

HONEYWELL CFX™ **FOR PFAS WASTE DESTRUCTION**

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Honeywell
UOP

FLUORINATED WASTE / DISCHARGE PERSISTENT THROUGHOUT CHEMICALS INDUSTRIES

Coatings

Fluorinated Acrylates & Methacrylates | PTFE |
PVDF | Perfluoroalkyl Sulfonates | PFPE | Side-
Chain Fluorinated Polymers | CF_4 | C_2F_6 | PFH/O

Dispersions

PFOA | PFOS | PFBS | FTOHs | PFPE | Side-Chain
Fluorinated Polymers

Surfactants

PFCAs | PFSAAs | FTOHs | Perfluoroalkyl Ethers

Sealants

PFCAs | PFSAAs | Fluoropolymers | FTOHs | PFPEs

Resins

Fluorinated Methacrylates | PFPE | Fluoroalkyl
Silanes | Small-Chain Perfluoroalkyl Acids | CF_4 |
 C_2F_6 | PFH/O | PFPE

Films

PFCAs | Fluorotelomers | Fluoropolymers | PFPEs

Membranes

ETFE | Fluoropolymers | PFSA | FTOHs | PFPEs

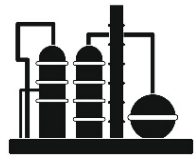
Lubricants

PFPE | PTFE | Fluorinated Coating

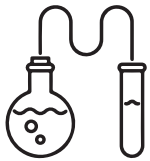
HONEYWELL CFX™ — ADVANCED OXIDATION SYSTEM



Up to **1400 °C**
stable operation



1-1200 GPH
capacity



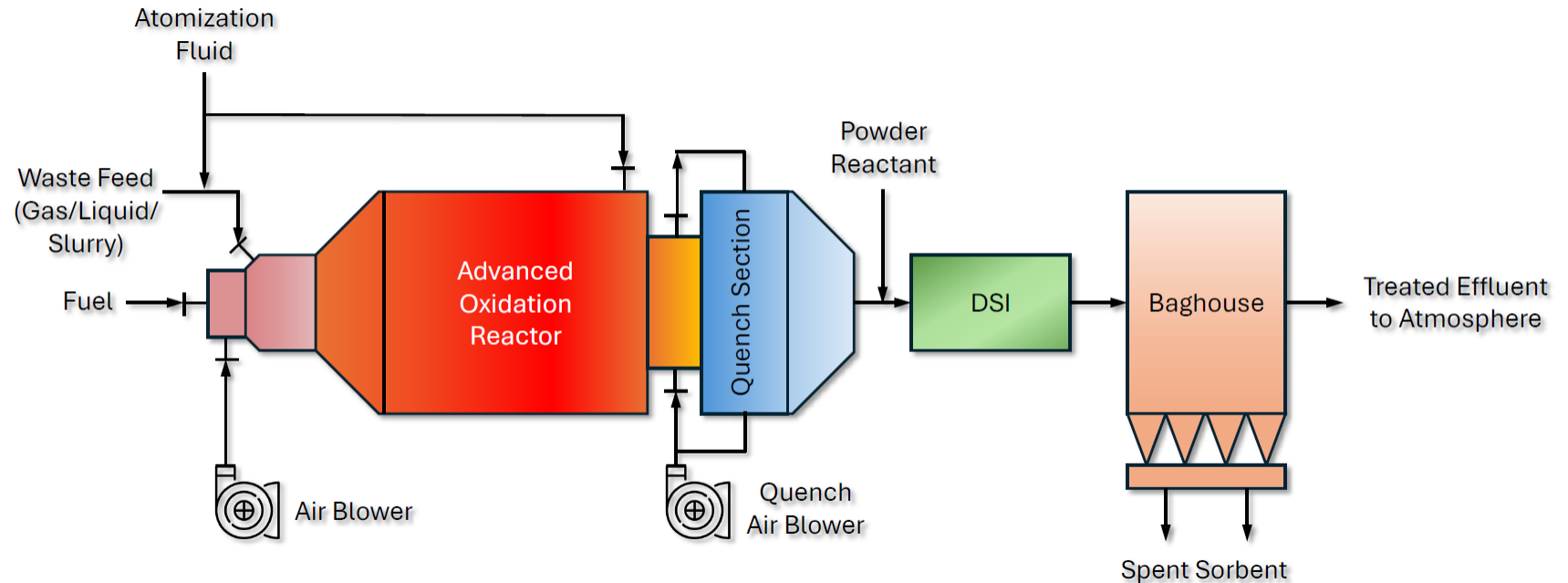
Designed
for **CF₄ destruction**



Zero liquid waste
discharge



Automated
with minimal maintenance



CF₄ DESTRUCTION SIGNIFICANCE

C—F BONDS

C—F is the **strongest** single **bond** in organic chemistry—dissociation energy of **485 kJ/mol**

- Short bond length of 1.35 Å—small atomic radii of C & F
- Large electronegativity difference between C & F makes for strong electrostatic attraction

CF₄ is comprised of **100% C-F bonds**

C-CHAIN LENGTH

Based on number of carbons—the shorter the molecule, the stronger it is

CF₄ has **no C—C** bonds nor functional end groups—no weak sites to initiate attack

MOLECULAR SYMMETRY

Perfectly symmetrical—tetrahedral geometry, minimizing electron-electron repulsion

109.5° bond angles—most stable for 4 electron pairs around central C atom

STABILITY

1,200°C+ uniform temp for decomposition—inert to many reagents, acids, & hydroxides

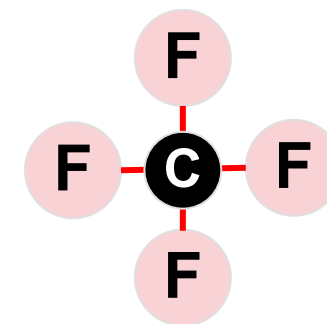
50,000-year atmospheric lifetime—potent GHG—**7,390 times** the **GWP** of CO₂

INCOMPLETE DESTRUCTION BYPRODUCT

Occurrence of fragmentation, generating fluorinated radicals: CF₃•, CF₂•, CF•, F•, with **most stable** endpoint being CF₄

- Molecular strength of **CF₄** makes it an effective **chemical dead-end** (with **other destruction techs**)

CF₄ **destruction** is **benchmark**



for **measuring** fluorocarbon **destruction** efficiency

HONEYWELL CFX™ — FOR PFAS WASTE DESTRUCTION

TECHNOLOGY	APPLICABILITY
■ Optimized by 30+ years of experience destroying PFAS waste ■ Leverages Honeywell Automation for consistency of operation, safety, and personnel avoidance ■ Sustains 1,400°C throughout reactor for complete destruction	■ CFX already destroys the same breadth of halogenated (& other) compounds across the chemical manufacturing industry ■ Proven >99.998% DRE for ultra-short chain C-F gas at scale ■ 15 systems worldwide continuously destroying severe & highly concentrated ultra-short & short-chain carbon-fluorine waste
VALUE	BENEFIT
■ Unique consolidated PFAS destruction technology that efficiently handles all phases and a variety of media at commercial scale ■ Leverages caloric value of waste, like organics, for energy savings while avoiding disposal fees and logistics costs ■ Seamless integration with a broad range of pretreatment capture and concentration technologies	■ Wide and variable feed acceptance allows for improved operational flexibility ■ High throughput and long equipment life allows for low-cost solution, ≤\$1/gallon OpEx for liquids / slurries ■ Recycled CaF₂ byproduct helps address global supply shortage and reduces reliance on imports (i.e., China)

HONEYWELL CFX™ — HOW IT WORKS

SYSTEM DESIGN

- Targeted **placement** of varied **injection ports** specific to **waste feeds' phases** and chemistries
- Built on **proprietary metallurgical** architecture and **special refractory** for **corrosion-resistant** halogenated waste destruction
- **Low** system **pressure** drop **eliminates** the need for upstream **compressor**

EXCESS OF HYDROGEN RADICALS

- **•H** is sourced from fuel (usually natural gas), organics (like ethanol, which also lowers energy costs), and **water / steam**
- **•H** radicals are **highly reactive** to **form HF** as an **intermediate**
- Thus **avoiding** (reversible) **carbon-fluorine recombination** reactions and **stoichiometrically** ensuring destruction of ultra-short chain C-F-gases for **optimal** destruction removal **efficiency**

EXTREME HEAT — 1,400°C

- Needed for near-**complete destruction** of very **strong carbon-fluorine bonds** (with **dissociation energies** up to **485 kJ/mol**)
- Used to **destroy ultra-short** chain gaseous **C-F** species
- For increased reaction kinetics, enabling **shorter residence times** for **greater** overall **throughput**
- Quickly creating carbon radicals and **fluorine radicals**

MINERALIZATION OF FLUORINE

- Dry **sorbent injection**, using lime, allows calcium to react with the HF intermediate to **produce** a **recycled CaF₂**
- By 2035, CaF₂ **demand** is projected **to surpass supply by 40-70%** – highlighting the need for **circularity**
- United States & Europe rely heavily on CaF₂ **imports** from China, Mexico, Vietnam, Mongolia, Pakistan, and Afghanistan

HONEYWELL CFX™ — DIFFERENTIATED OFFERING

	Honeywell CFX™	Plasma	Catalytic Reduction	Incineration	SCWO	HALT	ECO
Scalability	15 Systems at Industrial Scale	Point-of-Use	Small Scale / Lab Systems	Commercial	Commercial / Pilot	Pilot	Bench and Pilot
Ultra-Short Chain DRE	99.998%	90 – 99.9%	60 – 95%	60 – 99.99%	TFA's shortest C-F with 99%	>90% for TFA	Unknown
Feed Compatibility	Gas, Liquid / Solvent, & Solid	Primarily Gas	Primarily Gas	Gas, Liquid, & Solid	Primarily Liquid	Primarily Liquid	Primarily Design Liquid
Residence Time	~1.5–2 seconds	<1 second	0.5–2 seconds	2–7 seconds	10–90 seconds	10–60 minutes	1–24 hours
Operational Simplicity	Runs Continuously via HON Automation	Power & Gas Flow Tuning	Reducing Gas Control	Feed Swings Impact Temps	Sensitive to Feed Changes	Batch / Semi-Batch	Limited by Electrode
Energy Efficiency	Steady-State, Heat Recovery	High Electrical Input	Lower Input, Less Effective	High Energy Demand	High Pressure	Chemically Assisted	Low Net Energy
Maintenance Needs	Minimal	Electrode Wear; Fouling	Catalyst Poisoning	Corrosion Checks	High Pressure	Chemical Control	Fouling Cleaning
Reliability / Life	>90% Uptime; >15 Year Life	Frequent Part Replacement	<1 year Catalyst Life	Refractory Lasts 1+ yrs	3–10 yrs, Liner	2–5 yrs, Batch Vessels	1–3 yrs, Electrodes

HONEYWELL CFX™ — ENCOMPASSING SOLUTION

	Solids (≤ 20wt% & 500µm)			Liquids			Gas
	Soil	spent GAC	spent IX	Still Bottom	Foamate	RO Reject	C-F Bonds
CFX	●	●	●	●	●	●	●
SCWO	●	●	●	●	●	●	●
HALT	●	●	●	●	●	●	●
Incineration	●	●	●	●	●	●	●
Ball Milling	●	●	●	●	●	●	●
Electron Beam	●	●	●	●	●	●	●

Developing Technologies

Limited applicability & **expensive**

Technically **challenging** & **slow**

Shortcomings of Others

Landfilling is future **liability**

→ **Incineration** can have **incomplete** destruction that releases to atmosphere

GAC reactivation has **limited** applicability

Solving the problem of diverse waste with a **one-stop** shop for **total destruction**

HONEYWELL CFX™ — READY-NOW AT INDUSTRIAL-SCALE

SUPERIOR

destroys strongest waste and highly persistent pollutants like PFOA, PFOS, GenX, biosolids, & industrial byproducts

SUSTAINABLE

avoids gaseous release of CF_4 , C_2F_6 , & C_3F_8 , which are 7,390 – 12,200 times the GWP of CO_2

ADVANCED

runs on Honeywell automation – avoids dedicated personnel

PRACTICAL

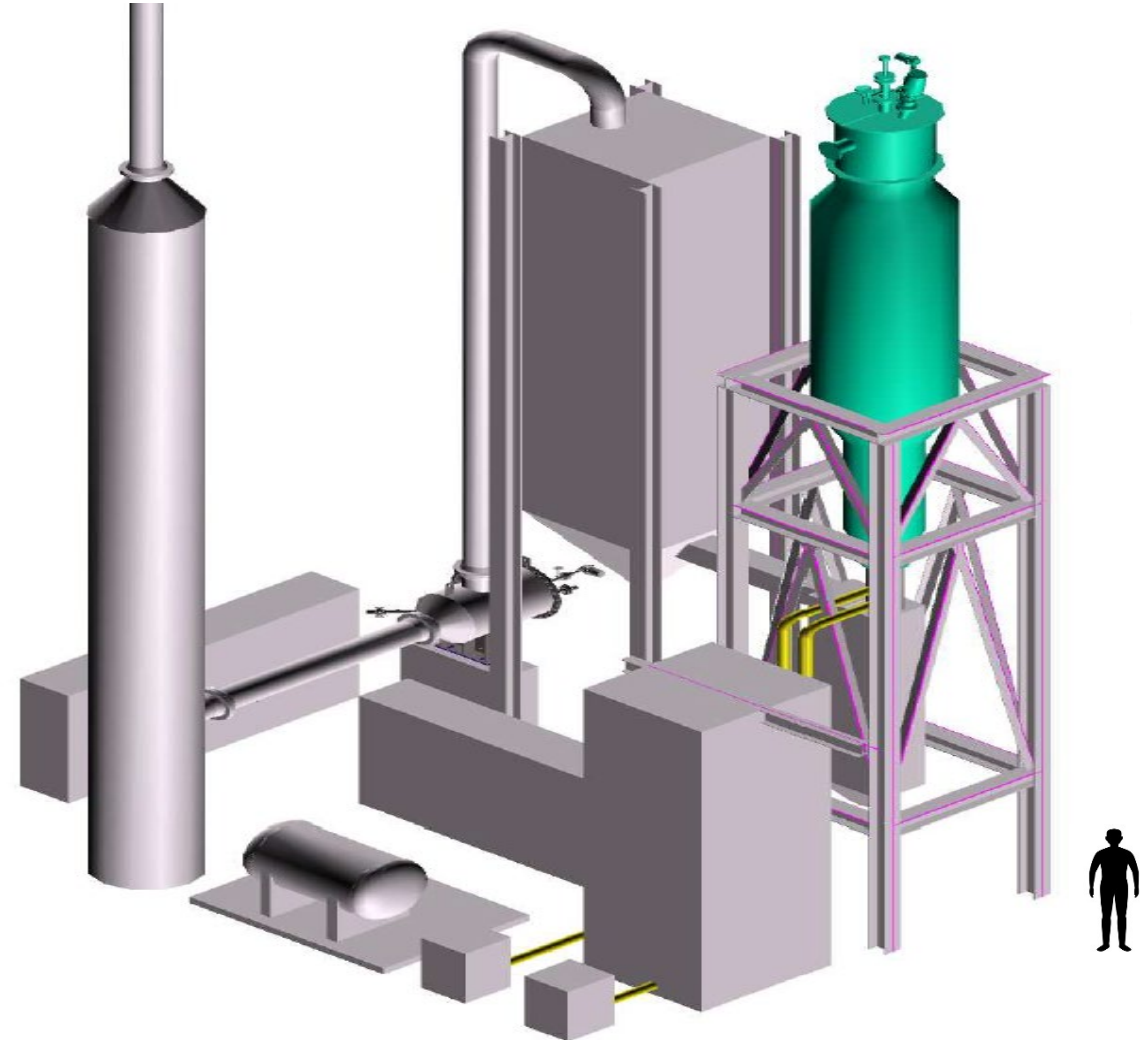
mature & ready-now with 30 years proven performance

RISK AVERSE

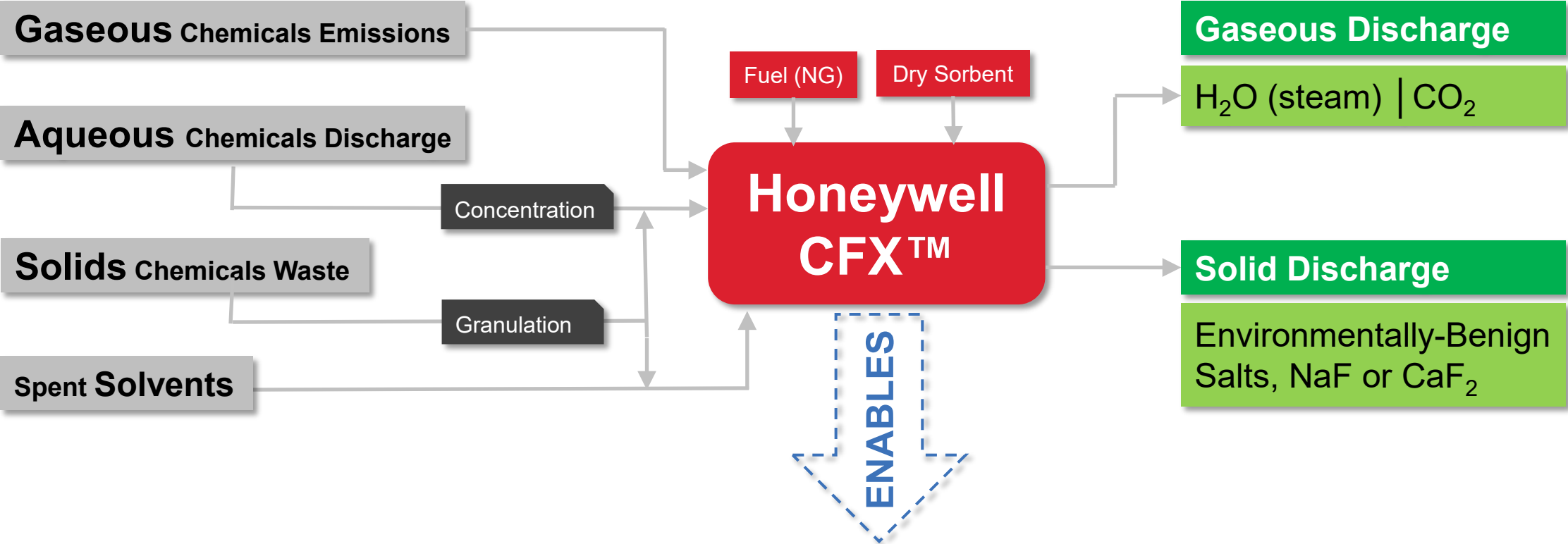
>99.99% destruction of all waste (ex-nuclear), **eliminating** landfilling & long-term contamination & liability risks

ECONOMICAL

high throughput and corrosion resistant for **MAX** system life



CHEMICALS PFAS WASTE DESTRUCTION VIA CFX



COMPLIANCE	AVOIDANCE	SUSTAINABILITY	SAVINGS
with current & future environmental regulations by minimizing releases	of LIABILITY common with disposals to landfills / wastewater	that is innovatively driven to achieve environmentally responsible corporate values & low GWP	by avoiding disposal logistics, insurance, & external charges and increasing asset uptime for greater rev.

SUSTAINABILITY SOLUTION

The **Honeywell CFX™** technology is a **proven** solution for managing challenging and diverse wastes effectively to avoid environmental threats & associated liabilities.

KEY FEATURES of Honeywell CFX™



High Success Rate

Eradicates over 99.99% of hazardous/toxic wastes.



Landfill Avoidance

No risk of landfill contamination to groundwater and soil.



Cost-Effectiveness

Eliminates disposal, logistics, insurance costs and liabilities with onsite solution.



Environmental Safety

No toxic emissions/byproducts – cleaner water and air for safer communities.