**1:** Designing the lab scale plasma reactor for methane cracking.<br>2: Arranging additional accessories and equipments to perform experiment in BARC lab.<br>3: Designing the Pre-production Plasma Pyrolysis Plant |

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| supply and diagnostics, already available in BARC lab. Necessary safety recommendations, as recommended by competent BARC authority will be arranged by incubate.<br>2) Technical help and consultancy in measurement of percentage methane cracking with various plasma torch parameters with the help of detectors arranged by incubate.<br>3) Technical help and consultancy to optimize the plasma torch design, operating parameters and to maximize percentage methane cracking. | **4:** Pre-production Plant fabrication and erection<br>**5:** Modification and optimization schemes<br>**6:** Designing and developing a small-scale production plant |

Machinery and Equipment

| Sr.no. | Major equipment/components |
|---|---|
| 1 | CNG feed system (10 cylinders) |
| 2 | Reactor (with refractory) |
| 3 | Plasma gun with IGBT power supply |
| 4 | Gas -gas heat exchanger |
| 5 | Cooling tower |
| 6 | Carbon filter unit |
| 7 | Compressor with anti surge & pressure regulating system |
| 8 | Cyclone separator |
| 9 | Pressure regulating system, pressure transmitter, with control valve |
| 10 | Bottling station |
| 11 | Gas flare |
| 12 | PLC & control panel with HMI |
| 13 | Chiller |
| 14 | Temperature monitoring and control |
| 15 | Flow meters and control (two) |
| 16 | Pressure safety valves (two) |
| 17 | Flame arrester |
| 18 | PSA system |
| 19 | Carbon black removal and filling system |
| 20 | Hydrogen analyzer |
| 21 | Hydrogen gas sensors |
| 22 | Fire fighting system |
| 23 | Flame detector |
| 24 | Bulk piping, piping components, and valves |

Others

N. A.

Any special requirements for plant, industry, location utilities, handling storage, safety etc.

- While ***designing a factory***, the following should be considered: 1) Hydrogen is flammable and ignites easily, 2) Leaks are hard to detect, 3) Flames are hard to see, and 4) Hydrogen is buoyant.
- ***Ventilation:*** Hydrogen gas is much more buoyant than other gases, so it will rise rapidly when it leaks into the air. This is advantageous for hydrogen systems installed outdoors because the leaking hydrogen is rapidly dispersed. In enclosed spaces, leaking hydrogen will accumulate in the ceiling pockets, potentially creating an explosive mixture. Ventilation systems should be designed to prevent such accumulations
- ***Electrical:*** Guidelines described in the international standard **IEC 60079-10 Electrical apparatus for explosive gas atmospheres** should be followed. Great care will be taken in the Design of hydrogen systems to minimize the probability that an electric spark will ignite any hydrogen.
- ***Leak detection:*** One should follow the best practices as shown (not an exhaustive list): 1) Hydrogen gas detectors should be permanently installed indoors where leaks may occur or where hydrogen may accumulate; 2) One should also use a portable hydrogen detector; 3) One should train people to be vigilant to listen for the sound of high-pressure gas escaping; and 4) One should train people to be vigilant to listen and watch for alarms from instruments and various detectors.
- ***Flame detection:*** One should follow the best practices as shown (not an exhaustive list): 1) Flame detectors should be permanently installed to monitor areas where hydrogen is dispensed or handled; 2) A portable flame detector (e.g., thermal imaging camera) also should be used; 3) One should train people to be vigilant to listen for venting hydrogen and watch for thermal waves that signal the presence of a flame; and 4) One should train people to use a combustible probe made of materials that will easily ignite if they contact a flame (e.g., a broom).

Limitations and risks of operating Argon Plasma Torch

- Erosion of electrodes in plasma torch is unavoidable for operation at any power level. Erosion is more at higher power of operation. Electrode needs replacement after stipulated hours of operation.
- As arc strongly responds to variation in self-influenced electric and magnetic field, any arc has certain degree of unpredictability in behavior.
- As arc devices operate at high voltages, there are certain probabilities of

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| | breakdown of gas outside the device if not wired carefully. This may lead to fire hazard.<br>• As arc devices operate at high currents, there is a probability of overheating and melting of electrodes in case of insufficient cooling.<br>• Arc voltage cannot increase indefinitely. After certain high voltage, inter electrode breakdown will take place inside the device.<br>• Arc core temperature is extremely high (10000K or more). Finding material to confine arc is challenging. Appropriate thermal engineering is necessary.<br>• Arc offers extremely high gradient. This strongly limits the volume of plasma interaction.<br>• Use of high current requires very thick heavy current carrying cables. This limits easy handling of equipment.<br>• Use of high arc voltage enhances the chances of electric shocks if not handled carefully. |

**Note: As per in-house technology incubation policy, the incubatee should be a licensee of the existing technology. Alternatively, the applicant will be required to take the license of the existing technology before entering incubation agreement.**

If interested in Incubation, kindly ***download -> fill -> scan -> send*** the application form to -

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