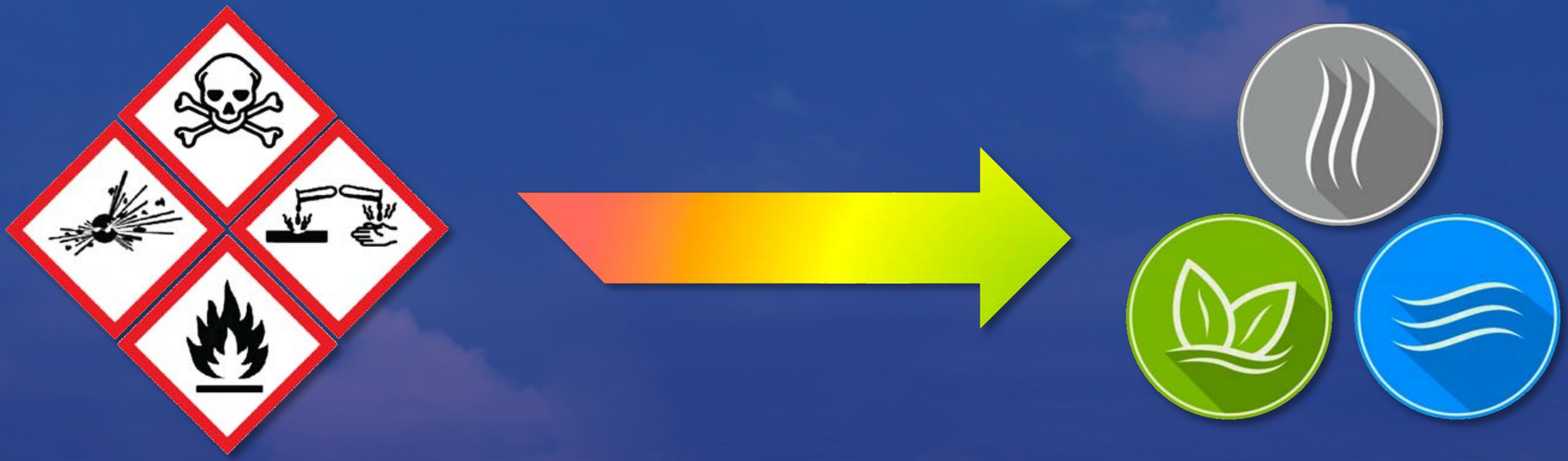
EcoSys Abatement
M91A Plasma/Wet Integrated Scrubber Introduction

June 7th, 2024

Sustainability & the Path to Net Zero

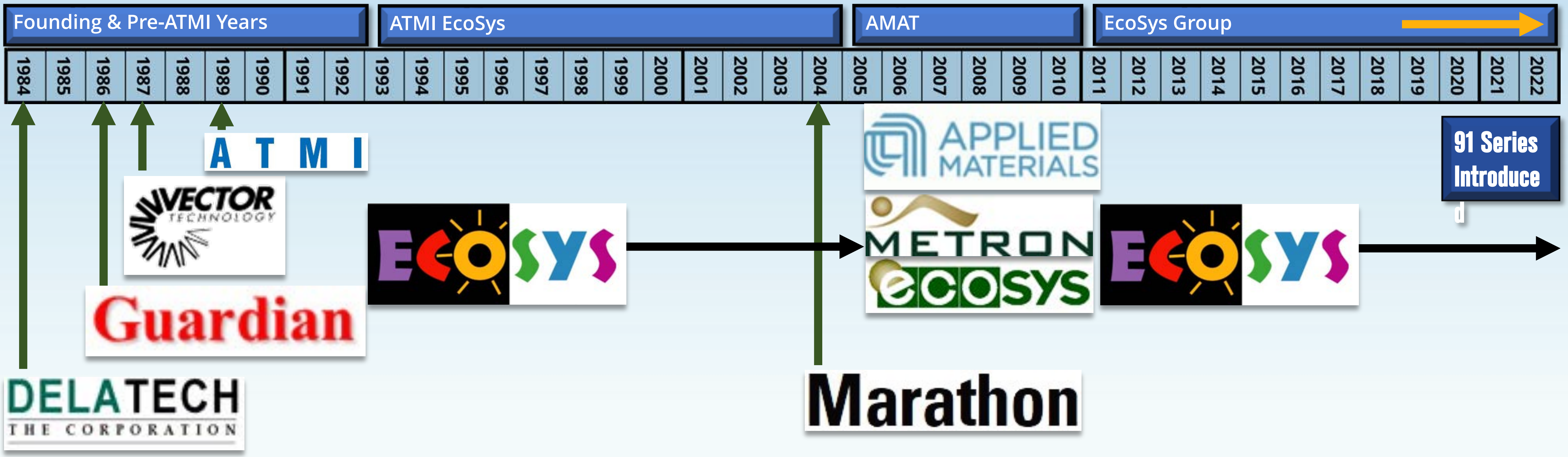


EcoSys Microwave Plasma Gas Abatement:

- Best Available Technology
- No Fossil Fuel Used
- Reduce CO_2 eq. by 1,000’s Tons/Year
- Reduce NO_X emissions up to 85%
- Reduce operating cost $\geq$ 25%
- Treats all gases, including GHGs >99%

ECOSYS Forging the Future of Abatement Technology

EcoSys Brand History

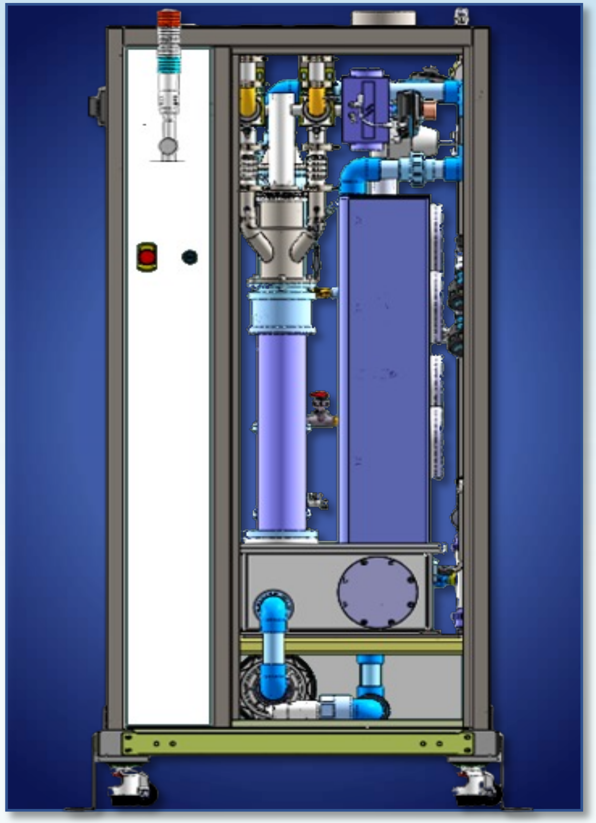


- 1984 – Delatech (Innovative Engineering) launches CDO™ furnace
- 1986 – MG Technologies introduce the Guardian™ burn box
- 1987 – Vector Technology introduces the Vector™ water scrubber
- 1989 – Delatech introduces the CDO integrated scrubber
- 1989 – ATMI introduces the Novapure dry scrubber
- 1993 – ATMI acquires Vector and creates EcoSys™ Brand
- 1996 – EcoSys acquires Guardian
- 1999 – EcoSys acquires Delatech (CDO)
- 2004 – EcoSys ships Marathon™ alpha unit
- 2005 – Applied Materials acquires EcoSys and merges into newly acquired Metron Fab Services division
- 2006 – Marathon integrated burn/wet scrubber officially released
- 2011 – EcoSys acquired by HT Advance Technology
- 2013 – HT Advance Technology reverts to EcoSys brand name
- 2020 – EcoSys launches “91”series products
- 2020 – HT Advance Technology reincorporated as EcoSys Group Pte Ltd
- 2020 – EcoSys launches “91” series product releases

Sustainability & The Path to Net Zero

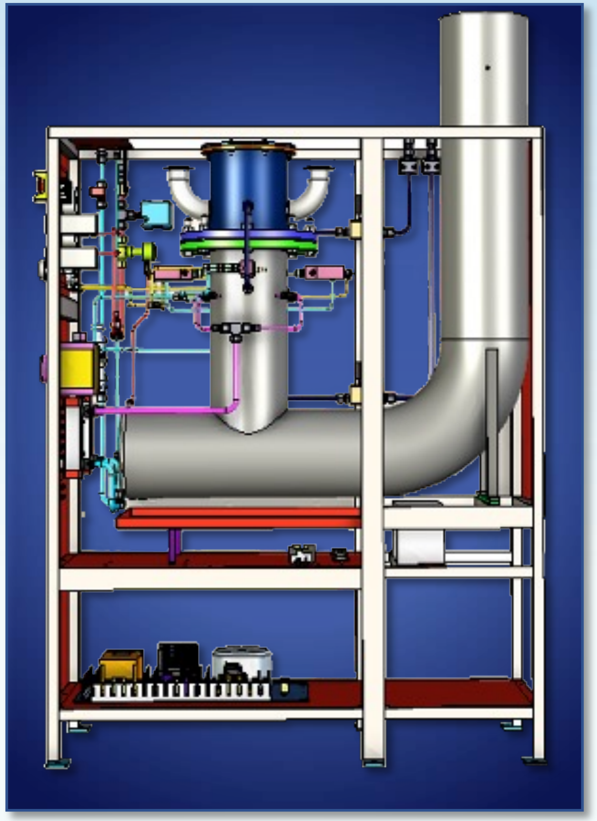
EcoSys 91 Series Product Line

MICROWAVE (µWAVE) PLASMA AVAILABLE



Vector™

(Wet)

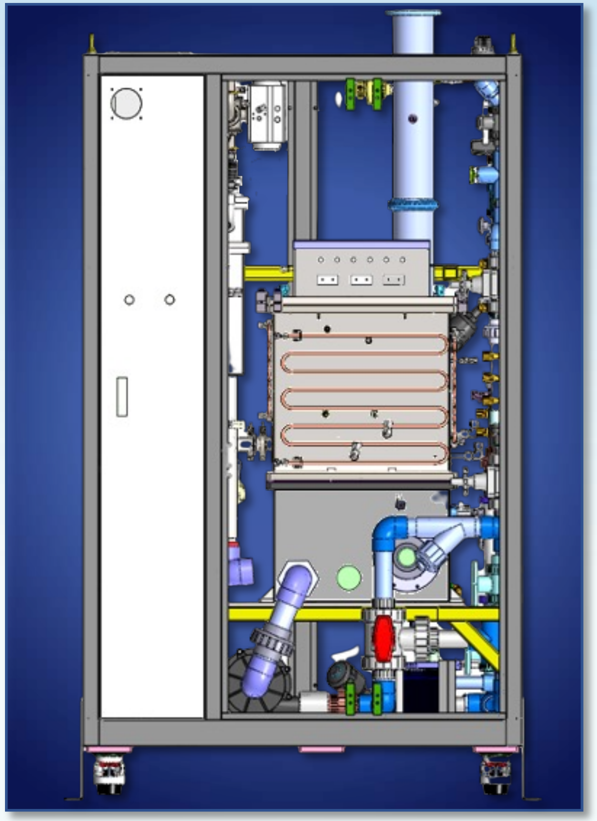


Guardian™

(Burn)

or

(Plasma)

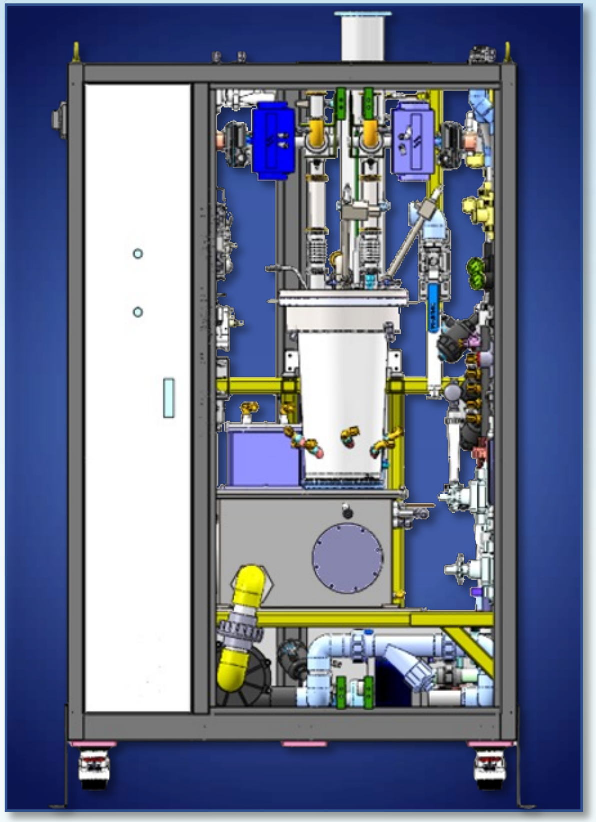


CDO™

(Thermal-Electric/Wet)

or

(Plasma/Wet)



Marathon™

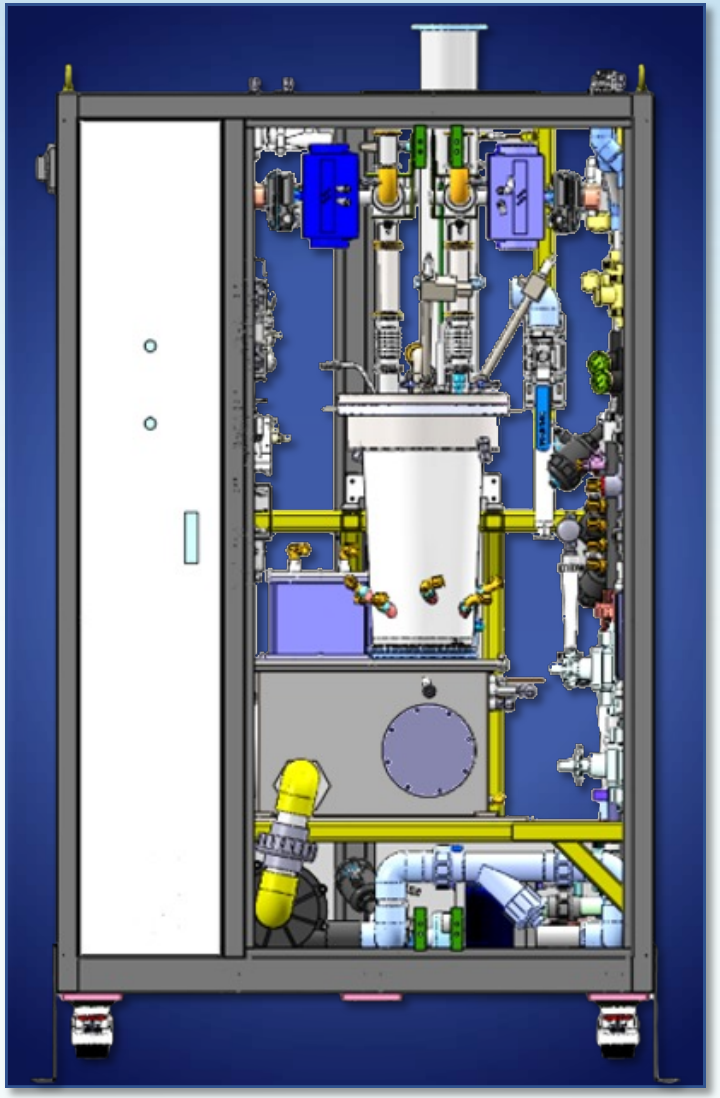
(Burn/Wet)

or

(Plasma/Wet)

Marathon M91/M91A Next-Gen Integrated Scrubber

- >99% DRE
- Ground up redesign with cutting edge new features for superior performance
- Suitable for all chemistries
- Burn/Wet and Plasma/Wet options
- Proprietary angled laminar flow inlet assembly concentrates gases directly in the flame/plasma for optimal efficiency and cost
- High reliability
  - High particulate capacity
  - SS tank & plumbing
- Highly configurable
  - Dual reactor option for higher capacity or redundancy
  - Pre-wet module option
  - Water filtration and PM 2.5 treatment options in development
- Fully certified & safety compliant



M91 Integrated Scrubber Reactor Entry Options

M91X – Burn/Wet

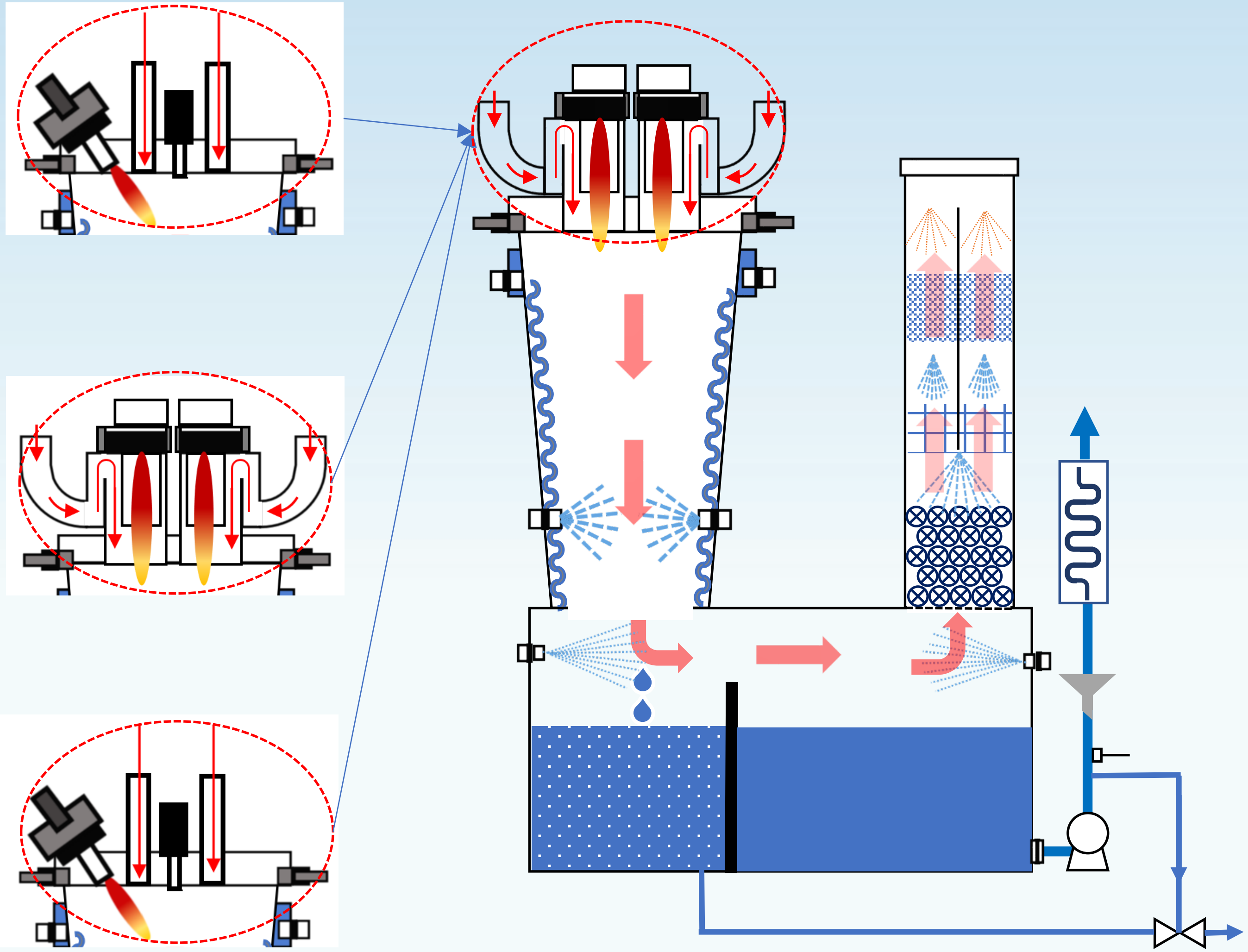
- Fuel fired (methane, hydrogen, LPG, etc.)
- Strong and stable pilot flame
- Angled flame injection ensures gases pass through flame
- Process dependent manual or auto fuel-air ratio

M91A – Plasma/Wet

- Decompose effluent by plasmafication
- No fuel required
- CDA, nitrogen or argon as plasma gas
- Suitable for PFC gases

M91P – Plasma/Wet (for Flammables)

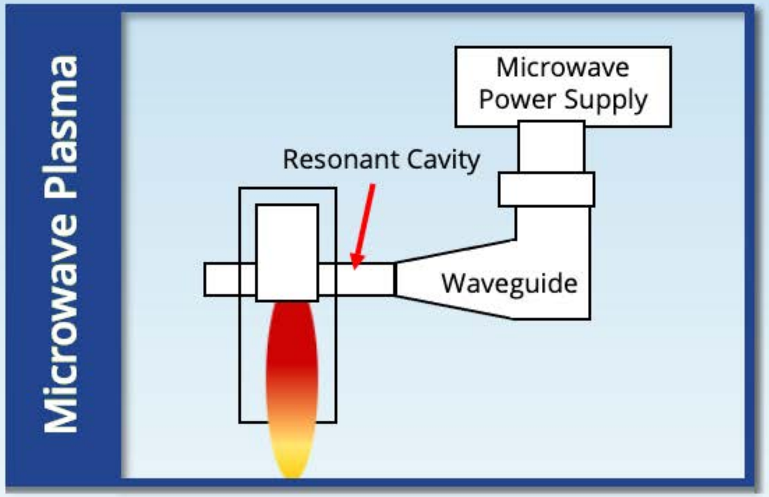
- Decompose effluent through high temperature from plasma gastification
- No fuel required
- CDA, nitrogen or argon as plasma gas
- Suitable for flammable gases

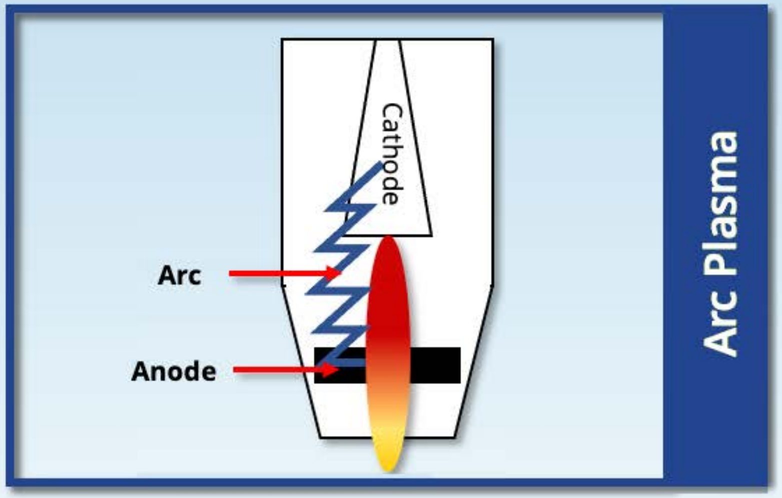


PLASMA REACTOR

Plasma Reactor Option for Marathon & Guardian

Abatement Plasma Technology Comparison



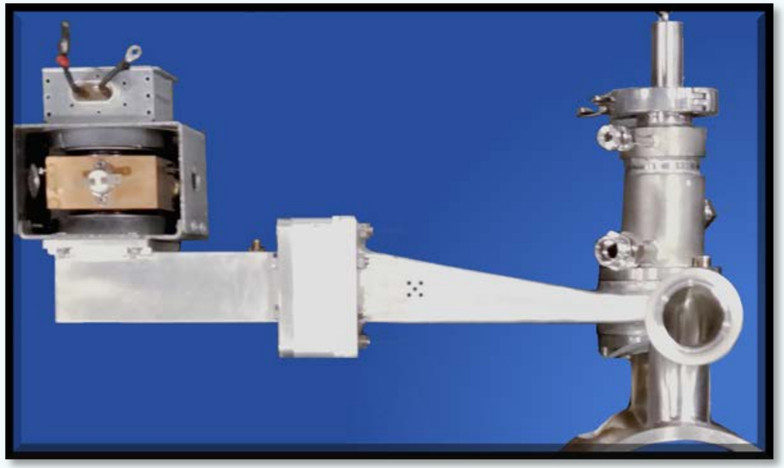


	EcoSys	Others
Decomposition Method	Plasmafication of effluent	High temperature from plasma arc
Power Consumption	Low power consumption (1.8 ~ 1.9 kW)[1]	High power consumption (8.0~20.0 kW)
Parts Cost	Commonly available microwave parts	High-cost power pack & torch
Parts Consumption	No electrodes and fewer internal components, which can reduce the frequency of component failure and maintenance	More consumable parts, especially electrodes, increase the frequency of component failure and maintenance

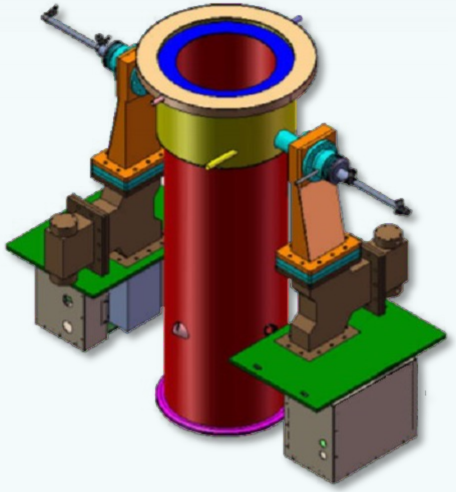
[1]Resonant cavity is not necessary for sustaining a microwave plasma and that microwave coupling efficiency to plasma can be close to 100%

91 Series Plasma Reactor Option

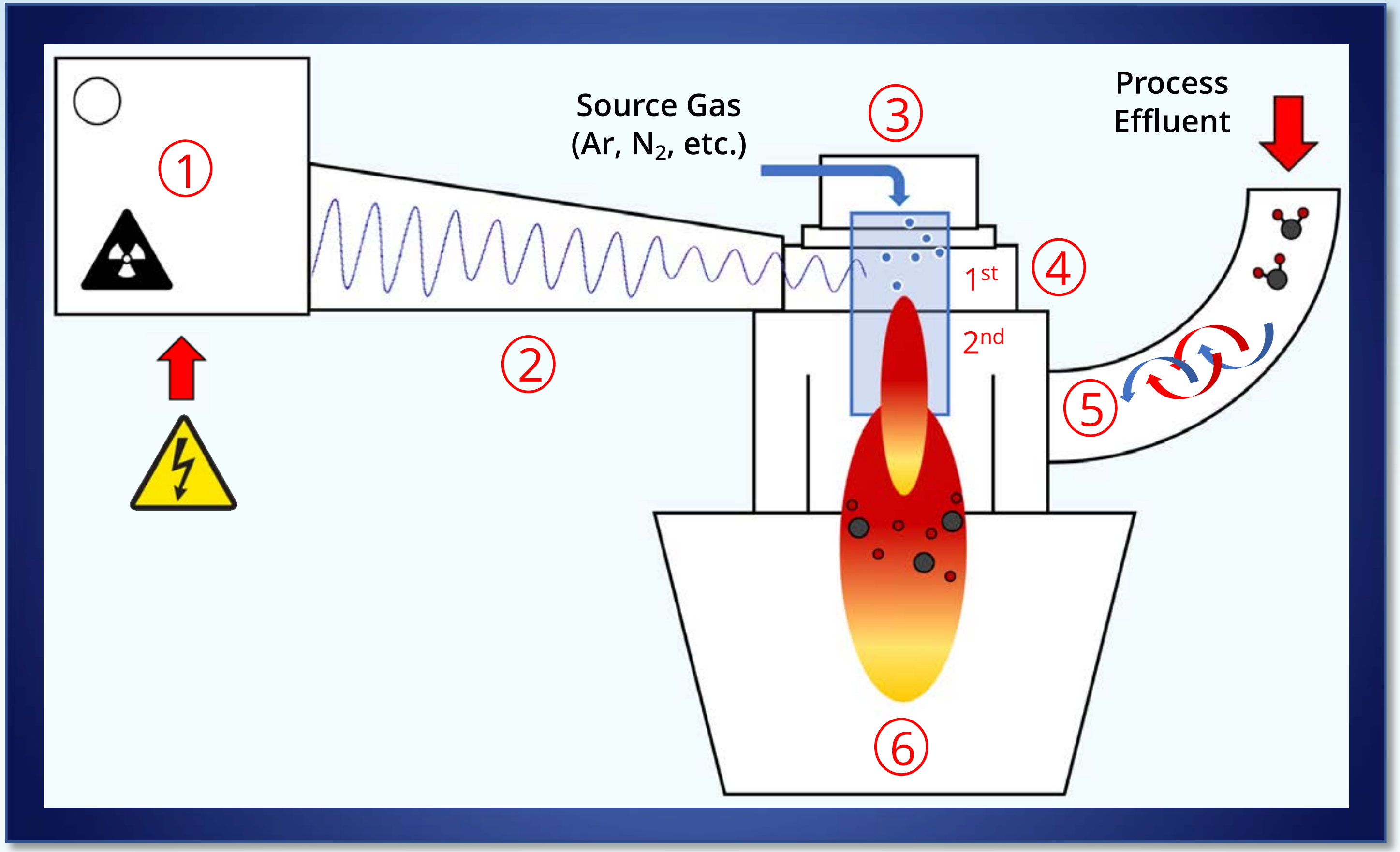
(Demo Unit Shown)



- >99% DRE for all chemistries
- Available option for Guardian, CDO and Marathon
- Low energy consumption microwave plasma
- Proprietary waveguide design
- Stable
- Low-cost combustion option
- No electrical heaters and no fuel gas!
- Huge NO_x reduction



The Solution – Proprietary Microwave Plasma!

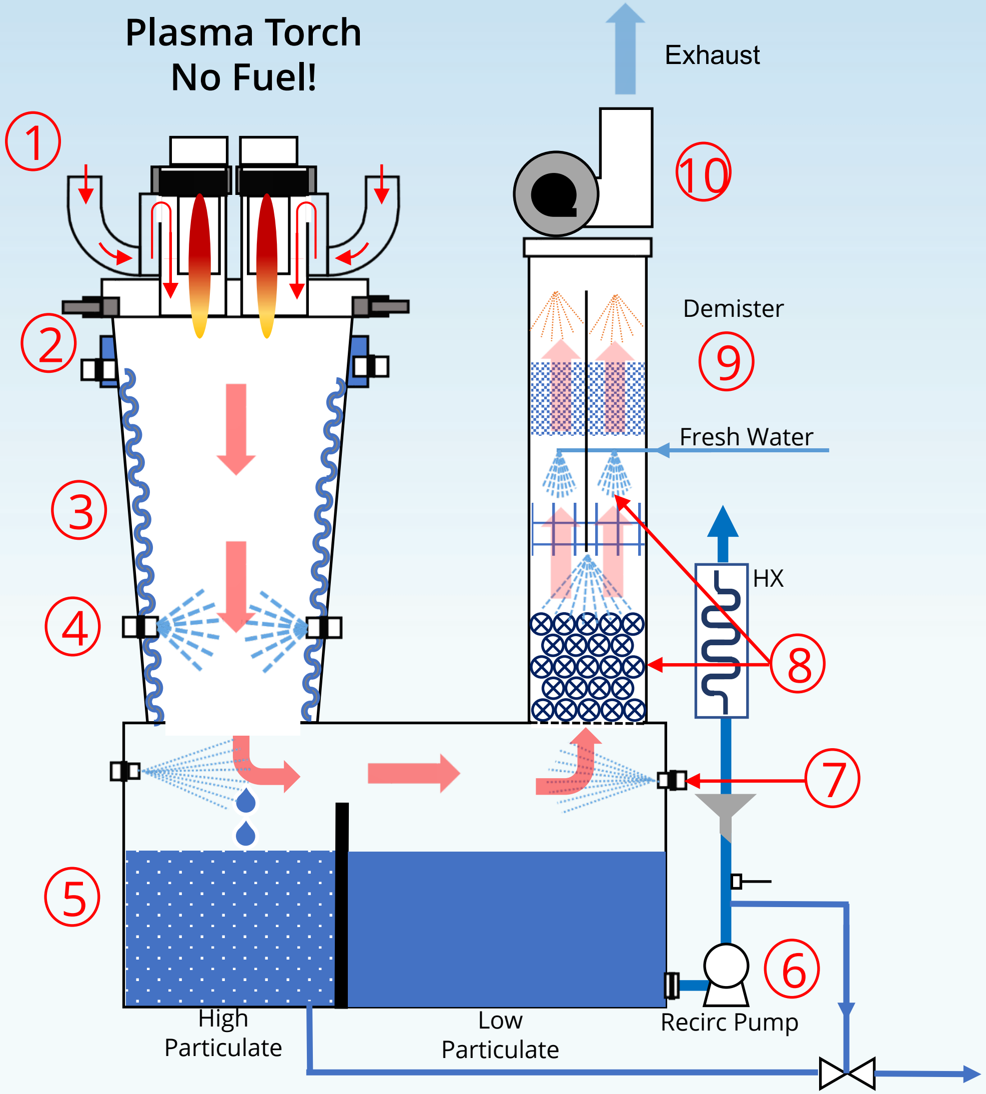


Not heat dependent!

- 1 - Magnetron converts small amount of electrical energy into microwaves
- 2 - Proprietary waveguide drives microwaves to center of a quartz tube to maximize “plasmarization” process
- 3 - Plasma source gas (Ar, N_2, etc.) enters 1st stage plasmarization zone
- 4 - Plasma source gas decomposed by microwave energy releasing large amounts of high kinetic energy electrons
- 5 – Turbulence causes effluent gases to swirl into 2nd stage of plasma reactor where the highest microwave energy resides, and target molecules are dissociated in the plasma
- Reaction rate further enhanced by collisions with high kinetic energy electrons from 1st stage plasmarization zone
- 6 – Atoms from target molecules recombine into desired by-products (lower energy state)

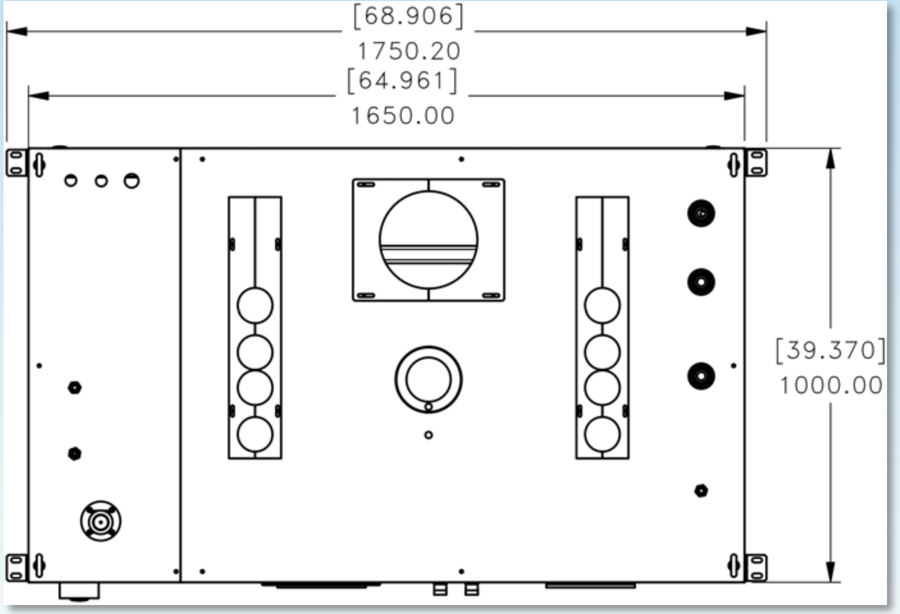
Marathon M91A Plasma/Wet Theory of Operation

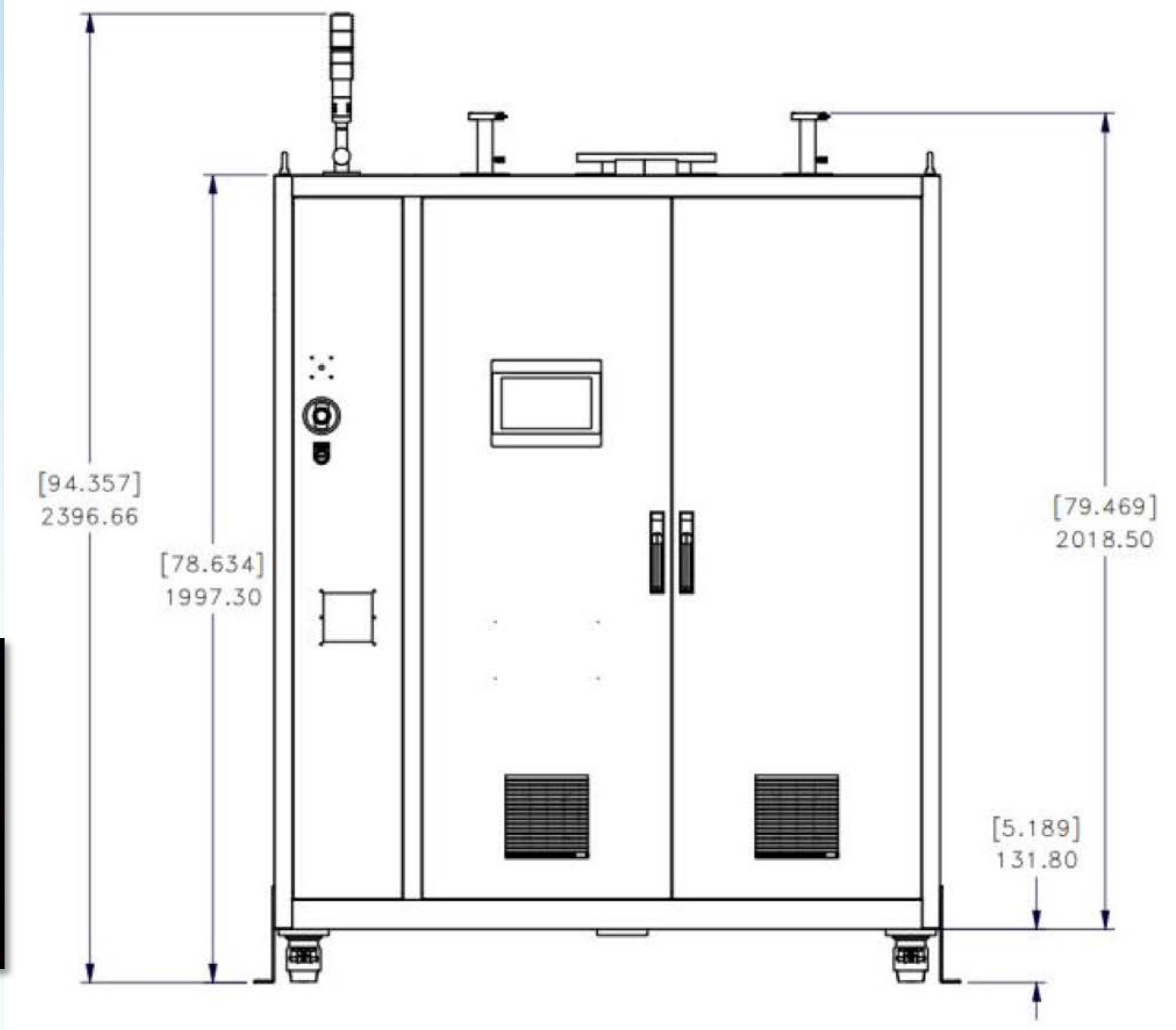
- 1 – Exhaust gases drawn into entry designed for turbulent swirling of molecules to maximize ionization efficiency inside of the plasma zone
- 2 – CDA injection and water vapor present for ionized gas recombination/oxidation
- 3 – Waterwall reactor prevents particulate build-up in reactor, moves solids towards high particulate side of recirculation tank, and cools gases
- 4 – 1st stage water scrubbing captures coarse particles and water-soluble gases, particulate falls into tank
- 5 – Particulate goes into high particulate side of sump tank and water is filtered for reliability



- 10 – Optional blower increases/regulates exhaust draw
- 9 – 2 chamber differential pressure exhaust drying zone, 1st stage uses media to condense moisture out of gas stream; 2nd stage uses fast compressed air jets to dry water vapor
- 8 – 2nd stage water scrubbing (high surface area counter-current packed bed) further removes particulates and water-soluble gases; Freshwater addition for polishing scrub
- 7 – Mist zone capture ultrafine particulate
- 6 – Water recirculated to reduce fresh water consumption; Optional drain control via specific parameters (pH, conductivity, etc.) instead of continuous draining for further savings

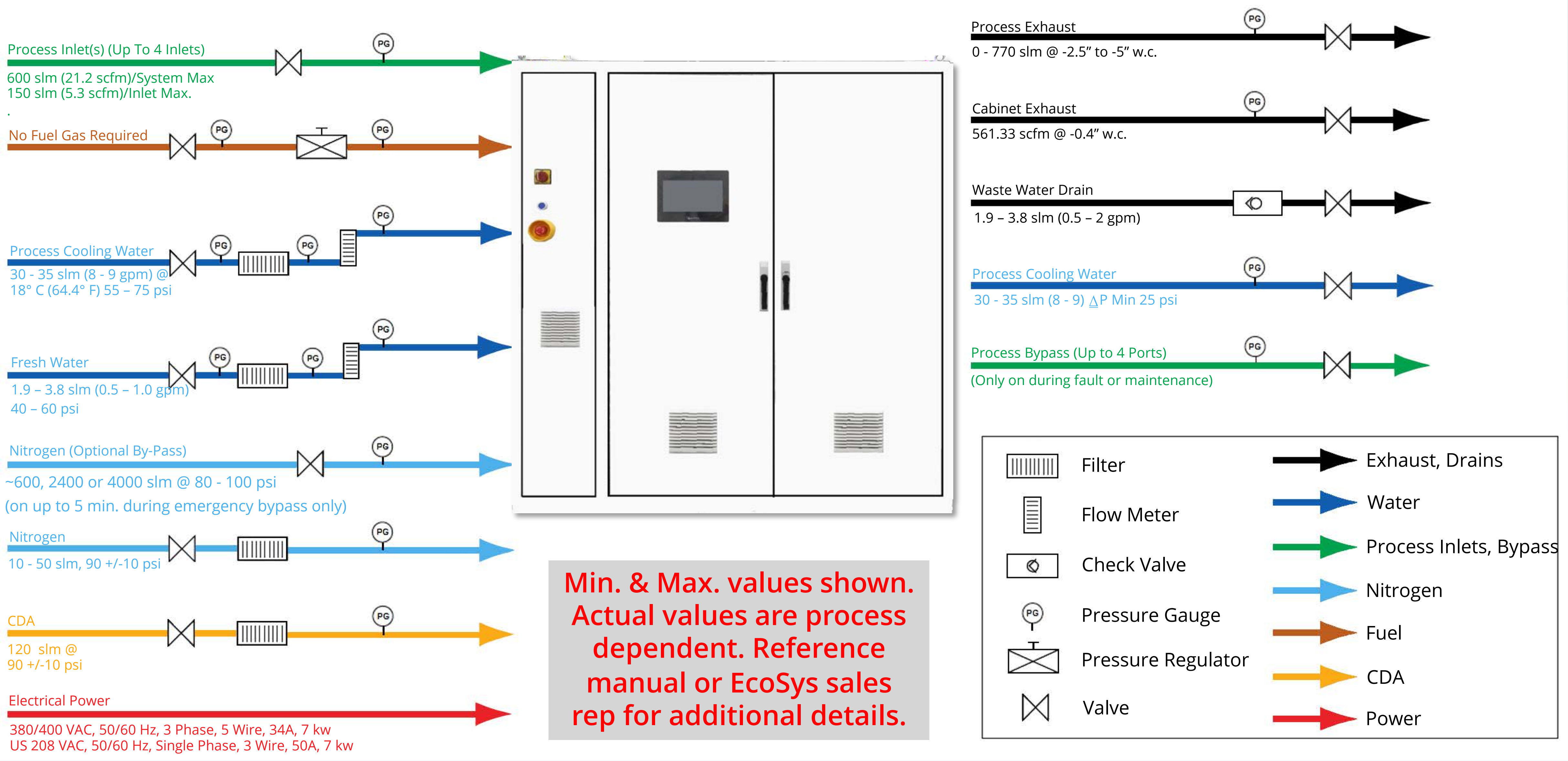
M91A Weight & Dimensions (4 Inlet)



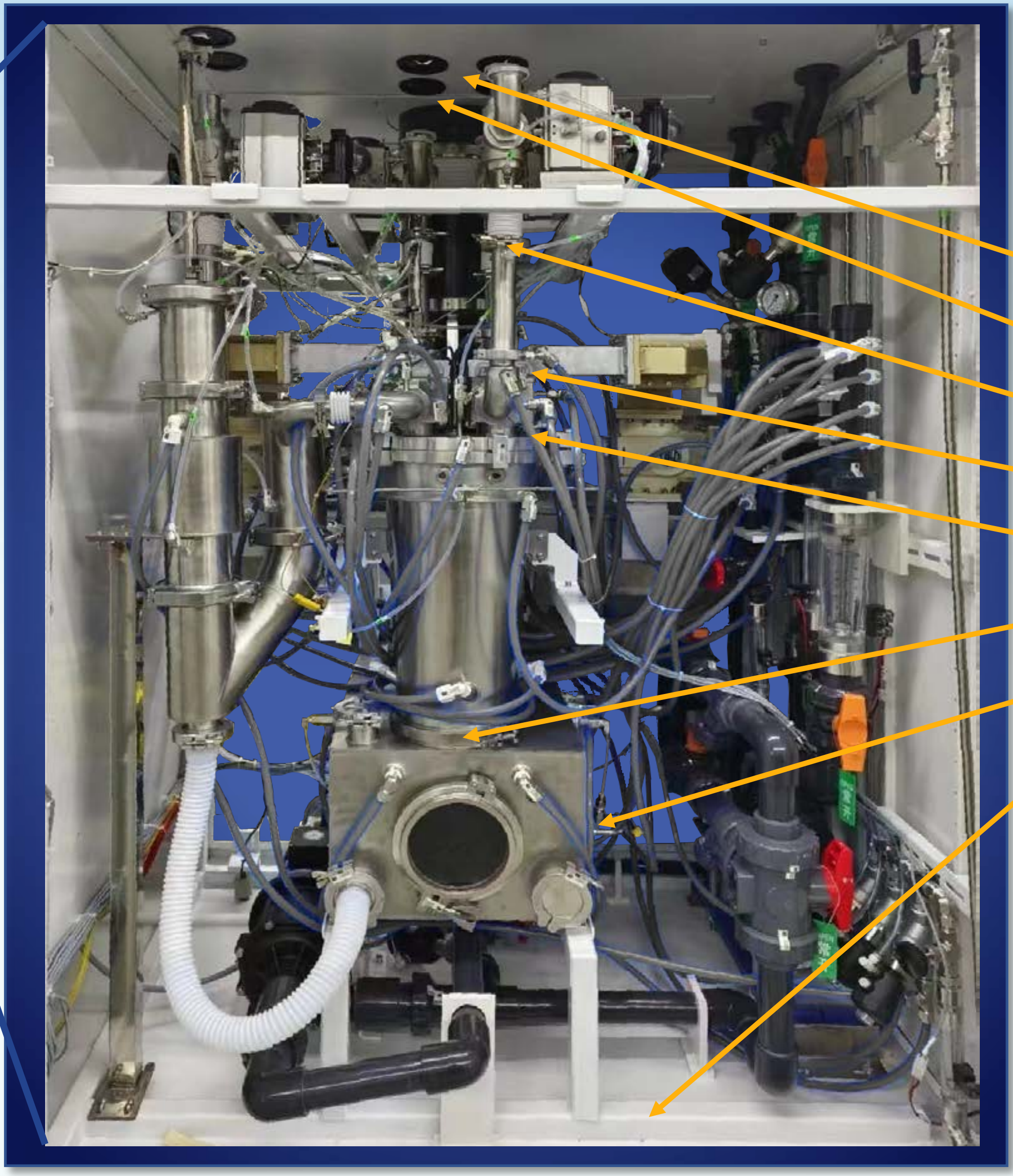


Parameter	Specification
Weiight (Dry)	1,984.16 lb./900 kg
Weight (Wet)	2,204.623 lb./1,000 kg
Dimensions	84.658" H x 64.961" W x 43.370" D 2,150.30 mm H x 1,650.00 mm W x 1,100 MM D
Dimensions w/ Light Bar	94.357" H x 64.961" W x 43.370" D 2,396.66 mm H x 1,650.00 mm W x 1,100 MM D

Marathon M91A Facilities Requirements Summary



Marathon M91A Safety Interlocks



- M91A system configured w/:
  - 4 entries
  - Integrated bypass
  - Dual plasma torches
  - SS tank & plumbing
  - Single pre-wet module

Safety PLC Monitors Multiple Parameters

- Cabinet exhaust draw
- Cabinet exhaust pressure
- Exhaust pressure & Delta-P
- Inlet pressure
- Plasma check (reflection wave sensor)
- Gas temperature
- Tank level
- Water leak
- Pressure relief device (optional)
- Cabinet door (optional)
- Hydrogen flashback arrestor (FBA)(optional)
- Cabinet hydrogen (optional)

M91A Destruction/Removal Efficiency (DRE)

Gas	DRE %	Gas	DRE %	Gas	DRE %	Gas	DRE %	Gas	DRE %
AsH_3	99	CHF_3	99	HCl	99	$SiCl_4$	99	TMB	99
BCl_3	99	CH_3F	99	HF	99	SiF_4	99	TMCTS	99
$B2H_6$	99	CH_2F_2	99	H_2	99	SiH_2Cl_2	99	TMP	99
BF_3	99	Cl2	99	NF_3	95	SiH_4	99	WF6	99
CF_4	95	ClF_3	99	NH_3	99	SF_6	99	3MS	99
C_2F_6	99	CO	99	NO	95	TCS	99	4MS	99
C_3F_8	99	DCS	99	NO_2	99	TDEAT	99		
C_4F_6	99	F_2	99	N_2O	98	TDMAT	99		
C_4F_8	99	GeH_4	99	OMCTS	99	TEOS	99		
C_5F_8	99	HBr	99	PH_3	99	$TiCl_4$	99		

Note – H_2 capacity up to 150 slm, high flows require SS tank & plumbing option