



Advanced Oxidation Frac Water Recycling System

Rich Abrams

**Presented at the 20th International Petroleum
Environmental Conference**

November 13, 2013

About Bisco

- Leading global provider of soil and water remediation process systems since 1989
 - >5000 integrated systems
 - >3000 air strippers
 - 750 ozone units
- Based in Taunton, MA
- Acquired assets and IP from Kerfoot Technologies for Advanced Oxidation Technology (Perozone®)



17,500 Square Foot Fabrication/UL Panel Shop



BISCO Products & Systems

Technologies/Capabilities

1. Air Sparge/Soil Vapor Extraction
2. Dual Phase Extraction
3. Air Stripping - Low Profile
4. Controls & SCADA Design
5. Build-to-Print
6. Ozone / Peroxide Technology
7. **Water Clean Up Units**



Forty-foot Container Systems



Bisco/Kerfoot Background

- Bisco and Kerfoot Technologies formed a Strategic Alliance to provide ozone/Perozone[®] systems in 2011
- In December 2012, Bisco acquired the key technology assets from Kerfoot for:
 - Remediation below ground
 - water/wastewater treatment
 - Frac water recycling
- Patent estate consists of >40 patents on applications/equipment, including frac applications

Perozone Technology Overview

- Advanced Oxidation (AO) chemistry
- Aggressively oxidizes and breaks down contaminants to CO₂ and water, including recalcitrant materials
- Metals oxidized to filterable particulate
- Bacteria is killed
- Can be used below surface in soils and groundwater
- Primary applications are above ground to economically and efficiently clean up water

For Frac Water Applications, Enables Recycling

Extensive Ozone & Perozone[®] Experience

- Over 750 successful installations in Europe and the United States
- Fast, reliable remediation with difficult compounds/soils
- Perozone[®] has demonstrated cleanup in periods of months
- Treats numerous compounds

1,4 Dioxane

MTBE

Napthalene

TBA- Alcohols

Chloroalkanes

TPH – alkanes and alkenes

Chlorophenols – PCP, TCP

Chlordane

Heptachlor

Aldrin

Dieldrin

DDT/DDD

Creosote – Napthalenes

Perozone[®] and C-Sparge Chemistry

- C-Sparge[™] (microbubble ozone)



- Perozone[®] (peroxide-coated ozone)



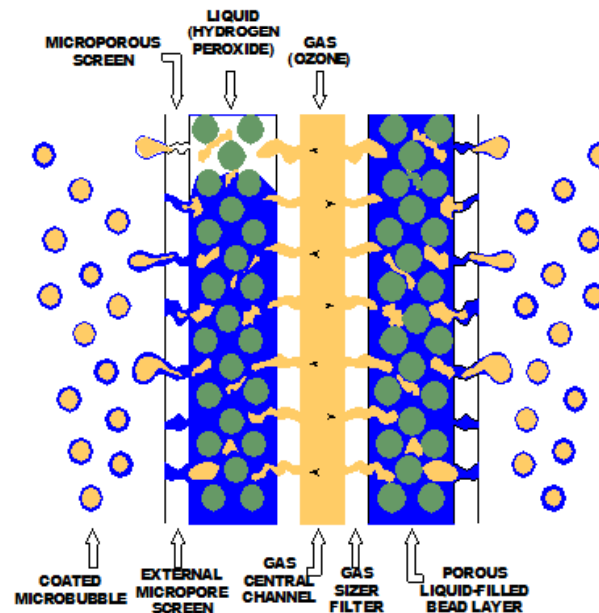
- Chemical reaction of Perozone[®] releases twice the hydroxyl radicals per mole of peroxide than Fenton's Reagent

The key to high performance is the use of the Kerfoot Spargepoint Injector

Perozone Injector

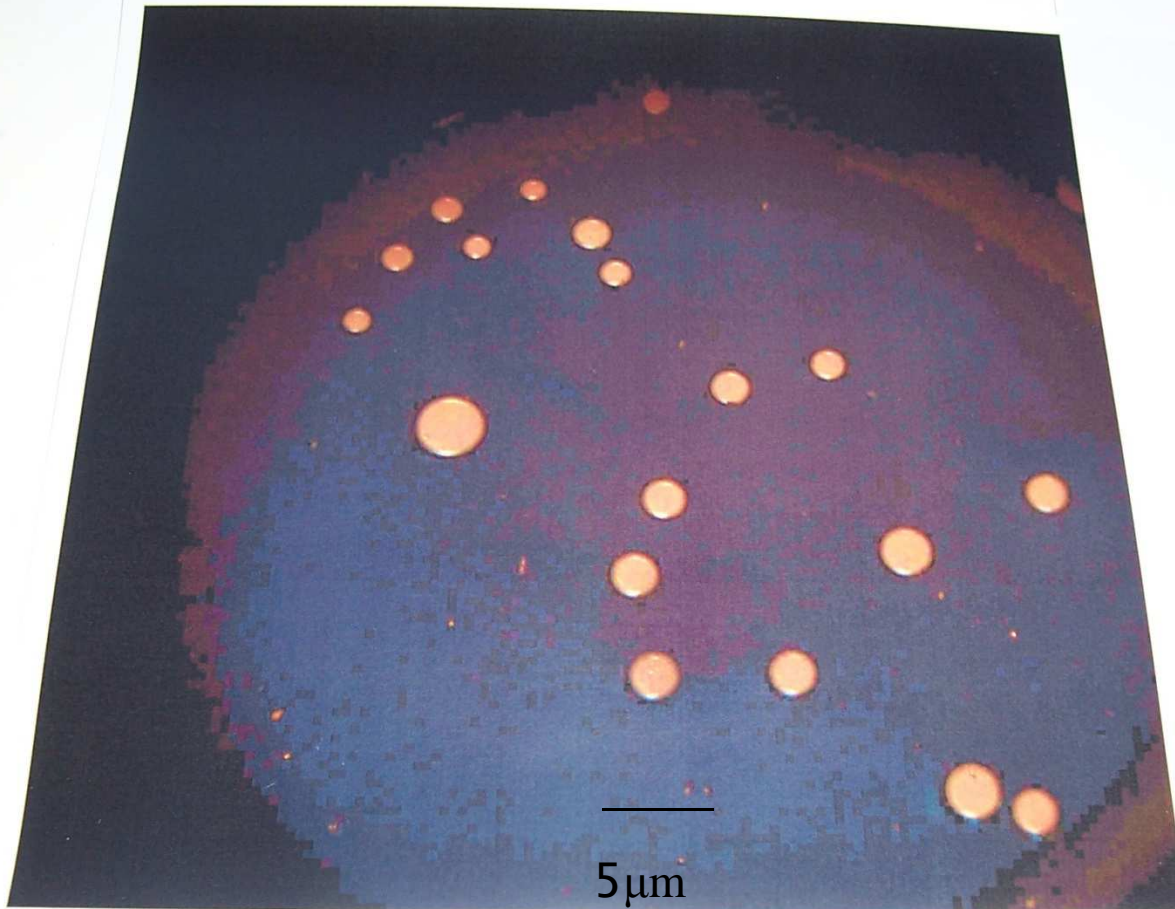
- Able to produce nanometer to micron sized peroxide-coated bubbles of ozone
- Generates extremely large surface area for reactions

FORMATION OF COATED MICROBUBBLES



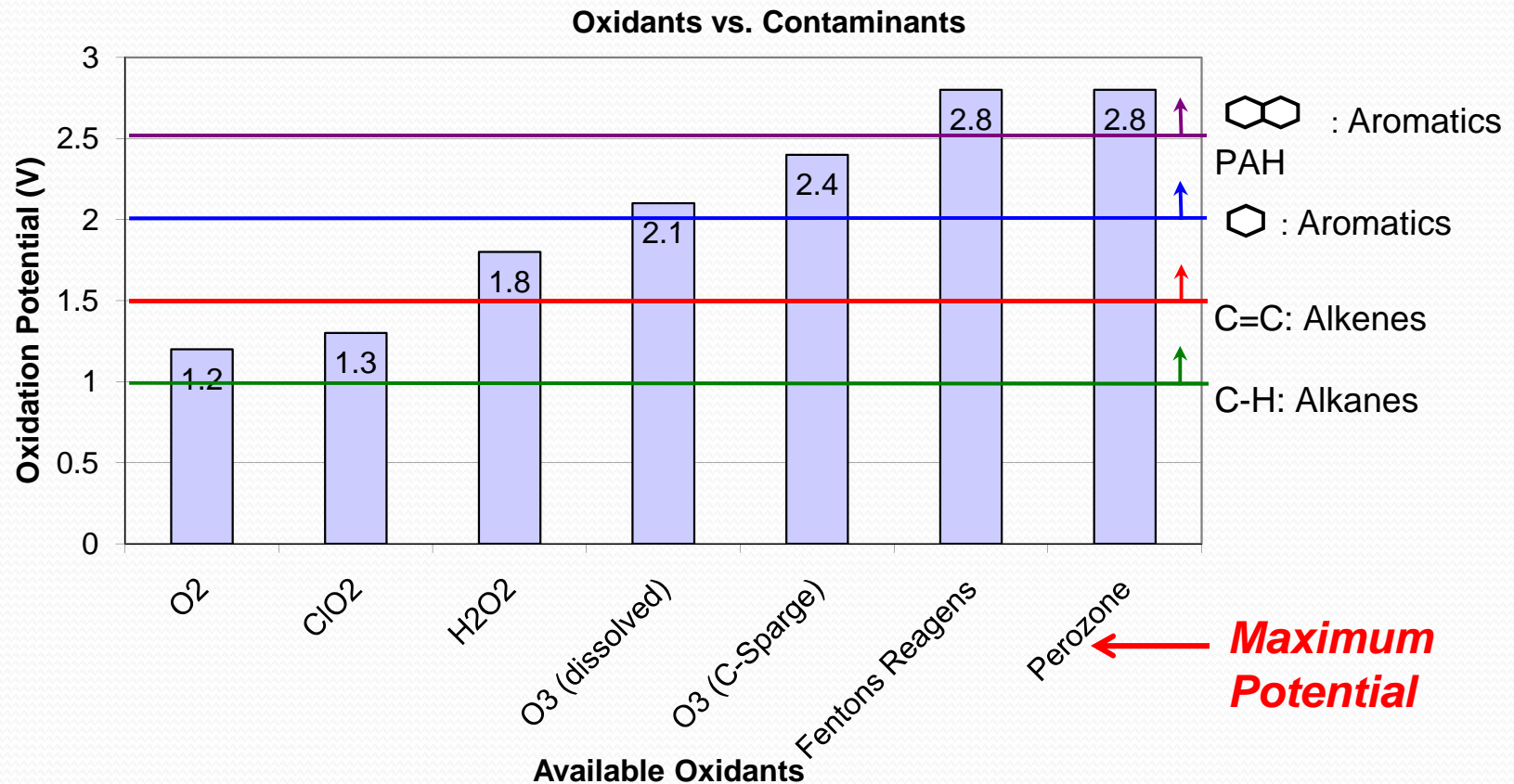
US PATENT 6,436,285

Nanobubble Structure



Oxidation Potentials- Indicates How Aggressive Oxidant Will Be

Need Aggressive Oxidation for Frac Contaminants



C-Sparge is Different than Conventional Ozone

	Observed % Reduction	
	Dissolved Ozone	C-Sparge Ozone
Paraffin hydrocarbons	0.0	95.7
Aromatic hydrocarbons	19.6	91.4
Naphthalenic hydrocarbons	29.3	92.0
Trimethylbenzenes	--	84.1
Propylbenzenes	--	75.0



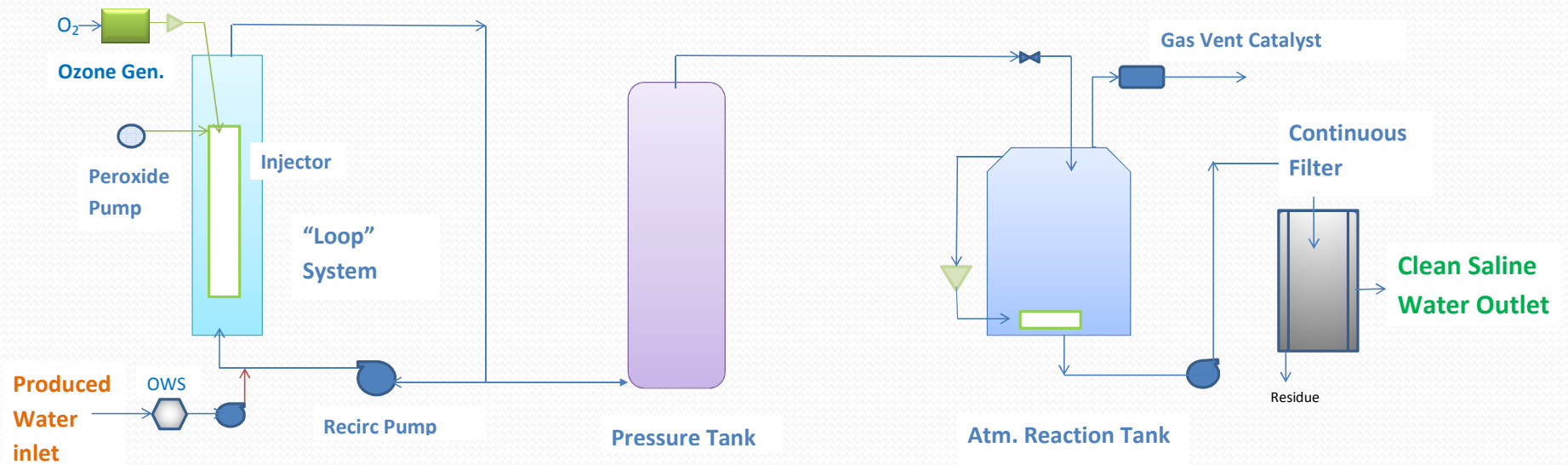
Frac-Cleanse Technology™

Frac Water- Recycling Objectives

- Economically and safely produce clear saline water for direct reuse, blending with fresh water, or as desalination pretreatment
- Remove hydrocarbons (free, emulsified, dissolved), gelling agents, metals, H₂S, iron sulfide, bacteria, and suspended solids
- Able to handle variability of inlet water
- Compact design- minimal footprint
- Eliminate scale-up risk- use modular design with proven injectors; each module processes 1400 BPD
- Overall cost – economical compared to new water and disposal

Bisco Frac-Cleanse™ System Meets Objectives

Frac-Cleanse Process



Reactions

Contaminant

- Hydrocarbons (oil, grease, polymers, BTEX, MeOH)
- Iron, Manganese
- H₂S, sulfides
- Calcium, Magnesium
- Barium, Strontium
- Bacteria

After Perozone

- CO₂, water
- High removal as oxides, hydroxides, sulfates; filtered out
- To S, then to SO₃, removed as insoluble metal sulfates
- Removed as carbonates or sulfates; chloride not removed
- Removed as sulfate or carbonate
- Oxidized and effectively killed

Frac Water Experience: Field Units

1. Unit installed in western PA in 2008
 - Processed 60 to 100 GPM of flowback water
 - Demonstrated high efficiency on flowback water
2. Frac-Cleanse trials in Permian Basin 2013
 - Produced water applications at disposal site
 - Produced water at well sites
 - Flowback water at fracking operations

Trials at over fifteen different sites resulted in clear saline odor-free water suitable for reuse



Marcellus Test Unit

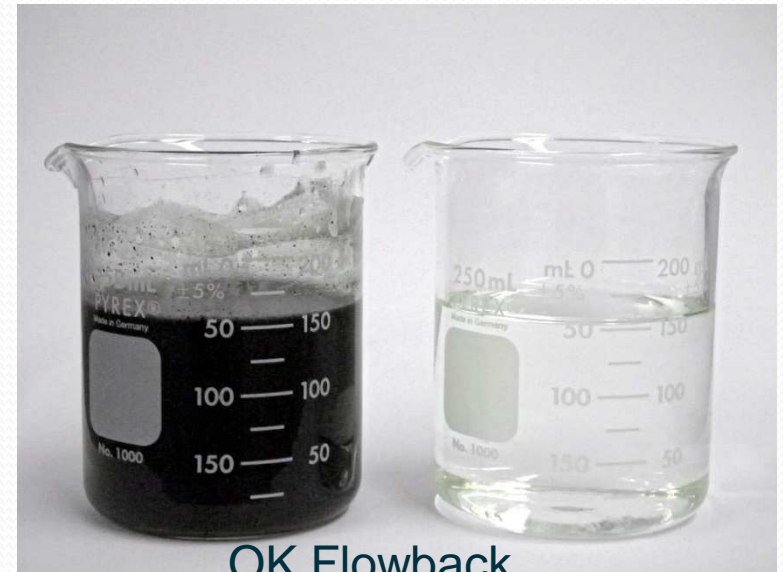
Results of Brine Water Treatment using Perozone™

	Raw Water ¹	Nanozox™ ²	System End ³	Removal Efficiency (%)
Volatile Organic Compounds (VOCs) (µg/L – ppb)				
Benzene	240	ND	ND	99.6+
Ethylbenzene	13	ND	ND	
Toluene	190	ND	ND	
Xylenes	110	ND	ND	
n-Butylbenzene	2.7	ND	ND	
Naphthalene	17	ND	ND	
n-Propylbenzene	2.5	ND	ND	
1,3,5 Trimethylbenzene	18	ND	ND	
1,2,4 Trimethylbenzene	35	ND	ND	
Metals (alkaline and transitional) (mg/L – ppm)				
Barium	175	69.6	7.65	95.6
Calcium	9800	6800	2573	73.7
Iron	20	ND	ND	99.5+
Magnesium	1100	850	802	27
General Chemistry (mg/L)				
Solids, total dissolved	100,000	87,000	81,900	18.1
Chloride	60,000	53,000	51,688	

Flowback and Produced Water- Frac-Cleanse



Marcellus Flowback Water



OK Flowback



NM Produced Water

Frac-Cleanse Demo Trailers

- Enables demonstration of the performance on-site with customer's flowback and/or produced water
- “Mini-trailer” enables quick on-site trials (1 GPM)
- Pilot Trailer has full scale loop injector to minimize scale-up risk and long term operation
 - Capacity is 12 GPM- 400 bbl/day
 - Fully automatic operation
 - Bisco controls included for remote operation
- Simple set up – Frac water inlet/ clean water out

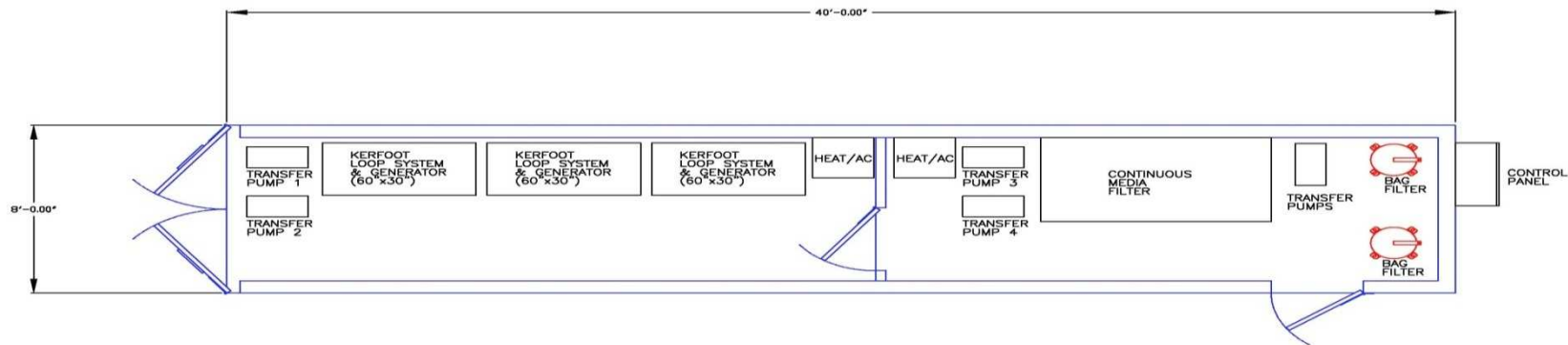
Mini and Pilot Frac Water Trailers



SWD site in New Mexico



3500 BPD Container Arrangement



- Designed for Safe Operation
- Suitable for Flowback and Produced Water
- Modular design minimizes scale-up risk
- Customer's Total Cost is <\$1/bbl
- Available within Four Months after Order

Frac Water Recycling Drivers

- EPA estimates that fracking uses >3 billion barrels (120 billion gal) of water per year
- Fresh make up water costs from \$1/bbl to \$3/bbl
- Residue disposal costs from \$0.25/bbl to >\$10/bbl
 - Trucking is primary cost
 - Total cost of fresh water and disposal is **\$1.25 to >\$10/bbl;**
\$3/bbl is typical

*Frac-Cleanse™ total cost of ownership is
<\$1.00/bbl*

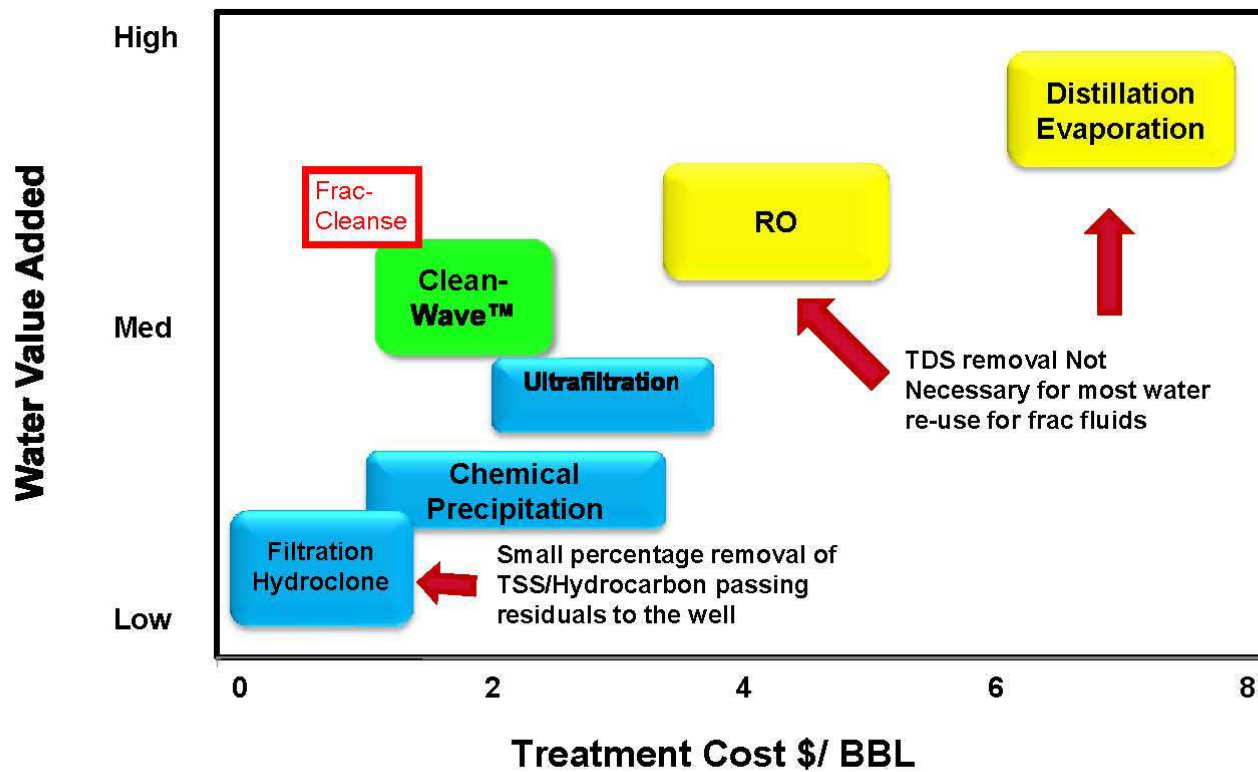
Frac-Cleanse *Total cost of ownership*

	150,000 gal/day	3571 bbl/day		
<u>Variable cost per day</u>				
Description	Quantity	Unit	Rate	Daily cost
Power	62.4	kw	\$ 0.11 per KW-hr	\$ 164.74
Bisco Oxidant	141.2	gal	\$3.56 per gal of 10%	\$ 502.59
Filters	0.5	per day	\$ 476.00 per filter	\$ 238.00
Filter Disposal (tons)	0.5	per day	\$70 per ton	\$ 35.00
Labor, 8 hrs/day	1	person	\$ 50.00 per hr	\$ 400.00
Total variable cost/day				1,340.32
Daily variable cost per barrel				\$ 0.38
<u>Recovered oil Value</u>				
0.5% oil in water recovered	18	bbl/day	\$85 per barrel	\$ 1,517.86
Net daily variable cost				Zero \$
<u>Annual Cost</u>				
Variable cost per 12 months	320	days	(Oil recovery not included)	\$ 428,903.76
Mobilization	1	times	\$ 7,700.00 ea. Time	\$ 7,700.00
System cost amortization	5	years		\$ 195,000.00
Annual Maintenance cost	2%		equipment cost	\$ 19,500.00
Total Cost for 12 months	48,000,000	gallons processed		\$ 651,103.76
	1,142,857	bbls		
All-in Cost per barrel			\$ 0.57	NO OIL RECOVERY
All-in Cost per barrel			\$ 0.19	WITH OIL RECOVERY

Oil recovered by Bisco oil/water separator offsets operating cost;
Net cost reduced to \$ 0.20 per barrel

Comparison to other Technologies

Water Treatment Technologies – Cost vs. Value Add



Competitive Advantages of the Technology

- Economical – less than \$1/bbl fully-loaded cost
- Safe design
- Able to remove multiple contaminants in one unit
- Compact
- Minimal secondary waste (not slurry)
- Suitable for mobile or fixed installations
- Proven performance

Frac-Cleanse Summary

1. Frac-Cleanse - compact, economical system to recycle produced and flowback water
2. One compact unit can treat many contaminants:
 - Effectively eliminates hydrocarbons; emulsified, gelling agents, BTEX, oils, grease and surfactants.
 - Metals are oxidized to enable filtration and removal
 - H₂S and iron sulfide are removed
 - Bacteria are killed
 - Suspended solids are removed
3. The technology can be applied in mobile units or in a fixed facility.
4. **The all-inclusive cost per barrel of <\$1.00/bbl is an economical solution to recycling produced water**

A Demonstration Unit is available for testing



Questions?

