PlasmaWhirl®
Foret Plasma Labs

Todd Foret
Todd@PlasmaWhirl.com
Cell: 337-298-8870

From Wastewater to 5,400°F Steam Plasma

Your electric splitting, cracking & heating decarbonization solution

Todd Foret
Todd@PlasmaWhirl.com
Cell: 337-298-8870

R&D = MARS OR BUST!

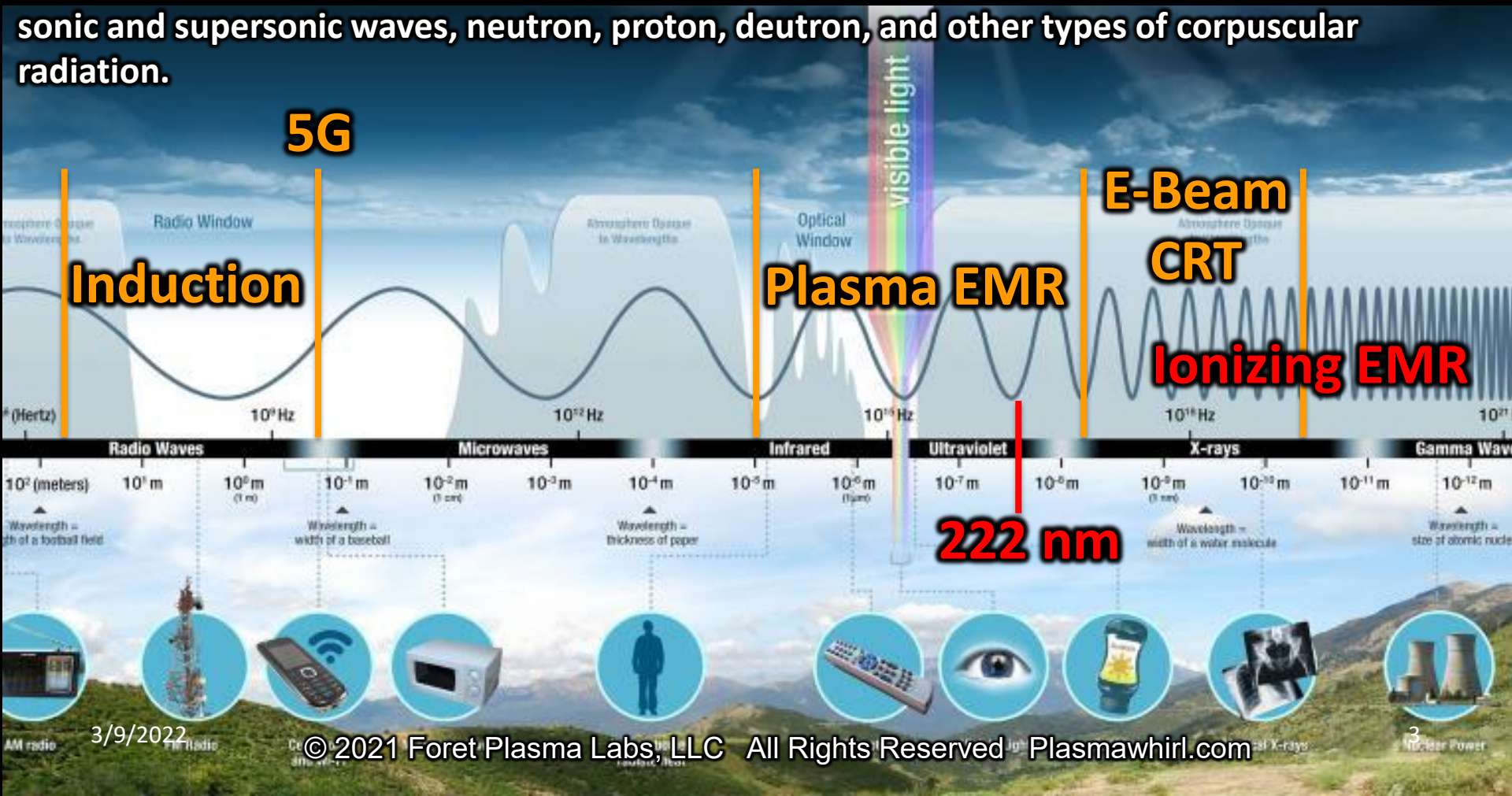
- Formed 2006
- Patents > 120
- Houston

Applying Wave Energy to Treat Matter

PlasmaWhirl®
Foret Plasma Labs

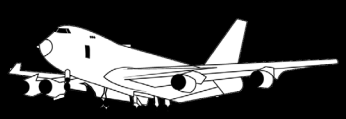
USPTO
Class 204
CHEMISTRY: ELECTRICAL AND WAVE ENERGY

For the purposes of this class, "wave energy" includes radiation as well as wave energy transmitted by various mediums and embraces electromagnetic wave energy or radiation, sonic and supersonic waves, neutron, proton, deutron, and other types of corpuscular radiation.



Scenario 1: Zero CO_2 Wave Energy in your Plant

PlasmaWhirl®
Foret Plasma Labs



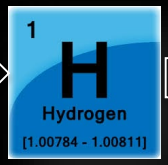
Austin, TX
Army Future Command

Waste Water

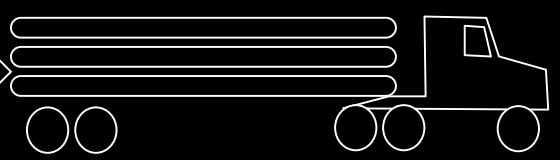
Turbo Expander

Plasma in a Box

Plant

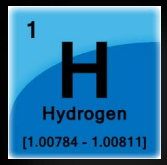


Tube Trailer

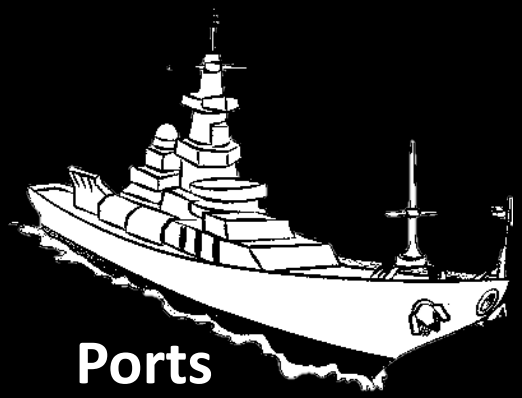


HENG Pipeline

LNG Facility



H2 Turbine



Ports
Navy & Shipping
Decarbonization

PlasmaWhirl®
Foret Plasma Labs

Plasma 101

3 Key Parameter Blocks

4th State Ionized Infinite	Ignite Confine Sustain

Transmitted Power Density

PlasmaWhirl®
Foret Plasma Labs

Plasma 101

T = 3915 K (3642°C, 6588°F)

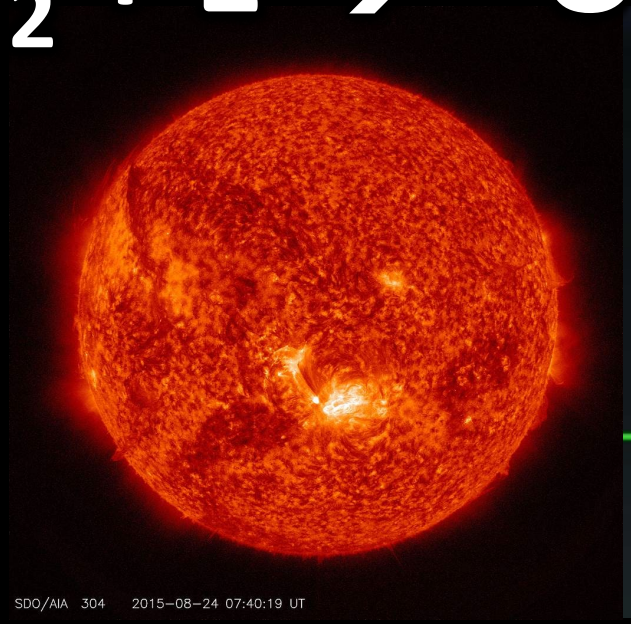
4th state of matter

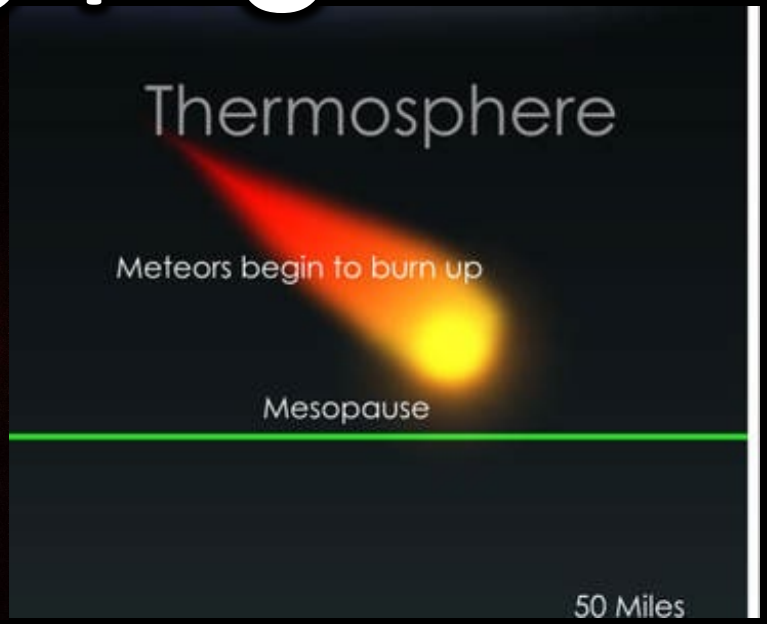
Energy (E)

Plasma 101

Ionized gas

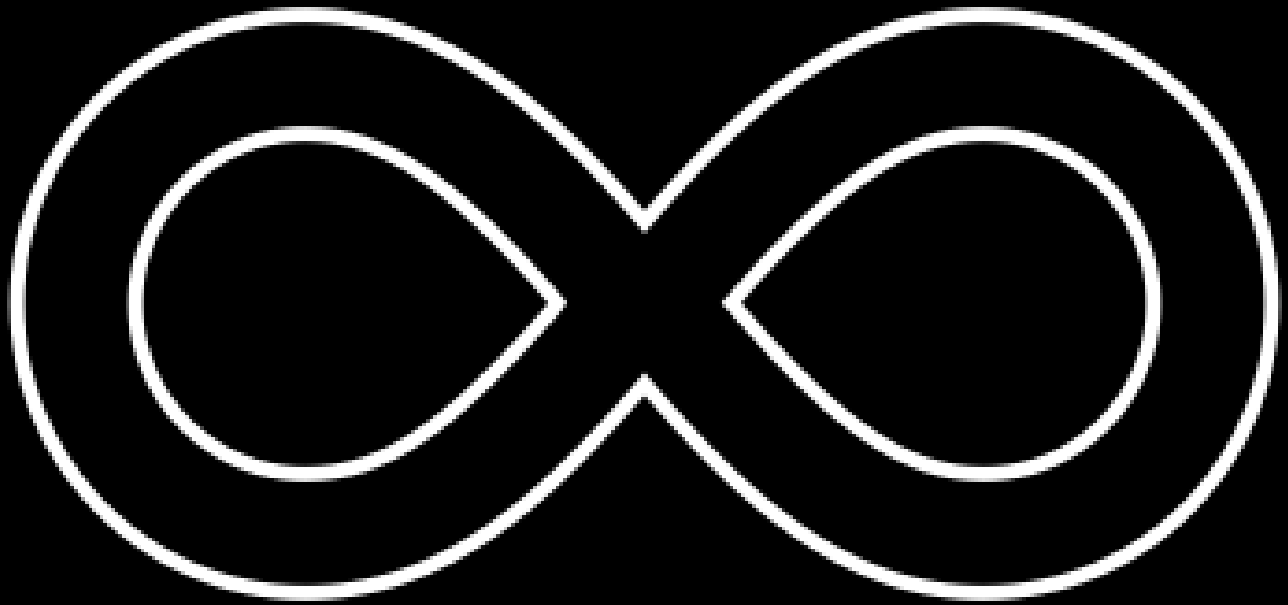
$O_2 + E \rightarrow \bullet O + \bullet O$





Plasma 101

Infinite Electrical Conductor



Plasma 101

Ignite

Electric Arc

EMR

Aerodynamic Heating

AKA

Friction Braking

PlasmaWhirl®
Foret Plasma Labs

Plasma 101

Ignite

Pulstar PlasmaCore
Sparkplug

V-8=20 Hz DC

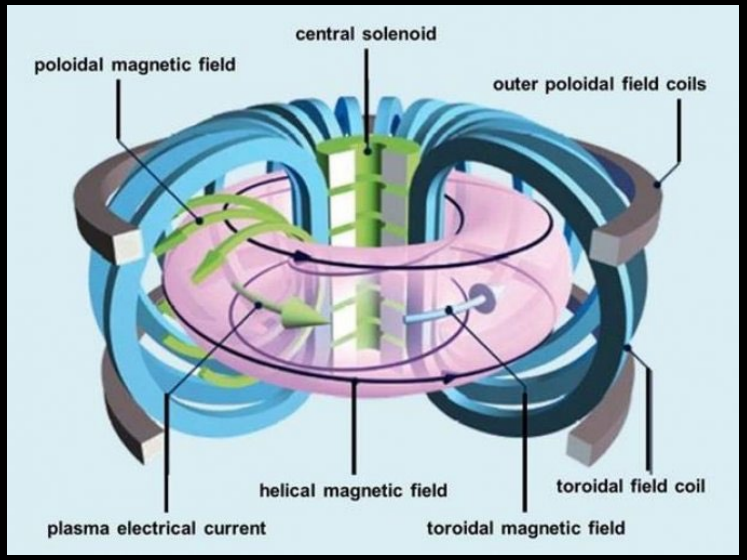
18 KHz DC

Plasma 101

Confine

Inertia

Magnetic



PlasmaWhirl®
Foret Plasma Labs
www.PlasmaWhirl.com

Plasma 101

Sustain

Graphite + Ceramics

OR

3/9/2022

PlasmaWhirl®
Foret Plasma Labs

Plasma 101

Confine + Sustain

Whirlpool

Plasma 101

Don’t be fooled with jargon!

Pulsed Plasma

Gliding Arc

Non-Thermal

MM Wave

PlasmaWhirl®
Foret Plasma Labs

Plasma 101

What is Pulsed Plasma?

1. 60 Hz AC → 400 Hz or higher
2. AC → DC
3. Diodes "fire" ON/OFF at ?
4. Diode = Check Valve
5. Current flows in only one direction

150 amps 370 OCV Capex = $0.30/watt

If you don't want pulsed plasma, then

PlasmaWhirl®
Foret Plasma Labs

Plasma 101

Use Batteries or direct connect to Solar or Fuel Cell for ZERO Pulsed Plasma System

48 VDC

PlasmaWhirl®
Foret Plasma Labs

Plasma 101

MMWave Plasma

Aka “Microwave Oven”

Pros

Pure Samples

Cons

Very expensive about $1/watt

Not for industrial environments

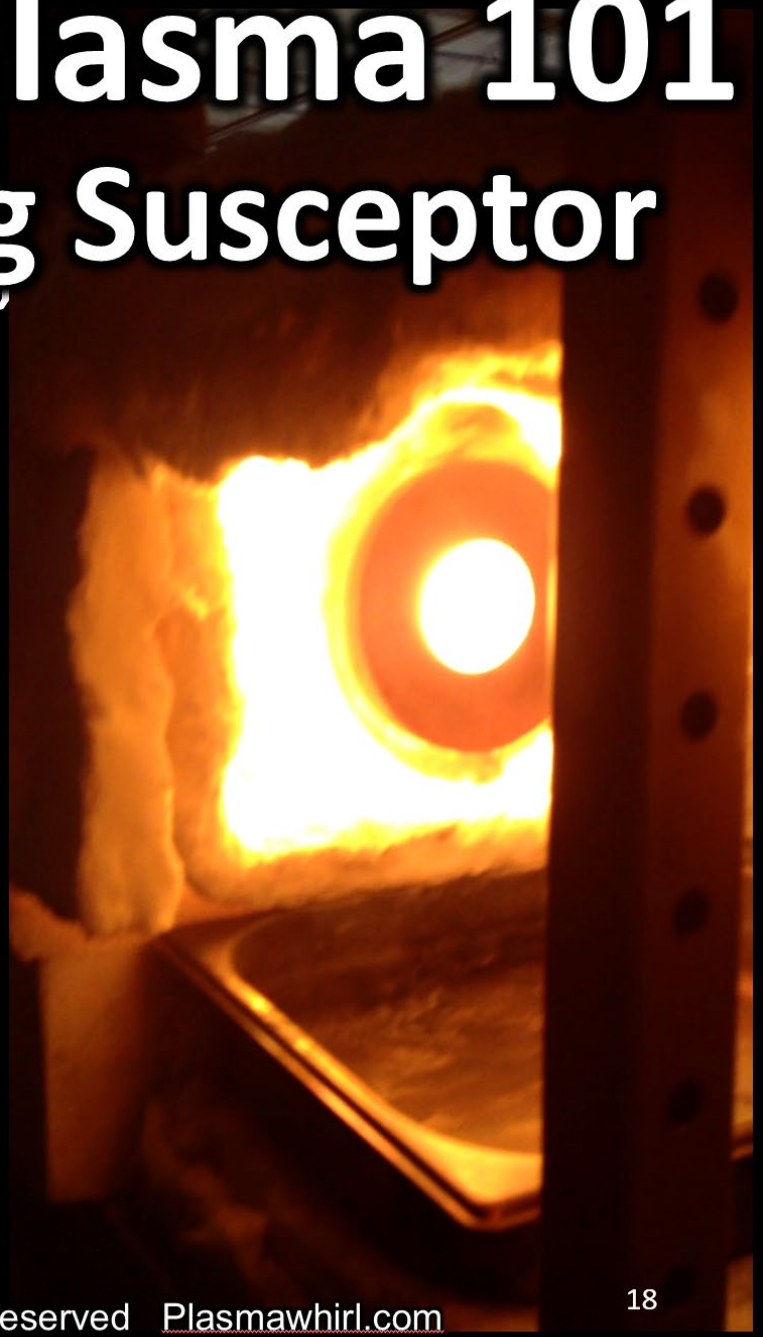
3/9/2022

PlasmaWhirl®
Foret Plasma Labs

Plasma 101

Induction Heating Susceptor

"Melting + Some Plasma at 22 Khz"



Pros

24/7/365 operation

Very High Power

CAPEX = $0.20/watt

Cons

Lots of cooling water

Coil is potted/cast in Alumina

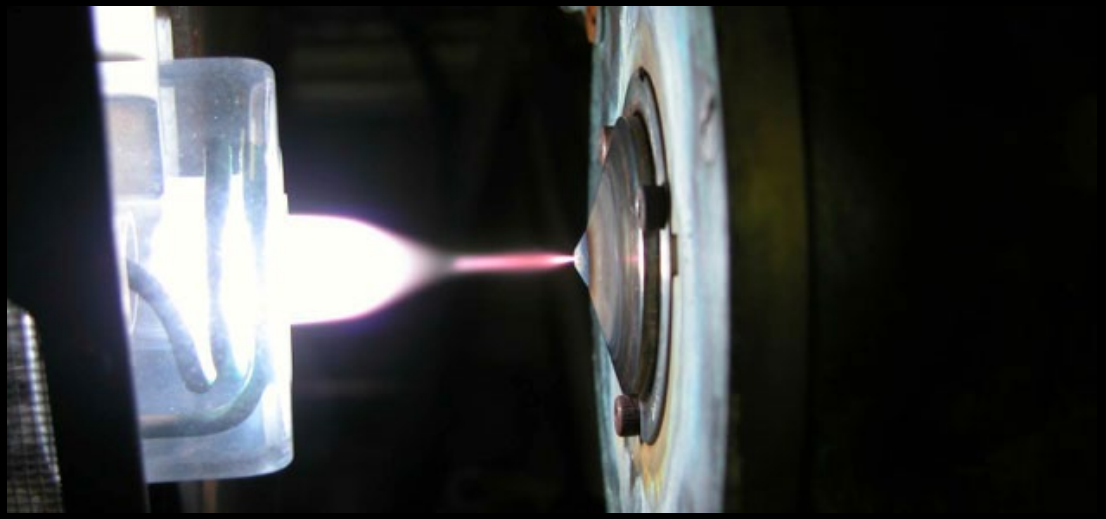
Reactor design is paramount

PlasmaWhirl®
Foret Plasma Labs

Plasma 101

Induction Plasma

Aka “ICP-MS”



https://www.jsg.utexas.edu/icp-ms/icp-ms/

Pros

Pure Samples

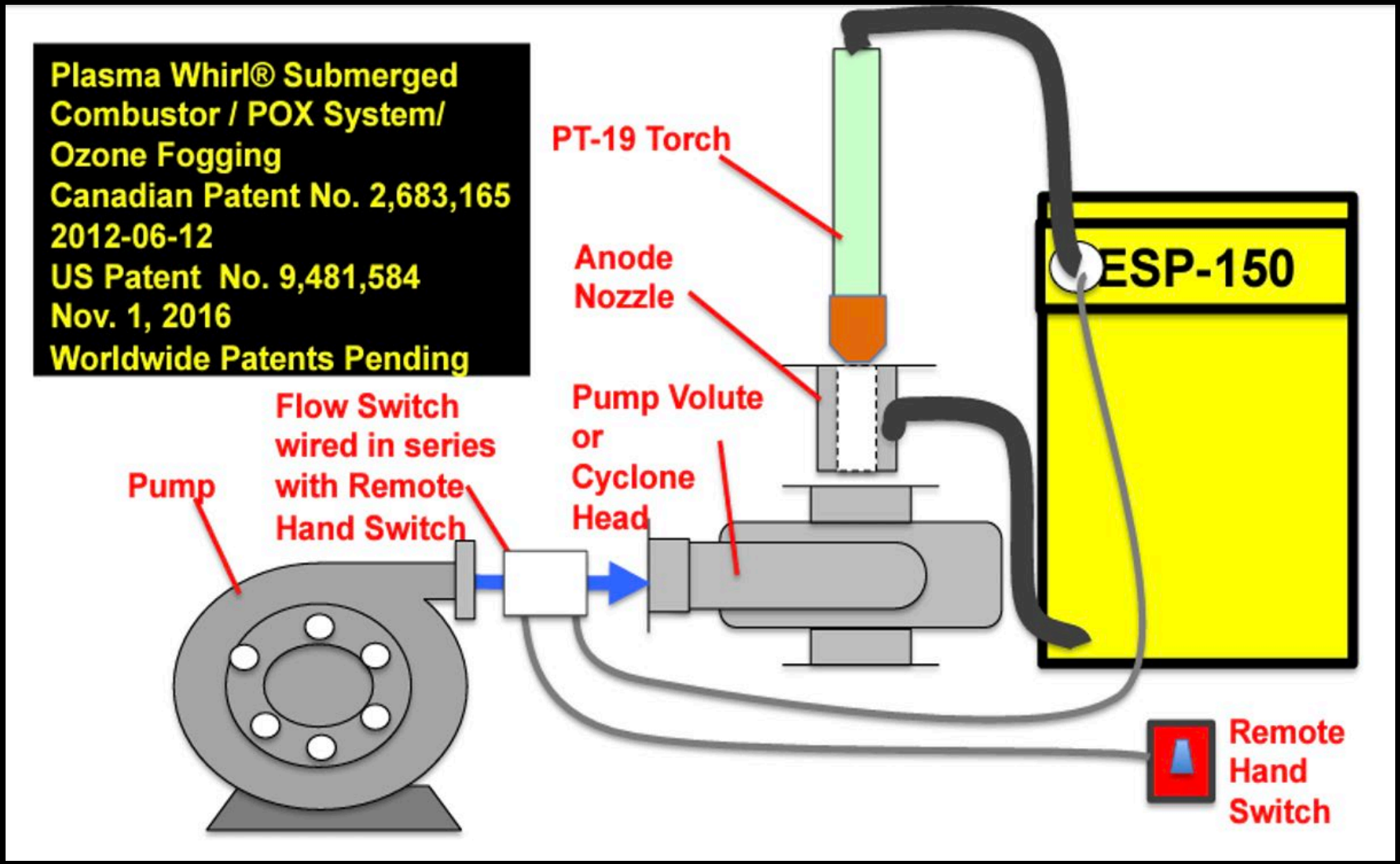
Very Low Power

Cons

High Frequency > 13.56 Mhz

PlasmaWhirl®
Foret Plasma Labs

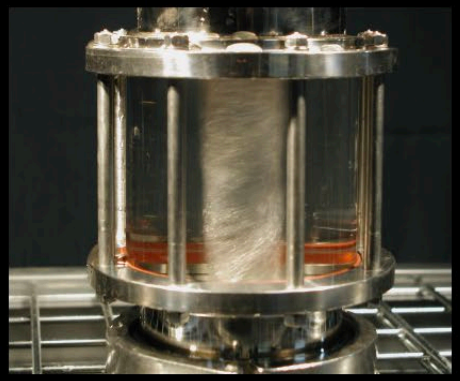
How to build a simple non-transferred arc plasma system?

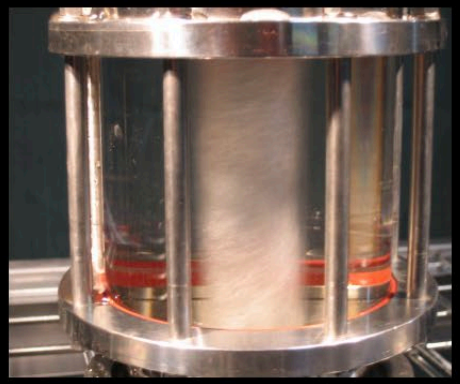


PlasmaWhirl®
Foret Plasma Labs

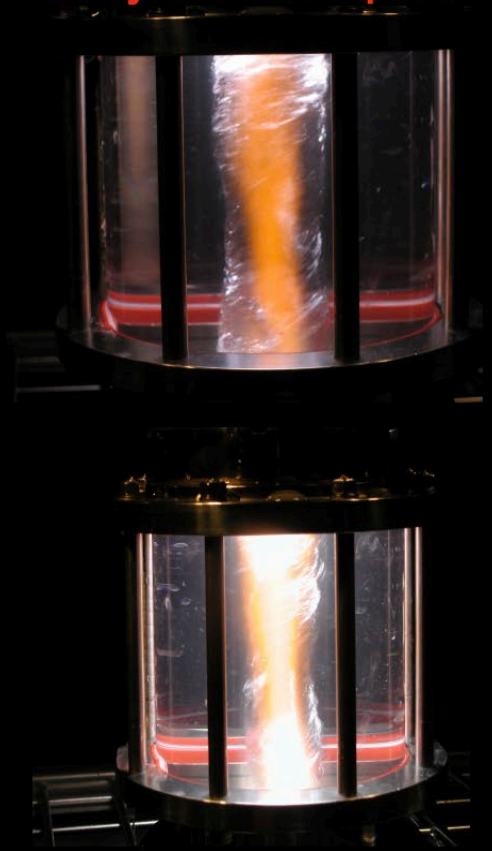
How to build a simple non-transferred arc plasma system?

Whirlpool Flow with Gas Core





Oxygen Plasma in eye of Whirlpool



Plasma Torch

Pump Volute

Oxygen Plasma

PlasmaWhirl®
Foret Plasma Labs
www.PlasmaWhirl.com

How to build a simple non-transferred arc plasma system?

00:00.00

PlasmaWhirl®
Foret Plasma Labs

How to build a simple plasma electrolysis steam system?

Filter Media

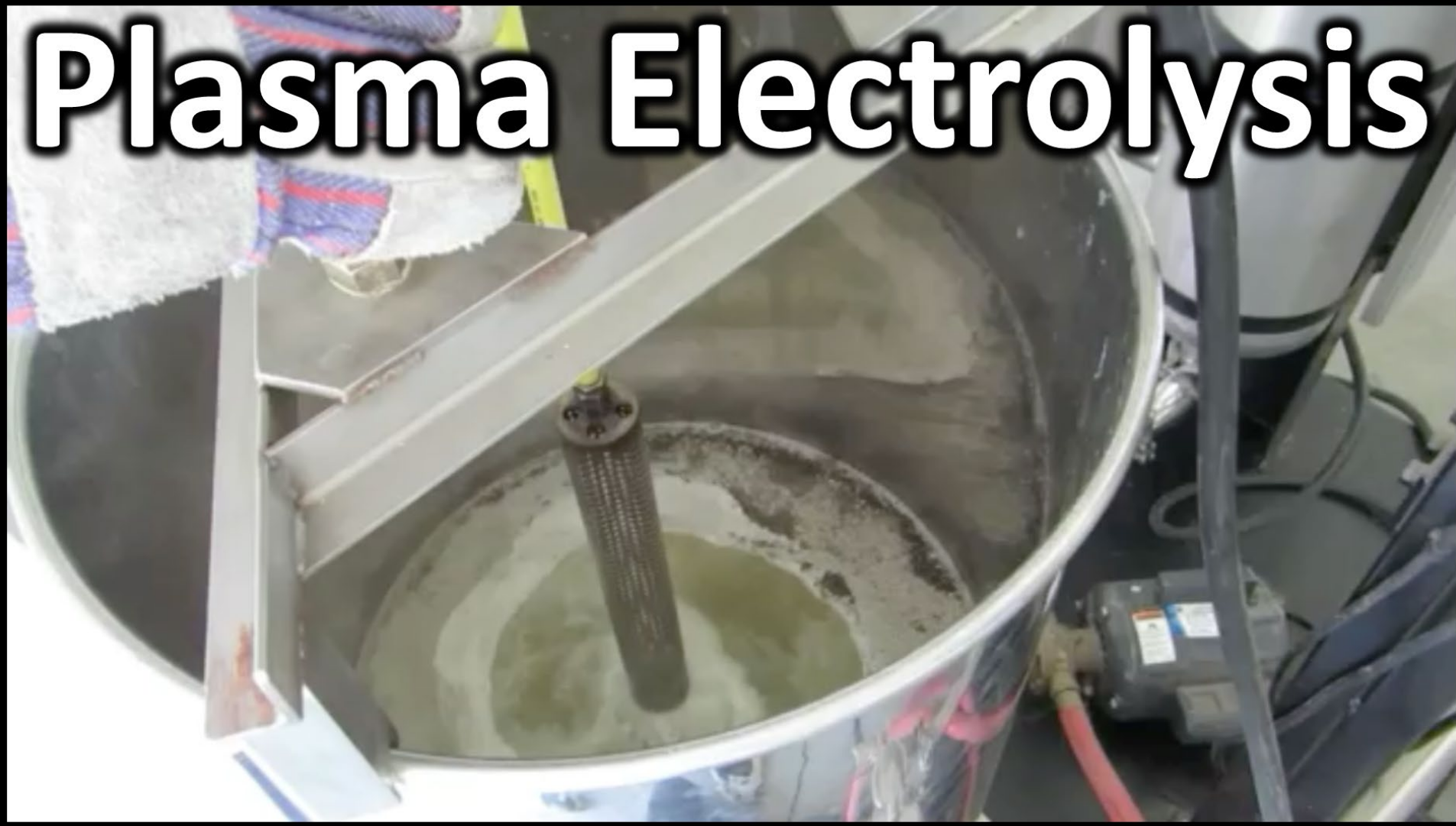
Cathode (-)

Tank

Zero Water Pretreatment

PlasmaWhirl®
Foret Plasma Labs

All electric steam generator using oily wastewater with an electrolyte



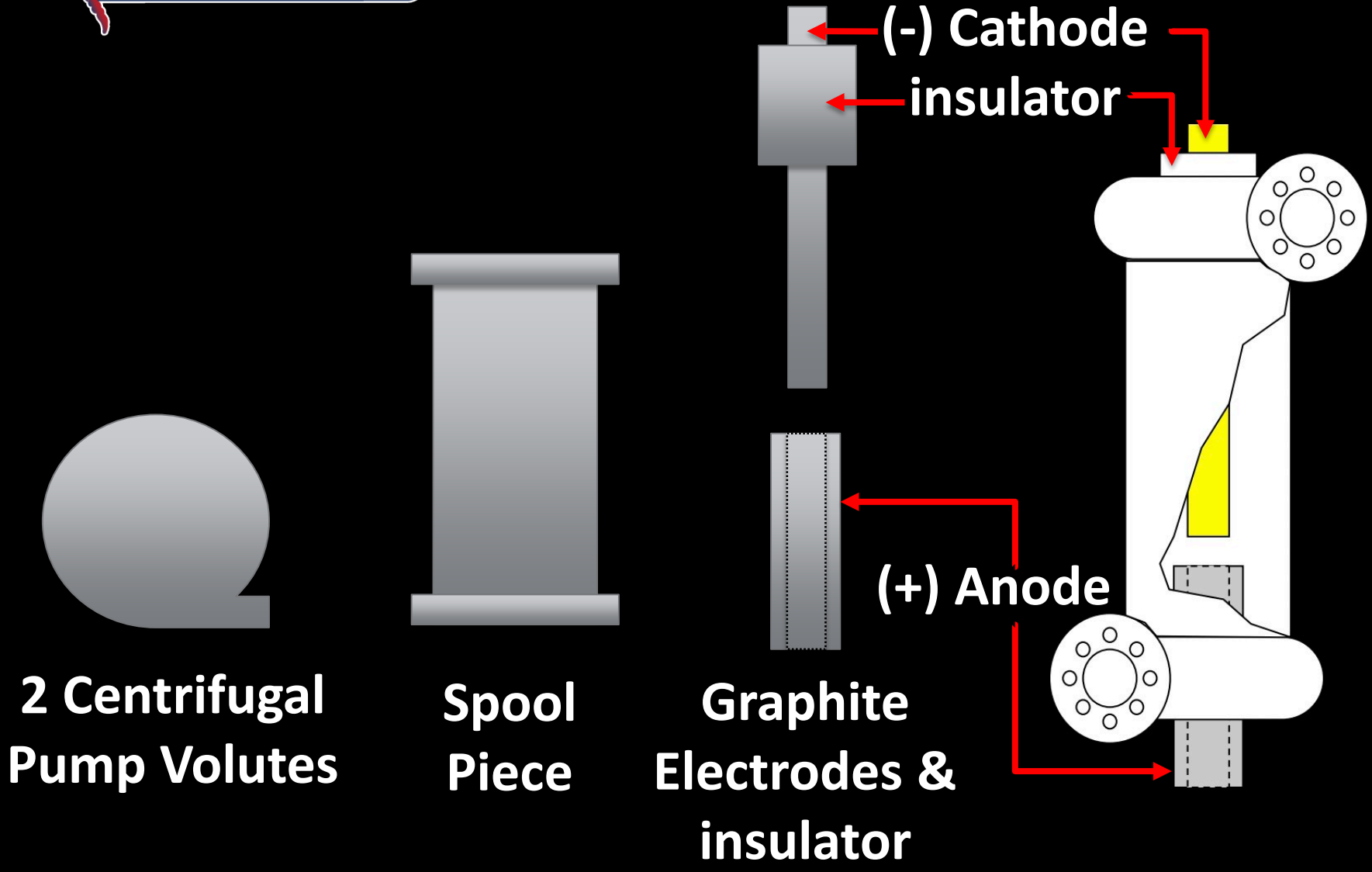
PlasmaWhirl®
Foret Plasma Labs

Up flow

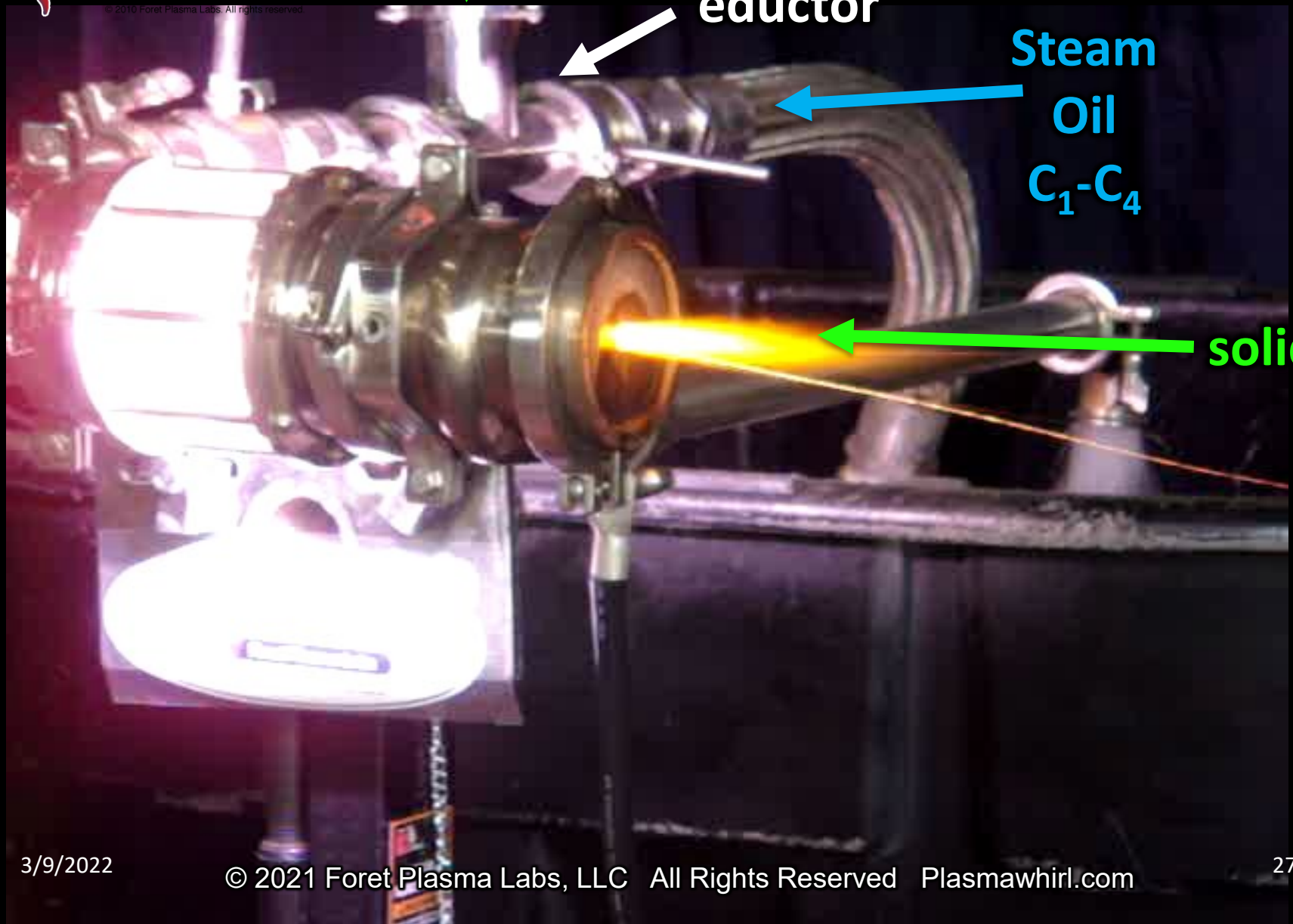
Best Electrolytes

Spent Caustic
Cesium Formate Brine
Urine
MAP/DAP Tailings Pond Water
Produced Water
Black Liquor

How to build a steam plasma torch?



PlasmaWhirl®
Foret Plasma Labs



Why Plasma?

TPD = Process Intensification

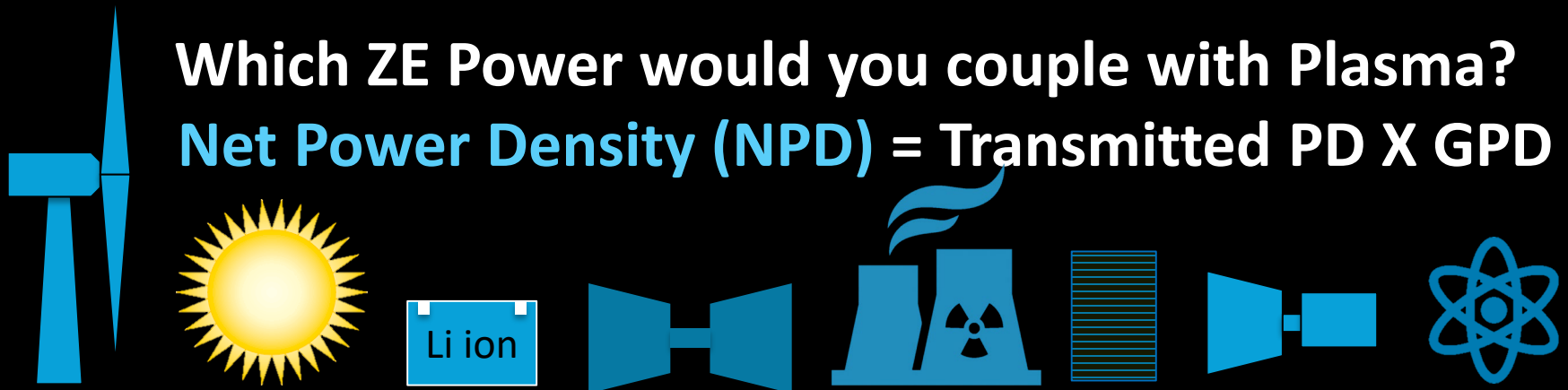
Table 1-3
Transmitted Power Densities

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Process	W/cm²
Gas	1 - 10
Infrared	1 - 30
Induction	5 - 5,000
Direct Resistance	10 - 10,000
Plasma	100 - 10^5
Electron Beam	1,000 - 10^9
Laser Beam	10,000 - 10^{15}

Which ZE Power would you couple with Plasma?

Net Power Density (NPD) = Transmitted PD X GPD



Land Area Generation Power Density (GPD) = watts/cm^2							
0.00015	0.0009	0.01	0.2	0.5	1.6*	3.6	800
Average Dependable Capacity							
14% onshore 27% offshore	20-40%	92%	84%	92%	92%	92%	N/A

https://www.ge.com/content/dam/gepower/global/en_US/documents/future-of-energy/ge-future-of-energy-white-paper.pdf

*https://www.osti.gov/servlets/purl/1420977

PlasmaWhirl® Foret Plasma Labs

PlasmaWhirl®
Foret Plasma Labs

Net Power Density for ZERO CO_2

Electrons to Storage to Electrons

Solar
0.0009 w/cm²
→ Faraday Electrolysis
10,000 w/cm²
→ 9 kw/cm²
→ Fuel Cell
1.6 w/cm²
→ 14.4 w/cm²

water → Plasma in a Box™ Plasma Electrolysis
→ 90 kw/cm²
→ Fuel Cell
1.6 w/cm²
→ 144 w/cm²

Solar
0.0009 w/cm²
→ Xtreme TPD
Plasma = 10^5 w/cm²

WATTS/cm²

NG → Plasma ArcWhirl® Jet
→ 90 kw/cm²
→ H2 Turbine
0.2 w/cm²
→ 18 w/cm²

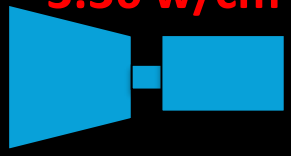
Solar
0.0009w/cm²
→ Plasma in a Box™
0.01 w/cm²
→ Li ion
→ 0.000009 w/cm²
Ultra-Low Undependable NPD
CAPEX + Disposal/Recycle

PlasmaWhirl®
Foret Plasma Labs

Net Power Density for ZERO CO_2

Electrons to Storage to Electrons

Turbo Expander
3.36 w/cm²



Faraday Electrolysis
10,000 w/cm²

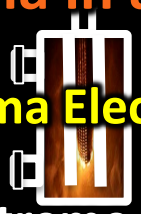
34 kw/cm²

Fuel Cell
1.6 w/cm²

54 kw/cm²

Plasma in a Box™

wastewater → Plasma Electrolysis



Xtreme TPD
Plasma = 10^5 w/cm²

336 kw/cm²

Fuel Cell
1.6 w/cm²

537 kw/cm²

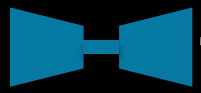
Turbo Expander
3.36 w/cm²

KW/cm²

NG →

Plasma Arc
Vortex

336 kw/cm²



67 kw/cm²

H2 Turbine
0.2 w/cm²

Plasma in a Box™

0.01 w/cm² →

0.037 w/cm²

Turbo Expander
3.36 w/cm²

Li ion

Ultra-Low Undependable NPD
CAPEX + Disposal/Recycle

PlasmaWhirl®
Foret Plasma Labs

Process Intensification

Compact — Scales — Xtreme-TPD

Portable — Decarbonization — Modular

PlasmaWhirl®
Foret Plasma Labs

Steam Plasma Reforming then Combusting Syngas

Compact

https://news.ucmerced.edu/news/2012/uc-merced-plasma-lab-turning-leftovers-cleaner-energy

Professor Gerado Diaz
UC Merced

Plasma Electrolysis Steam Generator

Steam Plasma Torch

Portable

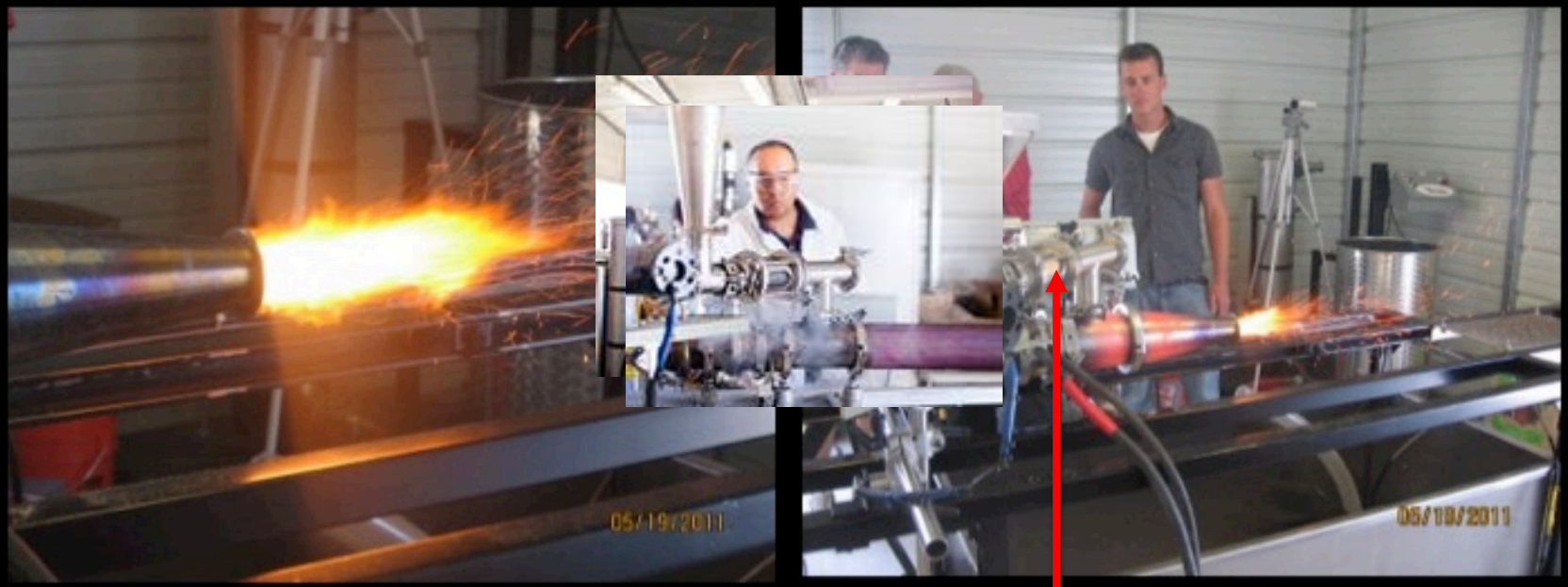
Biomass

Modular

PlasmaWhirl®
Foret Plasma Labs

Steam Plasma Reforming then Combusting Syngas

Compact



Portable — **Biomass** — Modular

PlasmaWhirl® Foret Plasma Labs

Steam Plasma Reforming

Compact — Process — Xtreme TPD

Intensification

Table 4 – Synthesis gas composition for different types of biomass (molar basis).

Biomass	CH_4	C_2H_6	C_3H_8	C_4H_{10}	H_2	O_2	N_2	CO	CO_2	LHV[a]
Hard wood shaving	3.9	0.0	0.0	0.0	55.2	1.0	3.7	14.5	21.5	9280.4
PB&MDFB	3.9	0.4	0.0	0.0	56.4	0.7	4.1	14.1	20.4	9180.9
Peach pits	4.6	0.3	0.2	0.2	57.0	0.8	2.4	18.8	15.7	10735.6
Almond hulls	1.8	0.0	0.1	0.1	52.4	1.2	4.4	11.7	28.3	7989.1
Grape pomace	2.8	0.0	0.1	0.1	59.1	0.5	2.0	14.1	21.2	9453.0
Coffee ground	2.5	0.0	0.0	0.0	77.0	0.2	1.3	4.1	14.9	9750.6

[a] LHV [kJ/Nm^3].

Portable — **Hydrogen** — Modular

PlasmaWhirl® Foret Plasma Labs

Steam Plasma Reforming

Where-is-the-H2?

Table 3 – Proximate analysis of biomass analyzed (weight fractions).

Biomass	Ash [%]	Fixed carbon [%]	Moisture [%]	Sulfur [%]	Volatile matter [%]
Hard wood shaving	4.03	7.53	5.72	<0.01	7.53
PB&MDFB	0.87	14.7	6.32	0.027	78.1
Peach pits	0.72	11.9	36.73	0.46	50.7
Almond hulls	8.86	18.9	8.01	<0.01	64.3
Grape pomace	5.29	18.5	8.97	0.12	67.2
Coffee ground	1.14	7.07	54.69	0.08	37.1

Portable Biomass Modular

PlasmaWhirl® Foret Plasma Labs

Steam Plasma Reforming

Where-did-H2-come-from?

Table 2 – Ultimate analysis (weight fractions) and LHV of biomass analyzed in this work.

Biomass	C [%]	H [%]	O [%]	N [%]	LHV [kJ/kg]
Hard wood shaving	48.41	6.28	41.1	0.13	18854.5
PB&MDFB[a]	4.98	6.16	41.41	3.53	19289.5
Peach pits	52.52	6.18	39.74	0.38	20754.9
Almond hulls	44.31	5.64	40.13	1.06	18040.5
Grape pomace	52.74	6.23	33.48	2.14	21883.0
Coffee ground	56.13	7.16	27.03	2.53	23771.7

[a] PB&MDFB = Particle Board and Medium Density Fiber Board.

Portable — Hydrogen — Modular

Best Plasma Arc Cracking Feedstock?

$C_1 - C_4$

Alkanes **Olefins** **Flare Gas**

PlasmaWhirl®
Foret Plasma Labs

Cracking NG

$ Upcycling NG to H_2 + C with Zero CO_2 Emissions $

NG Henry Hub Prices = $3.00/mcf vs CA City Gate Price = $3.65/mcf
https://www.eia.gov/dnav/ng/ng_pri_sum_a_epg0_pg1_dmcf_m.htm

1 mcf = 4.79 kg Hydrogen + 14.47 kg Carbon

H2 Merchant Price/kg..... $4	H2 CA Retail Price/kg.....$16.51
Carbon Black/kg..... $1	Anode Graphite/kg.....$3
H2 Sales = $4 x 4.79 kg.....$19.16 CB Sales = $1 x 14.47kg.....$14.74	H2 Sales = $16.51 x 4.79.....$79.08 AG Sales = $3 x 14.47.....$43.41
UPCYCLED VALUE/mcf ($19.16 + $14.74) - $3 = **$30.90**	UPCYCLED VALUE/mcf ($79.40 + $43.41) - $3.39 = **$119.42**

What is clean H_2?

Thank You

Todd Foret
Todd@ PlasmaWhirl®
Cell: 337-298-8870