Technology for Space Station Evolution Workshop

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JSC ECLSS R&T Program Overview

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NASA - JSC

Technology for Space Station Evolution Workshop	Crew and Thermal Systems Division	
	A.F. Behrend	1-16-90

Content

- Advancements in Electrochemical CO2 Removal
- Supercritical Water Waste Oxidation
- Electrooxidation for Post-treatment of Reclaimed Water
- Photocatalytic Post-Treatment of Reclaimed Water

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Advancements in Electrochemical CO2 Removal

Objective

- Investigate and develop fundamental process enhancements in electrochemical CO2 removal

Benefit

- Improve performance and reliability
  - CO2 removal efficiency improvement (5-10% improvement achieved)
  - Cell composition improvement
  - Hydrogen feed elimination

Advancements in Electrochemical CO2 Removal

Technical Description

- Air passes through electrochemical cell where CO2 is absorbed at cathode and evolved at anode
- Electrochemical CO2 removal with hydrogen utilizes alkaline hydrogen/oxygen fuel cell reaction
  - O2 from air supplied at cathode where CO2 is absorbed
  - H2 supplied at anode where CO2 is evolved
  - CO2 reacts with hydroxyl ions (OH^-) to form carbonate and bicarbonate ions ($CO_3^=$ and HCO^-) which migrate to anode where heat energy from the fuel cell reaction releases the CO2
  - Half-cell reactions at both electrodes are thermodynamically spontaneous
  - Process generates electricity
- Same process can be carried out without supply of hydrogen
  - Series of reactions not spontaneous
  - Power must be supplied (approximately 105W/per person)

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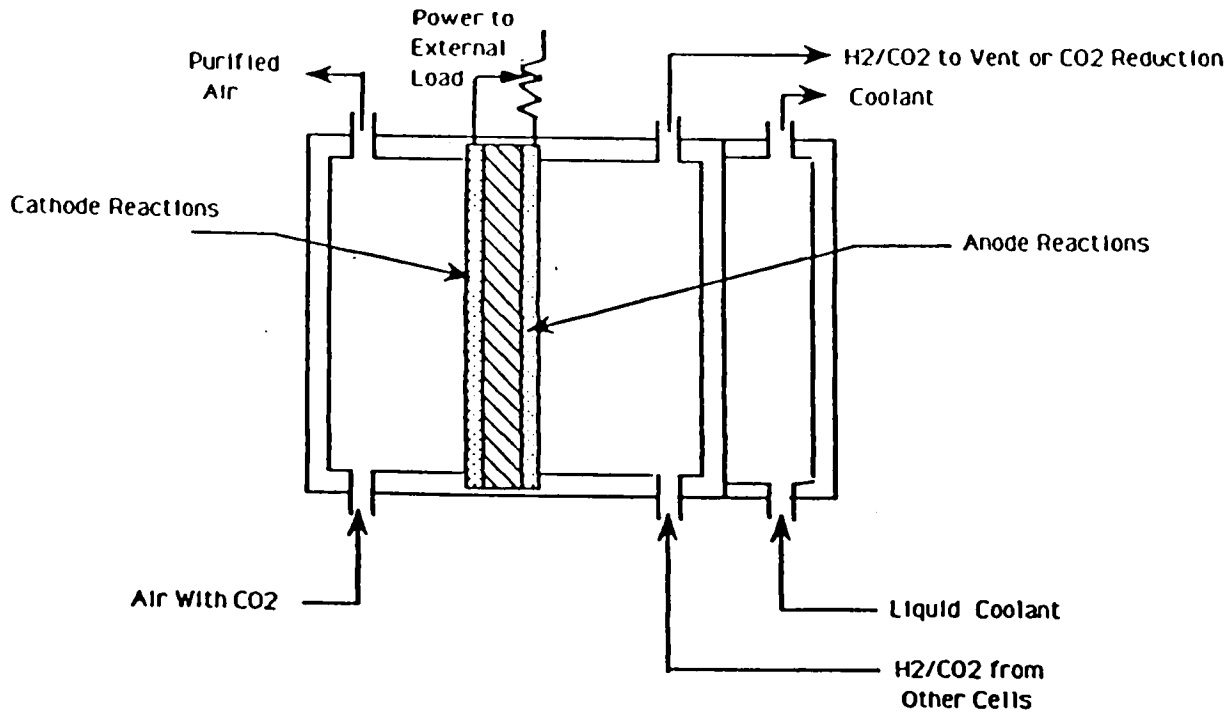
Advancements in Electrochemical CO2 Removal

$CO_3^=$ Transfer: $2CO_2 + 2H_2 + 2O_2 \rightarrow 2H_2O + 2CO_2$ + Electric Power + Heat

HCO_3^- Transfer: $2CO_2 + H_2 + 1/2O_2 \rightarrow 2CO_2 + H_2O$ + Electric Power + Heat

Schematic



Electrochemical Carbon Dioxide Removal with Hydrogen

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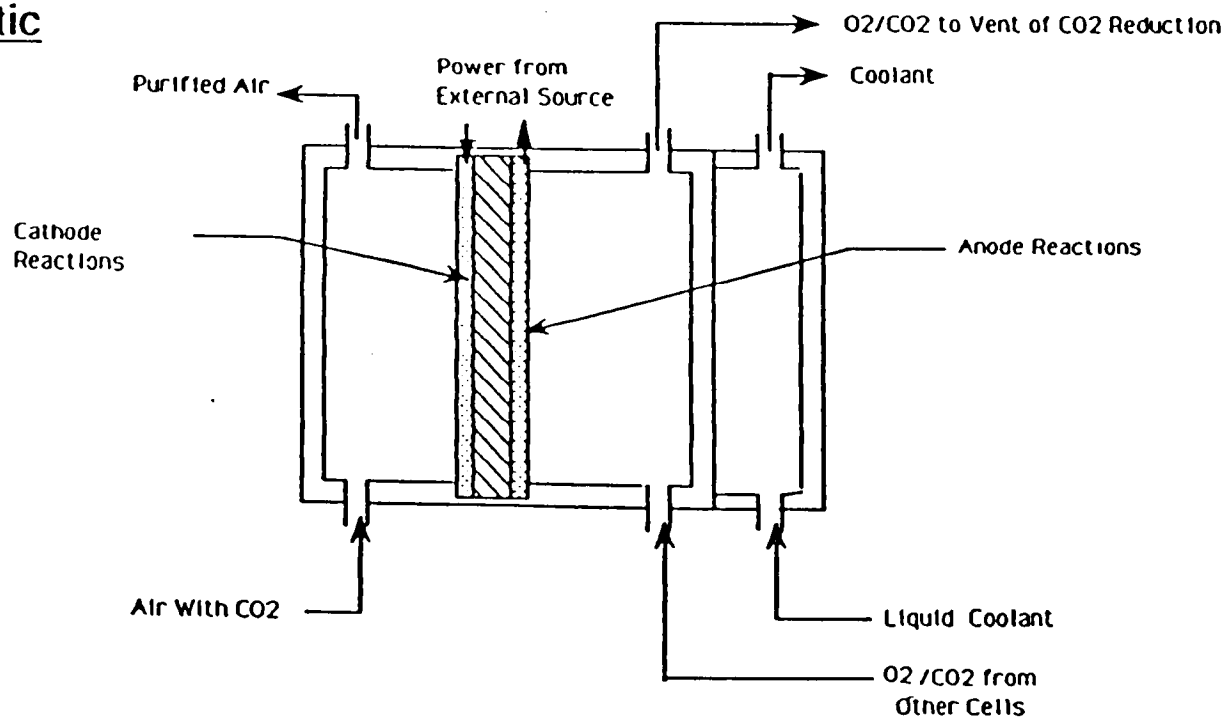
Advancements in Electrochemical CO2 Removal

$CO_3^=$ Transfer: $CO_2 + 1/2O_2 \rightarrow CO_2 + 1/2O_2$

HCO_3^- Transfer: $2CO_2 + 1/2O_2 \rightarrow 2CO_2 + 1/2O_2$

Schematic



Electrochemical Carbon Dioxide Removal without Hydrogen

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Advancements in Electrochemical CO2 Removal

Status

- Program with Life Systems, Inc./Texas A&M; Initiated in December 1987
- 2 year Phase I to investigate and develop fundamental process enhancements
  - Literature review to identify areas of study for improved performance and operational flexibility
  - Bench-scale laboratory testing of cell components to identify best candidates for integrated testing
  - Single cell unit design, fabrication, and testing
- Single cell testing being completed now
- 1 year Phase II for multi-cell unit design, fabrication, and test

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Advancements in Electrochemical CO2 Removal

Results

- Determined optimum electrocatalyst loading and binding agent content for gas diffusion electrodes
- Developed an improved electrode fabrication method using ultrasonic device for the dispersion of gas diffusion electrode components
- Proved that the electrolyte matrix thickness can be reduced to half of the baseline matrix thickness for improved performance without sacrificing the differential pressure capability
- Identified and developed electrode materials for the anode of the "without hydrogen" electrochemical CO2 removal cell

FY90 Activity

- Documentation of Phase I Results
- Initiation of Phase II Multi-cell Unit Design and Fabrication

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Supercritical Water Waste Oxidation

Objective

- Expand the fundamental understanding of the SCWO waste treatment process
- Determine reaction mechanisms and effect of SCWO process variables (temperature, residence time, feed concentration, pressure) for simple compounds - methane, ammonia, etc.
- Determine mechanism of reaction residue (salt) formation - rate, temperature, etc.

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Supercritical Water Waste Oxidation

Benefit

- System and crew waste approximately 6-8 lb/person-day (approximately 0.25 ft^3/person-day)

- SCWO process potentially
  - Reduces waste storage (35 ft^3 reduced to approximately 0.1 ft^3)
  - Produces excess water
    - o Enhanced hygiene
    - o Radiation protection supplement
    - o EVA support

Supercritical Water Waste Oxidation

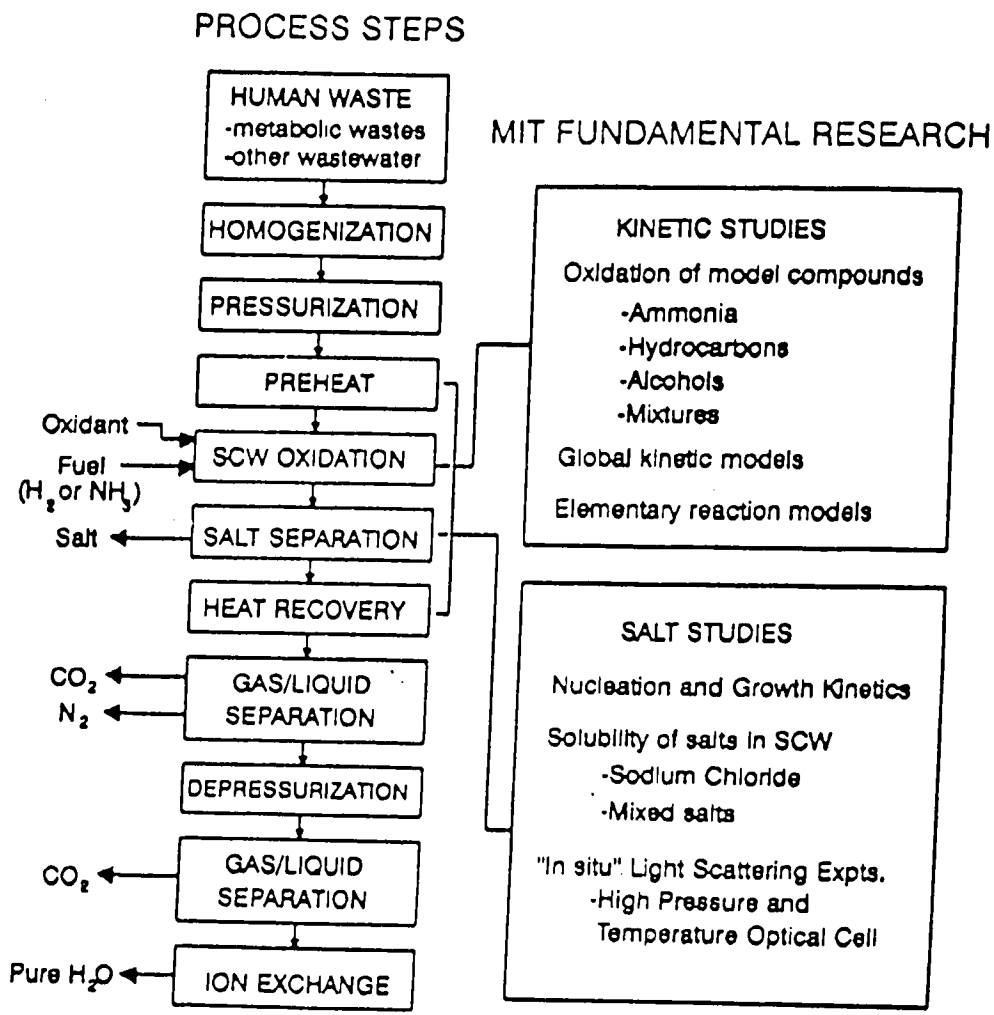
Technology Description

- SCWO process converts organic waste (feces, urine, trash) to carbon dioxide nitrogen, and water
- Process operation above the water critical point (3200 psia, 705 °F; 218 atm, 374 °C)
- Organic material is oxidized leaving reaction residue in the form of salts and oxides
- Process depends upon containment and removal of reaction ash

Status

- M.I.T. grant in final phase
  - September 1987 to September 1990
- Focus upon reaction kinetics and salt formation with analysis and experimental results

HUMAN WASTE TREATMENT AND RECYCLE BY OXIDATION IN SUPERCRITICAL WATER (SCW) (MODAR PROCESS)



Supercritical Water Waste Oxidation

Results

- Reaction kinetics
  - Expanded experimentsal capability to 700 °C, 300 atm
  - Measurement of kinetics and correlation to analytical models for carbon monoxide, ethanol, methanol, methane, ammonia, ammonia/ethanol, carbon monoxide/ethanol
- Salt formation
  - Completed test apparatus assembly and initial checkout with water
  - Initiated preliminary sodium chloride experiments
  - Progressing with numerical modeling of salt mixing and precipitation

FY90 Activity

- Complete salt nucleation and preciptiation experiments and modeling
- Expand kinetic database to examine pressure variation, alternate oxidants, dissolved salts, heat transfer rate

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ELECTROOXIDATION FOR POST-TREATMENT OF RECLAIMED WATER

OBJECTIVE

- DEMONSTRATE FEASIBILITY OF ELECTROOXIDATION TECHNIQUE FOR POST-TREATMENT OF RECLAIMED WASTE WATERS (DISTILLATES, PERMEATES AND HUMIDITY CONDENSATES) FOR POTABLE AND HYGIENE USAGE

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BENEFITS

- NEW COMPETING TECHNOLOGY FOR PURIFYING RECLAIMED WASTE WATERS
- NO EXPENDABLES
- REMOVES TOTAL ORGANIC IMPURITIES TO < 500 PPB
- SHOWS POTENTIAL FOR PROVIDING DISINFECTION

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ELECTROOXIDATION FOR POST-TREATMENT OF RECLAIMED WATER

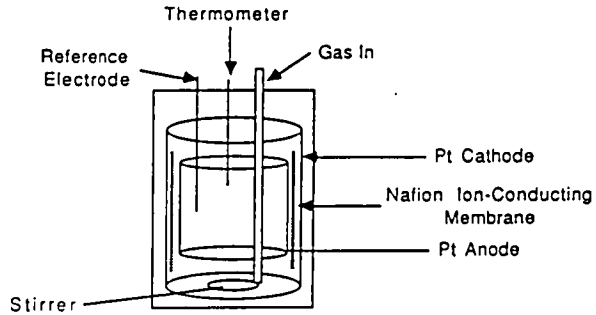
TECHNICAL DESCRIPTION

- ELECTROCHEMICAL CELL PROVIDES GENERATION OF STRONG OXIDIZING RADICALS (HO·)
- LIQUID ELECTROLYTE (0.7 M SODIUM PERCHLORATE)
- 170 W-HR REQUIRED TO OXIDIZE 50 PPM OF ORGANIC IMPURITY TO < 500 PPB IN 1 LITER OF WATER
- NO MOVING PARTS

STATUS

- GRANT INITIATED WITH TAMU IN APRIL 1989
- EVALUATING FEASIBILITY OF CONCEPT AND OBTAINING PARAMETRIC DATA FOR DESIGN AND FABRICATION OF A BREADBOARD SYSTEM
- COMPLETION OF RESEARCH GRANT IN APRIL 1990

ELECTROLYSIS TEST CELL: INCORPORATING AN ION-CONDUCTING MEMBRANE



TYPICAL DISSOLVED ORGANIC CONTAMINANTS

Acetic Acid: $CH_3COOH + 2H_2O \rightarrow 2CO_2 + 4H_2$

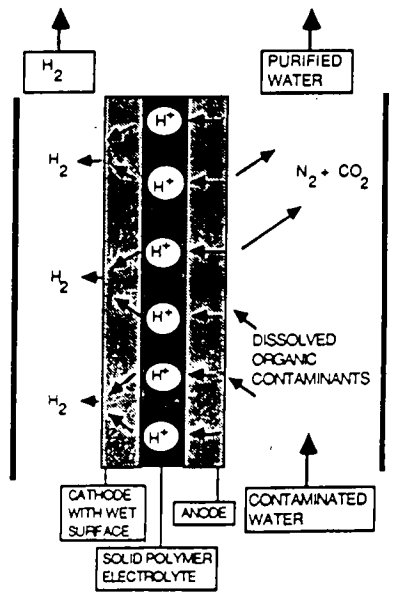
Benzoic Acid: $C_6H_5COOH + 12H_2O \rightarrow 7CO_2 + 15H_2$

Octanoic Acid: $CH_3(CH_2)_6COOH + 14H_2O \rightarrow 8CO_2 + 22H_2$

Urea: $NH_2CONH_2 + H_2O \rightarrow CO_2 + N_2 + 3H_2$

ORGANIC OXIDATION REACTIONS

SCHEMATIC OF ELECTROCHEMICAL WATER POST-TREATMENT UNIT



ELECTROOXIDATION FOR POSTREATMENT OF RECLAIMED WATER

FUTURE PLANS

- DEVELOP A BREADBOARD SYSTEM USING A SOLID POLYMER ELECTROLYTE FROM FUEL CELL TECHNOLOGY

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PHOTOCATALYTIC POST-TREATMENT OF RECLAIMED WATER

OBJECTIVE

- DEVELOP A BREADBOARD PHOTOCATALYTIC SYSTEM FOR POST-TREATMENT OF RECLAIMED WASTE WATERS (DISTILLATES, PERMEATES AND HUMIDITY CONDENSATE) FOR POTABLE AND HYGIENE USAGE

BENEFITS

- NEW COMPETING TECHNOLOGY FOR PURIFYING RECLAIMED WASTE WATERS
- REMOVES ORGANIC IMPURITIES TO LEVELS < 500 PPB
- PROVIDES DISINFECTION
- NO EXPENDABLES

PHOTOCATALYTIC POST-TREATMENT OF RECLAIMED WATERS

TECHNOLOGY DESCRIPTION

- ORGANIC IMPURITIES IN WATER ARE OXIDIZED BY POWERFUL OXIDIZING HYDROXAL RADICALS (OH•) AND HOLES (h +) PRODUCED WITH THE COMBINATION OF FINE METAL OXIDE CATALYST PARTICLES DISPERSED IN WATER WITH UV LIGHT AND DISSOLVED O2
- BATCH SYSTEM PROCESSES 12 LITERS OF WATER EVERY 2 HOURS
- SEPARATES CATALYST PARTICLES BY CROSS-FILTRATION THROUGH MICROPOROUS MEMBRANE
- RECOVERS PARTICLES FOR REUSE BY BACKFLUSHING OF MEMBRANE
- OPERATES CLOSE TO AMBIENT TEMPERATURE (35 ° C)

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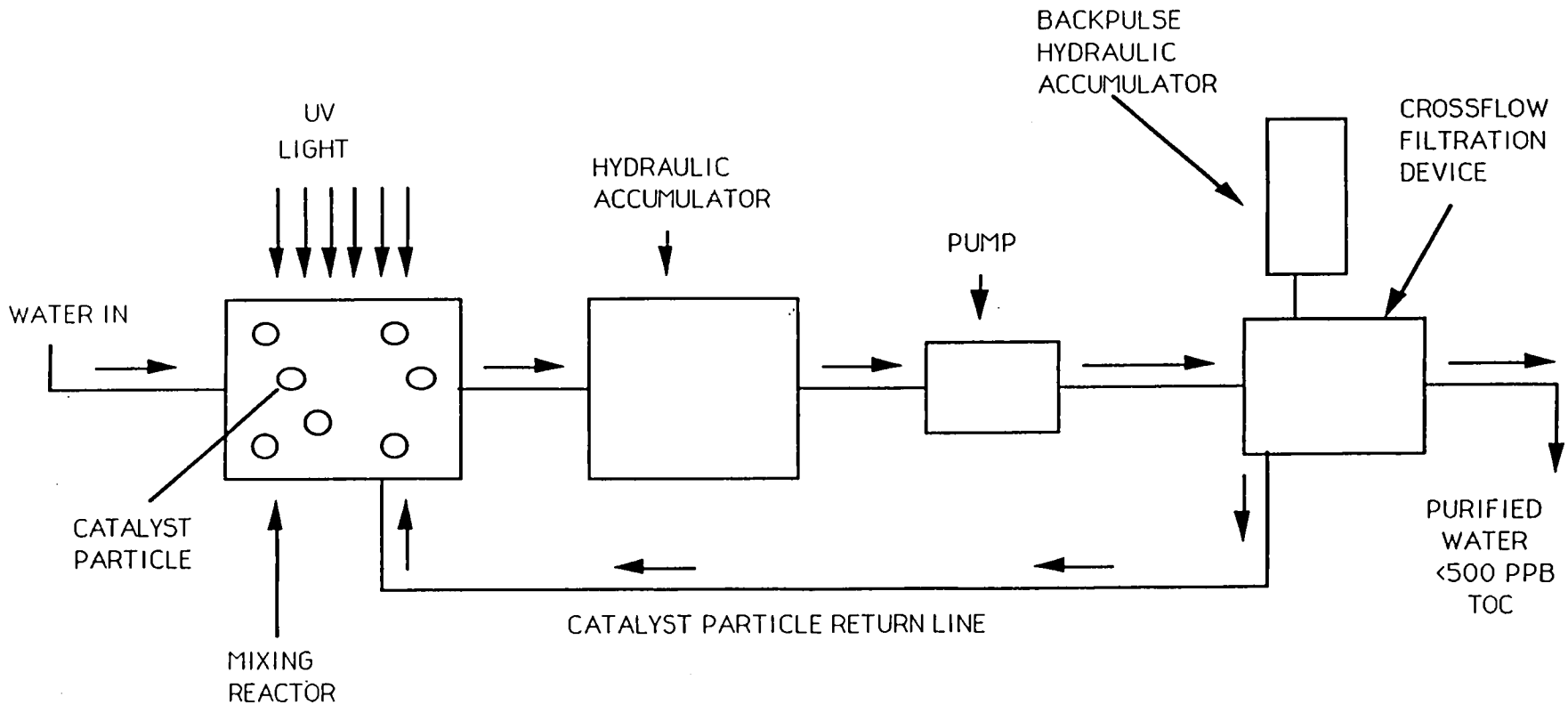
SCHEMATIC OF PHOTOCATALYTIC BATCH REACTOR POST-TREATMENT SYSTEM



POST-TREATMENT SYSTEM PROCESSES
12 LITERS PURIFIED WATER PER HOUR

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PHOTOCTALYTIC POST-TREATMENT OF RECLAIMED WATER

STATUS

- PHASE II SBIR WITH PHOTOCATALYTICS, INC. BOULDER, CO INITIATED IN APRIL 1987
- BREADBOARD SYSTEM IN FABRICATION AND SCHEDULED FOR COMPLETION FEBRUARY

FY 90 ACTIVITY

- TEST BREADBOARD SYSTEM WITH RECLAIMED WASTE WATERS TO DEMONSTRATE PERFORMANCE FOR
  - REMOVAL OF ORGANIC IMPURITIES TO < 500 PPB
  - DISINFECTION FROM 10 EXP 7 CFU TO O MICROORGANISMS
- CONTRACT COMPLETION IS APRIL 1990

FUTURE PLANS

- CONTINUE TECHNOLOGY DEVELOPMENT

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