General Atomics Electromagnetic Systems Group

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The use of GA's Commercial Supercritical Water Oxidation for the Destruction of Organic Waste

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John Follin, GA EMS Director of Strategic Development, Supercritical Water Oxidation

GENERAL ATOMICS
ELECTROMAGNETICS

General Atomics

LOCATION: San Diego, California

FOUNDED: 1955

STATUS: Privately held corporation

John Follin
Director
Strategic Development / Business Development
Demilitarization and Chemical Waste Destruction
John.Follin@ga.com

GA is a recognized world leader in high-technology research, design, and production for industry and government in the U.S. and overseas

General Atomics Organization

General Atomics
La Jolla, California

Energy
La Jolla, California

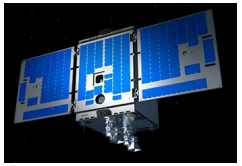
- Nuclear Fission
- Inertial Confinement
- Nuclear Fusion

Aeronautics
Poway, California

- Predator
- Grey Eagle
- Ground Services
- Mission Related Activities

Electromagnetics
Rancho Bernardo California

- Electromagnetic Launching
- Lasers
- Satellites
- Railgun
- Radiation Monitoring
- Gulftronics
- Demil / iSCWO / Maglev



What Differentiates between GA and other suppliers?

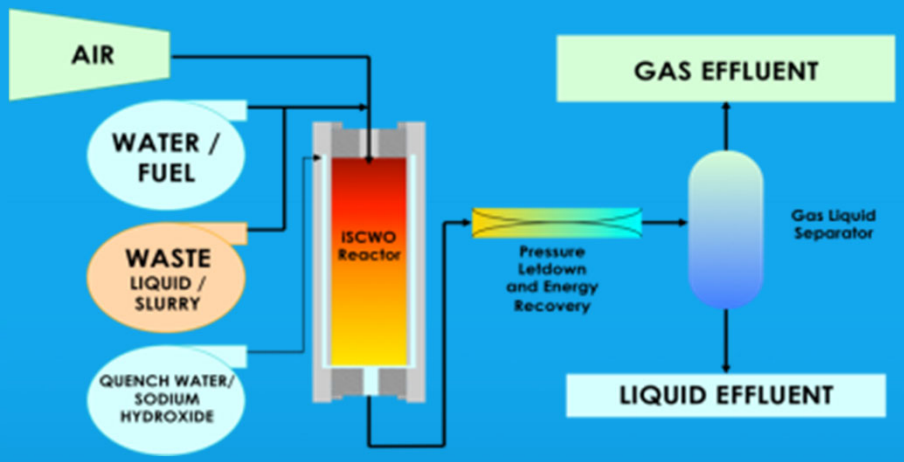
- **Worked with other methods of organic destruction – selected iSCWO**
- **Vast iSCWO experience with various waste feeds and salt/corrosion solutions – 35 years / Military Sales mid 2000's / Commercial Sales 2013**
- **GA is a large company – very healthy with a great future in all areas**
- **GA Worldwide iSCWO Sales Organization Structure (Life Cycle Support)**
  - Waste analysis and waste testing at GA
  - Contract sales / leases – GA's iSCWO system is a TRL 9 – *we sell real systems*
  - Fabrication/assembly at our fabrication facility in Tupelo, Mississippi
  - Factory Testing at GA in San Diego, Ca
  - Shipping, installation, checkout, startup and training support
  - After market support – field service, spare parts, process support
- **GA offers various configurations of iSCWO Systems (3 gpm to up to 10 gpm units) with different types of liners for material compatibility**
- **Experience with interfacing feed support (liquid, powders, solids)**
- **Our iSCWO product line is classified as EAR99 (Export Use)**
- **Full safety documentation (HAZOPS)**

Use of GA's iSCWO in Industrial Environments

iSCWO is excellent for the destruction of:

- Expired or obsolete pesticides, fertilizers, and fungicides
- Contaminated water (waste water cleanup)
- Expired or obsolete paints
- Petroleum, oils, lubricants and/or petrochemical waste streams
- Polychlorinated biphenyls (PCBs)
- Organic cleaning solutions and antifreeze
- Sewage sludge/animal waste products
- Pharmaceutical waste
- Fire retardant materials
- Plastic waste
- Energetic material (explosives or propellant)
- PFAS and other fluorinated organic compounds
- Materials not suitable for normal transportation or disposal

iSCWO: Technical and Cost Advantages



- Perfect for onsite waste destruction
- Cost competitive with incineration or any other oxidation process at the site
- No airborne particulates
- No afterburner or complex secondary processing equipment
- Clean water by-product requires little or no post-treatment prior to discharge to POTW
- Air supply for oxidant instead of LOX
- Simple design – easily maintainable
- Waste stream testing in San Diego

Rapid, complete organic destruction with no pollution abatement system

What we offer – Commercial Modular iSCWO Systems

Stationary iSCWO skid

Two transportable iSCWO systems

Systems are sold and delivered as viable commercial systems – ready to run

Modular design allows for rapid setup and start of process operations without the need for complex infrastructure

Multiple Options for iSCWO Waste Feed

- **Liquid feed**
  - Generated by in-line process or liquids stored onsite
  - Pumped directly into the iSCWO system

- **Slurry Feed**
  - Powdered solids (e.g., pesticides or pharmaceuticals) in water
  - Ground-up solids (resins or GAC) in water solution
  - Size-reduced solids pumped directly into the iSCWO system

- **Reverse Osmosis (RO)**
  - Large Amounts of Contaminated Water
  - RO reject stream (stew) is pumped into the iSCWO system

- **Thermal Desorption (TD)**
  - Contaminated Soil Cleanup (e.g., PCB)
  - TD waste stream (scum) is pumped into the iSCWO system

- **Gaseous Diffusion (GD)**
  - Contaminated Hardened Material
  - GD waste stream is condensed and pumped into iSCWO

Micronized Feed for Slurry Feeding into iSCWO

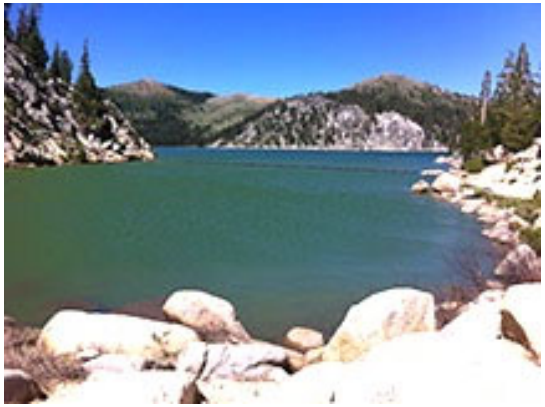
Wood

Carbon

Plastics/Rubber

Slurry

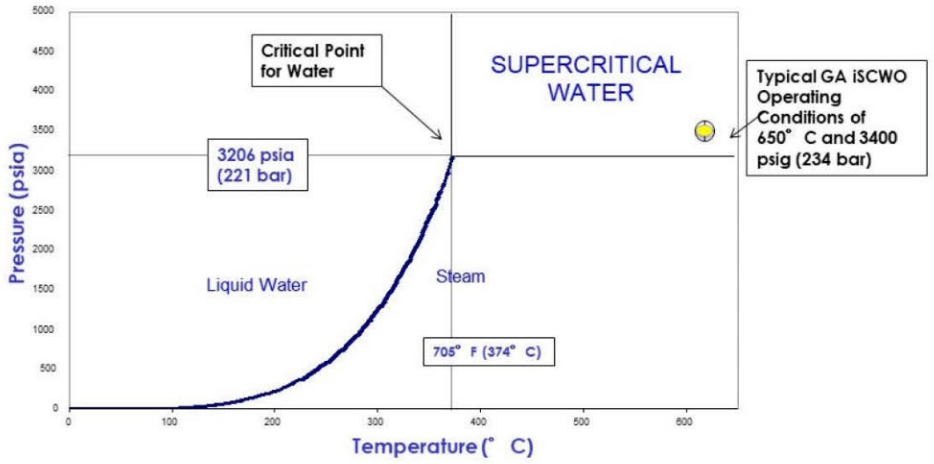
iSCWO Release Streams Meet Environmental Requirements



Waste Feed	Gas Release	Liquid Release
Hydro Carbon	O_2 CO_2 Nitrogen Water vapor Organic free	Organic-free water Neutral pH
Halogens		Some salts (depending on chemical feed)
Metals		Metallic oxides particles (depending on chemical feed)
-ites, -ates O_2 O_3		Molecular oxygen can reduce the amount of cfm needed by air compressor

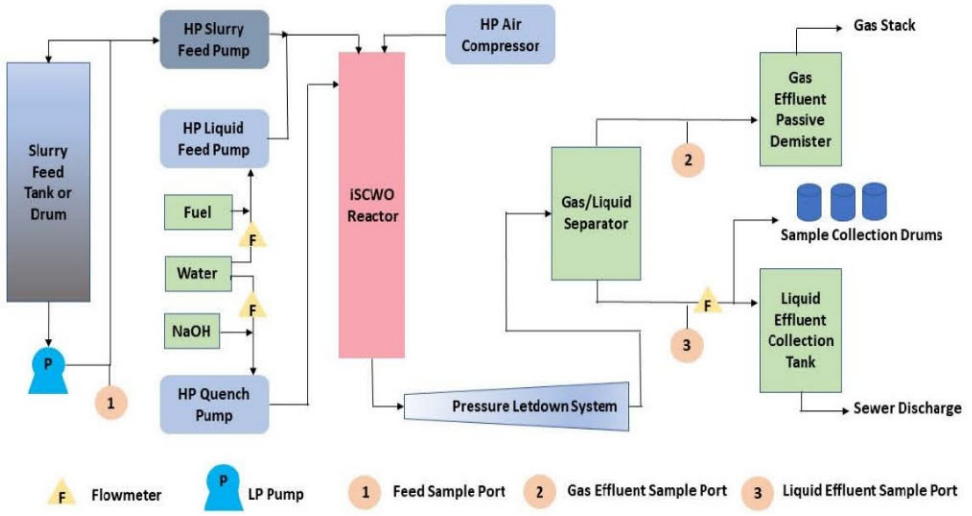
All Liquid Releases Designed for Discharge Directly to a Public Owned Treatment Works (POTW)

GA iSCWO Typical Process Flow Setup



Supercritical water is water that is heated and pressurized above its thermodynamic critical point of 374°C and 221 bar

We operate at 650°C and 234 Bar to ensure complete oxidation of wastes



- A wide variety of wastes can be fed into the iSCWO system
- GA's iSCWO system nominally operates at 3400 psi and 650C for the complete destruction of organic waste
- Stack gases released are excess O_2, CO_2, N_2 (from the air), and H_2O (steam)
- Liquid releases are H_2O plus any salts created by the neutralization of halogens
- System operates in a continuous feed mode 24 hours / 7 days a week

GA sells Commercial iSCWO Systems for Onsite Waste Destruction

GA iSCWO Demonstration System – No R&D – TRL 9

iSCWO System used for different chemical waste treatment tests

Dedicated iSCWO Test Facility that customers can observe tests

No R&D – Just confirmatory tests for both process and environmental regulatory permits

System arrangement allows for easy tests with data analysis

GA iSCWO Test Setup – Waste Material Input

All types of shipments accepted – Tanker Truck, 55 Gallon Barrels, Chemical Storage Totes and/or Specialized Tanks

GA iSCWO Demonstration Test Results

Liquid and Gas Analytics are Performed by Independent Laboratories and Results sent to Customer and Government Permitting Officials

Recent Halogenated Organic Destruction Tests*

Material	Matrix	Feed Concentration	Throughput (gallon/min)	Quantity processed (gallons)	Destruction Efficiency	Comments
CCl_4 / CS_2	Liquid	100%	0.052	107	99.999%	Non-detect
Tear Gas	Slurry	10% solids	1.6	425	99.99%	Non-detect
1,4-Dioxane	Liquid	0.4%	1.6	107	99.9%	Non-detect
Bromine-Polymer Wash	Liquid	1%	1.1	14	99.99%	Non-detect

*Note – the feed concentration, rates, and quantities were defined by the customer

Recent Slurry Organic Destruction Tests*

Material	Matrix	Feed Concentration	Throughput (gallon/min)	Quantity processed (gallons)	Destruction Efficiency	Comments
Mining ore with gold	Slurry	10% solids	1.1	420	99%	Improved gold extraction
Plastics	Slurry	10% solids	1.1	95	99%	Non-detect
Food waste	Slurry	10% solids	1.1	55	99%	Non-detect
Ground resin beads	Liquid	15% solids	2.2	1060	99.9%	Solids reduction

*Note – the feed concentration, rates, and quantities were defined by the customer

Other Recent Organic Destruction Tests*

Material	Matrix	Feed Concentration	Throughput (gallon/min)	Quantity processed (gallons)	Destruction Efficiency	Comments
Energetics Waste (NH_4NO_3)	Liquid	25%	2.5	1,060	99.99%	Non-detect Air bypass to reduce NOx
Organics containing NaI and CsCL	Slurry	10%	1.2	95	99%	Non-detect
EDTA with hydrazine	Liquid	15%	3.9	1,075	99.99%	Non-detect
Corrosive Solvent Waste	Liquid	15%	2.2	400	99.9%	Non-detect
Cresylate	Thick Liquid	20%	1 – ntrlzd 0.5 – nt ntrlzd	215	99.99%	Non-detect

*Note – the feed concentration, rates, and quantities were defined by the customer

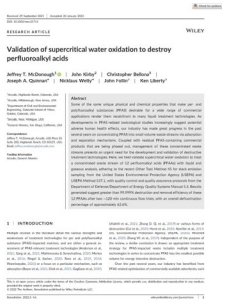
PFAS Destruction Efficiency via iSCWO

Destruction of PFAS efficiency: >99.99% for multiple tests

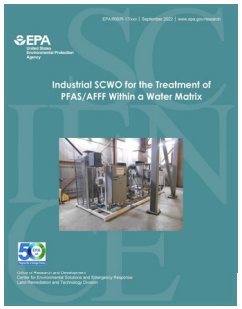
Materials Tested for DRE Calculations Include:

- Aqueous Fire Fighting Foam (AFFF)
- 6:2 fluorotelomer sulfonic acid (6:2 FTS)
- Perfluorooctanesulfonic acid (PFOS)
- Integrated Derived Waste (IDW)

Published Reports



Arcadis



EPA

Test	Total Processed	Dilution of Waste	PFAS Feed	Source of Material	Destruction Efficiency
Test 1 AFFF	253 gal	1000x	~30 ppm	Lightwater	99.9996%
Test 2 AFFF	252 gal	1000x	~30 ppm	Lightwater	99.9996%
6:2 FTS	350 gal	0x	210 ppb	Fire pit wash	99.9929%
PFOS	350 gal	0x	1700 ppt	IDW	Non-detect
Test 1 AFFF	310 gal	159x	~194 ppm	Aer-O-Water	~99.999%
Test 2 AFFF	302 gal	152x	~199 ppm	Aer-O-Water	~99.999%
Test 3 AFFF	310 gal	34x	~974 ppm	Aer-O-Water	~99.999%

Targeted PFAS Summary with Fluoride Concentration Analysis

PFAS average DRE > 99.99%
Test C (highest influent conc.) DRE > 99.999%

- **Targeted 21 PFAS in AFFF waste feed**
- **DRE does not fully reflect iSCWO's capabilities**
  - Non-detect PFAS amounts default to method limits
  - PFAS present in San Diego tap water used to quench liquid effluent

Test	Influent Sum of Targeted PFAS (ppt)	Effluent Sum of Targeted PFAS (ppt)	%DRE Targeted PFAS	Influent Fluoride‡ (ppm)	Effluent Fluoride‡ (ppm)	Theoretical fluoride from targeted PFAS* (ppm)	Theoretical PFAS from Fluoride* (ppm)
A	3,128,300	51.56	99.9984	0.81	173.61	1.86	289.35
B	3,294,600	82.03	99.9975	0.78	235.29	1.96	392.16
C	13,640,000	30.32	99.9998	1.5	482.21	8.07	803.68
Average DRE:			99.9985				

PFAS remaining - PFBA, 6:2 FTS, and sulfonates (C4-8) - undetermined whether from water or system

Effluent values include dilution factor of about 1.5 due to higher liquid flow from separator (~12 Lpm out vs ~8 Lpm in)

Effluent values from 120 minutes sampled

* Assumes 60% Fluorine content in associated targeted PFAS
‡ ~0.8 ppm fluoride typical in SD tap water

Non-detect of corrosion products

Air emissions from the iSCWO system would be considered *clean*

VOCs detected are *not* fluorinated

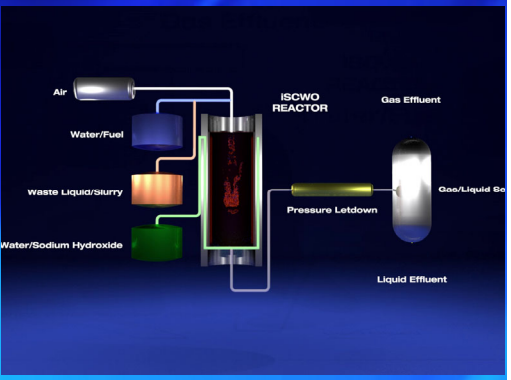
Most SCWO system and incinerator gas emissions have not been tested for PFAS release – GA's iSCWO has

Upcoming iSCWO Tests planned for CY 2023

- Explosive waste
- Whole resin beads
- Agent Orange
- Pesticide and Herbicide waste (Chloral, Chlorobenzene and DDT)
- Organic mixed waste containing nuclear isotopes (simulants such as cerium, cesium and iodine)
- Biosolids wastes
- Pharmaceutical waste (Isomers)
- Landfill Leachates
- Ground up baghouse filters containing organics and PFAS material

- Large PFAS projects planned for CY 2023 including GAC destruction

Conclusions



- Simple to operate, automated and easy maintenance
- iSCWO is an excellent waste destruction process suitable for ***onsite*** treatment of organic wastes at affordable cost
- iSCWO is fully capable of destroying a wide range of pumpable hazardous waste including AFFF / PFAS to strict environmental standards
- Mobility for multi-site waste destruction
- iSCWO systems use air rather than liquid oxygen which makes the processing site easier to permit and eliminates a number of safety issues related to LOX systems
- No pollution abatement system necessary to meet environmental regulations
- GA has 35 years experience with SCWO systems – no R&D
- GA provides testing capability and effluent analysis for customers – know before you buy

Contact Information

Thank you very much for your attention!

Any questions – please reach out!

John Follin
Director, Strategic Development / Business Development
Demilitarization and Chemical Waste Destruction
General Atomics Electromagnetic Systems Group
1 858 964 6805 (office)
John.Follin@ga.com

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