PLASMA & PLASMA CLEANING

What is a plasma?

Matter has been characterized as existing in four distinct states:

SOLIDS
LIQUIDS
GASES
PLASMA

A convenient way of reviewing these four states is to consider the water molecule.

At absolute zero (-273°C) water (H_2O), and all matter, is solid and atoms cease to vibrate.

As energy is imparted (in the form of heat), atoms start to vibrate again and molecular dynamics resume. Up to 0°C, the H_2O molecule remains a **SOLID** (ice).

Application of more energy causes the H_2O molecules in the solid form to vibrate to such an extent that a transition occurs; H_2O changes from solid to **LIQUID** (water).

Increasing energy to this liquid progressively activates the molecule until the water gain changes state; this time from liquid to **GAS** (steam).

Application of further energy renders the molecule so active that it can no longer maintain its molecular integrity. At this point H_2O will dissociate into its component parts (hydrogen and oxygen atoms), and release high energy free-electrons. A visible glow discharge is emitted due to the release of photons as electrons recombine with ions in this dynamic subatomic state of matter called "**PLASMA**".

As soon as the RF or Microwave source is discontinued, the subatomic species recombine to their more stable molecular forms.

Examples of plasma that occur around us are stars, neon and flourescent lights and the aurora borrealis.

Why plasma cleaning?

The purpose of plasma cleaning is to direct this high energy stream onto the surface to be cleaned where (for example) organic depositions will be oxidised in an oxygen plasma; particulate deposits will be mechanically scrubbed in an inert argon plasma etc. A wide range of gases (or mixture or gases) may be utilized to serve a broad array of cleaning requirements.

The cleaning process is further accelerated by the physical acceleration of ionized particles by the applied RF field. In fact, the intensity of the plasma directly relates to:

a) Reactor geometry
b) Intensity and frequency of the RF power used to excite the plasma.

c) Gas flow rates.
d) Pump speed.
e) Degree of vacuum.
f) Reactant and diluent gases used.

Types of Plasma Cleaners

As discussed, the basic ingredient to form a plasma is a discharge in a gas maintained below atmospheric pressure.

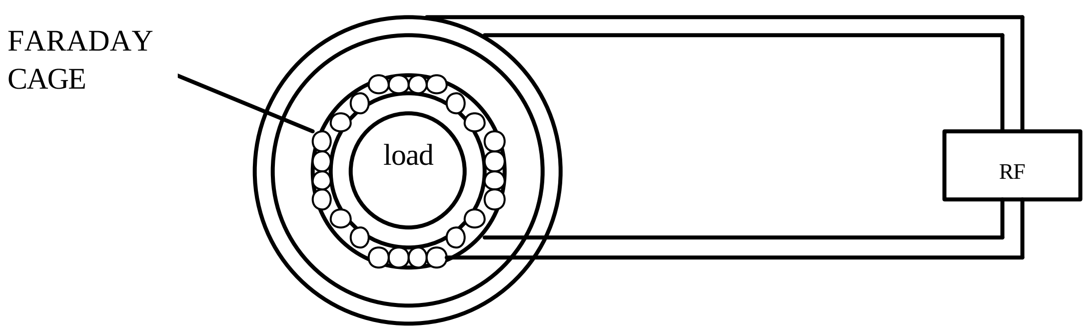
Among the variables listed above is **Reactor Geometry**, ie the configuration of the electrode set with relationship to the sample tray and the general chamber configuration.

The three prevalent designs are:

(1) Induction coupled "Barrel" reactors
(2) Capacitance coupled "Parallel plate" reactors
(3) "Down stream" reactors

These three types of reactors can be powered by either an RF (Radio Frequency) power supply or a Microwave power supply.

Induction Coupled Barrel Reactors



An early design of plasma cleaners involved a design termed a "Barrel" Reactor.

Here, RF energy is fluxed between the chamber outer wall and the electrically neutral perforated inner shield (Faraday Shield). Plasma is created between the inner wall of "barrel" and the outer wall of the Faraday shield.

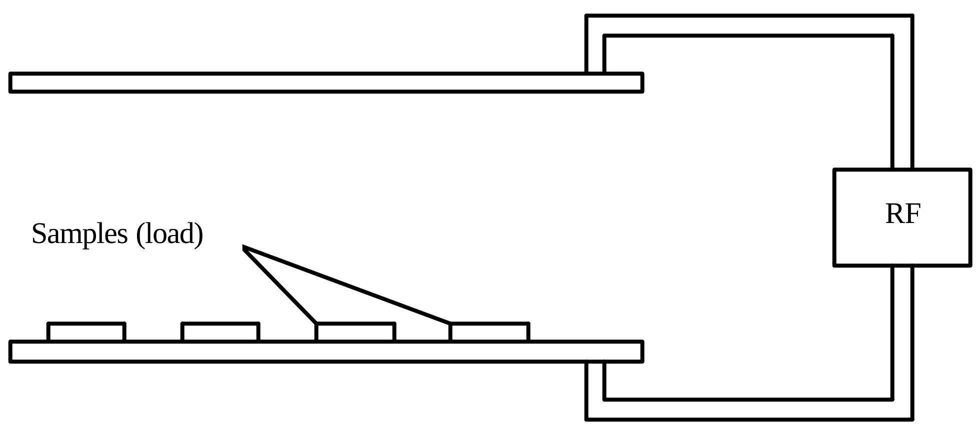
The inner perforated shield, being electrically neutral (and not electrically grounded forms only a mechanical barrier to plasma entering the work area, allowing some of the mixed subatomic species into the load area. In this way the power supply "sees" both the perforated Faraday shield and the workload as an inductive capacitance.

Thus the power supply matching network must be re-adjusted for each different work load to achieve uniform cleaning, run to run; a complex and failure-prone methodology.

Also, as the atomic gas must travel a relatively long distance from the inner shield to the workload, the efficiency of this method is very poor and the workload on the outer edges of the sample tray receive excessive treatment whilst the inner samples "see" almost no plasma at all.

For the above reasons, the industry has mostly moved away from this plasma cleaning geometry.

<u>Capacitive Coupled Parallel Plate Reactors.</u>



In this methodology, the sample is placed directly onto one of the electrodes. While the parallel plate concept produces a relatively uniform plasma across the sample load, the samples are, by design bombarded with magnetic, RF, electron, x-ray, neutral photon bombardment. Also, thermal energy is unpredictably produced in the workload.

<u>YES Parallel Plate CAPACITIVE DOWNSTREAM REACTORS</u>

This design is the result of the lessons learned from the designs described above.

Specifically, YES approached a broad cross-section of hybrid engineers to ask what their "ideal" Plasma Cleaner should (and should not) include.

Their ideal unit was stated as follows:

1. A unit that would apply an even plasma so that a sample on the outer edges of a tray would receive the same degree of cleaning as a sample in the center of the sample tray.

2. System power settings should be independent of how heavily (or lightly) the unit is loaded. The settings should be the same if only one sample is placed on one shelf or if all shelves are fully loaded.

3. The unit should offer as large a load capacity as possible.

4. No electron damage should occur to even the most sensitive samples during the plasma process.

At first this looked like an unreachable goal. -Several of these "ideals" seemed to be in conflict.

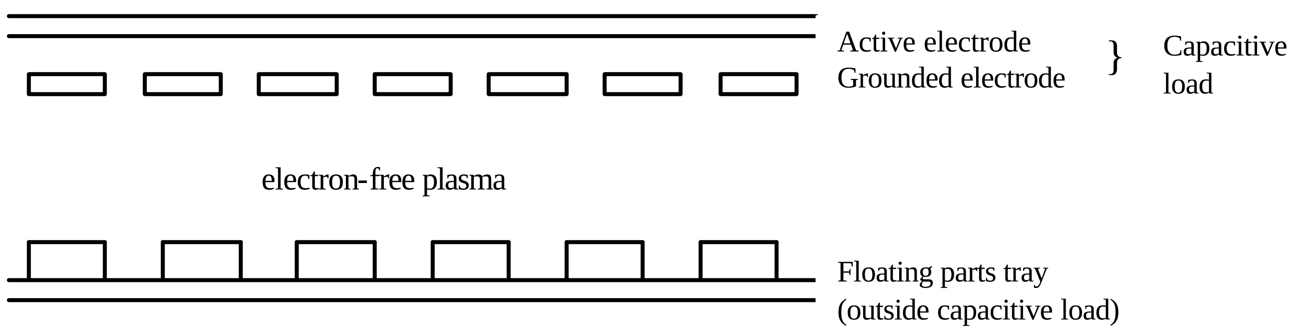
After quite some engineering effort, the concept of "Downstream Plasma" evolved, where the samples were placed were placed outside the capacitive load seen by the power supply. - This solved the problem itemized in item (2) above.

Parallel plates (instead of a "barrel") gave a totally even plasma across the sample surface and also gave maximum sample loading capability, thus fulfilling request (1) and (3).

Electrically grounding the lower electrode (rather than simply rendering it electrically neutral) ensured that all high energy electrons were taken to ground before they could contact the sample surface.

Number (4) was now taken care of.

The YES R-Series Plasma Cleaners are currently specified worldwide by a growing number of facilities with demanding cleaning needs. Although first designed for the hybrid industry, the unites have also found application into such various and diverse applications as the cleaning of clinical electrodes, gyroscope assemblies, lead frames etc. etc..



YES Plasma Cleaner configuration