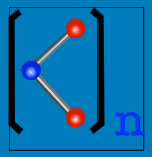
RADOX-23 Odor Control

Fenton Chemistry Revisited

Presented by



STEEN RESEARCH, LLC

Innovations in Chemistry and Engineering

Stephen R. Temple

October 10, 2008

Poultry Protein & Fat Seminar

Fenton’s Reagent

Discovered by Henry John Horstman Fenton in the1890s.

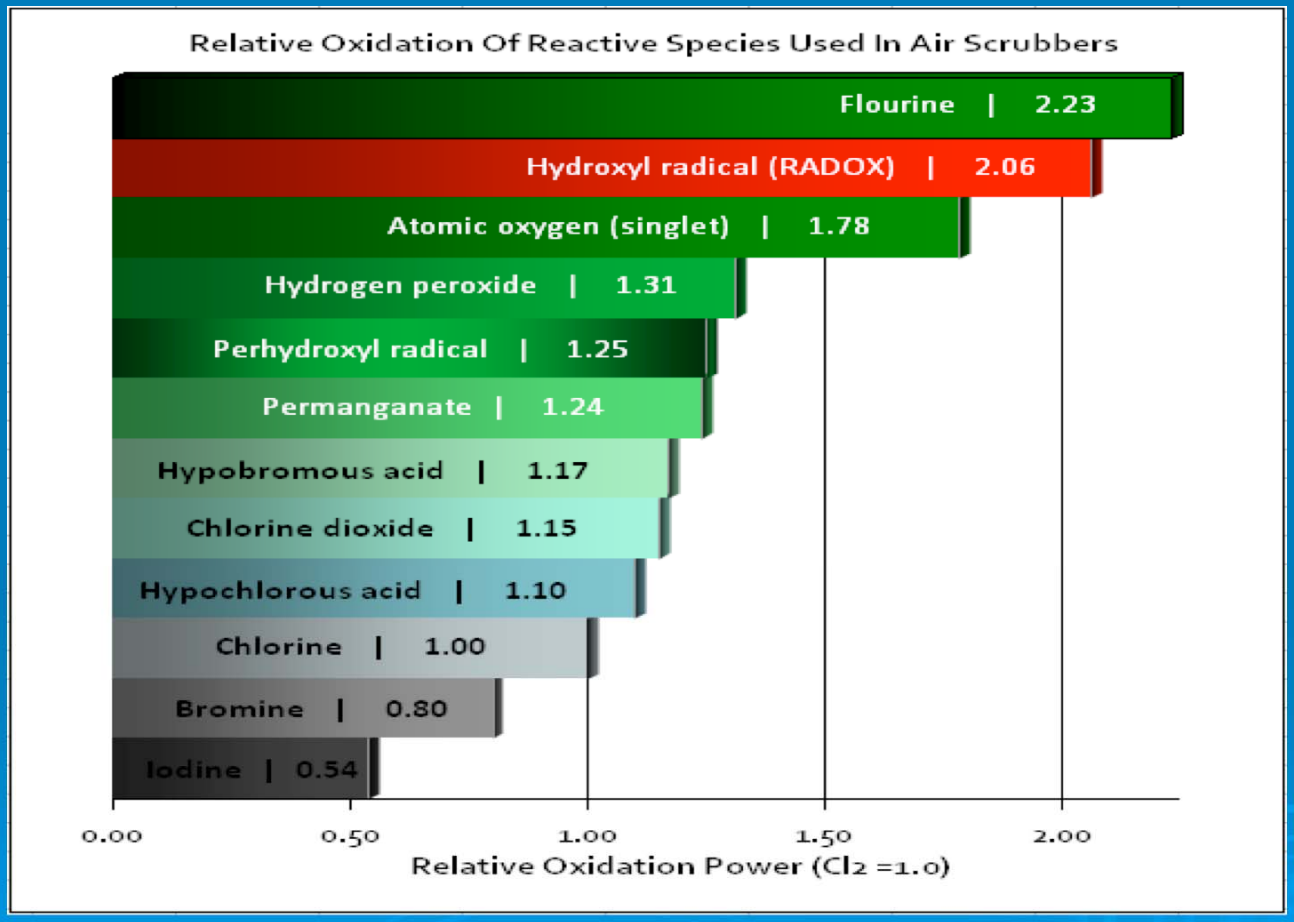
Classical Fenton's Reagent : Hydrogen Peroxide Combined with an Iron Catalyst.

Fenton’s was Not Widely Used Until 1930 When the Reaction was Suggested by Haber and Weiss.

They Postulated that the Successful Reaction Generates the Highly Reactive Hydroxyl Radical: OH

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^- + OH$$

Relative Oxidation Strength



OH (Hydroxyl Radical) is the 2nd Strongest Oxidizer Known to Man.

Fenton Chemistry's Multiple Oxidizer Power

Primary Hydroxyl Radical Creation

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^- + OH^0$$

Secondary Peroxide Free Radical Generation

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + H^+ + HO_2^0$$

Fenton Generated Peroxide Free Radical (HO_2^0) is a Powerful Oxidizing Free Radical and

Destroyer of Organics

Fenton Chemistry Features

Creates Multiple Highly Reactive Powerful Oxidizers:

- **Hydroxyl Radical:** OH^0
- **Peroxide Free Radical:** HO_2^0

Destroys Complex Organic and Inorganic Compounds

Ultimately Converts Odor Causing Compounds to Carbon Dioxide and Water.

Does NOT Generate Toxic or Carcinogenic By-Products (e.g. THM's) as with Bleach/Caustic or ClO_2.

Does NOT Generate Volatile Organic Compounds or Inorganic Solids as with Permanganate.

Does NOT Contribute Salts to Plant Effluent as with Bleach/Caustic or ClO_2.

Does NOT Create Fire or Explosion Hazard as with ClO_2.

Current Applications Of Fenton's Chemistry

Widely Used to Treat a Variety of Complex Industrial Wastes:

- ✓ **Soil and Groundwater Remediation**
- ✓ **Heavy Metal Contaminated Waste Water**
- ✓ **Destroys Organic Resins in Radioactive Contaminated Sludge**
- ✓ **COD and BOD Reduction**
- ✓ **Odor Control**

Steen Research First Applies Hydroxyl Radicals

Denim Jean Manufacturing

Problem: High COD and BOD from Dyes and Surfactants Used in the Stone Wash Process.

Standard Solids Removal Pretreatment Ineffective at Reducing Soluble Dyes and Surfactants.

Other Soluble Waste Treatment Systems Failed:

- Ozone
- Ultra Violet Light Oxidation
- Membrane filters

Steen Research Successfully Applied Fenton Chemistry:

- ✓ **70 Percent Reduction of COD and BOD**
- ✓ **Reduced Annual Sewer Bill $125,000**

Steen Applies Fenton's to Rendering Air Scrubbers

Mixed Feed Rendering 5-Million Pounds per Week

Application of Peracetic Acid (PAA) Chemistry a Comprehensive Failure:

- Expensive
- Minimal Odor Reduction (Weakly Masks Odors)
- Continuous Odor Complaints
- Creates Undesirable VOC's
- Air Board Demands Immediate Action
- Impending Plant Shut-Down

Steen Scrubber Water Jar Test

Collect Circulation Water Samples from High Intensity Scrubber Sump

Water Samples ***"Stink to High Heaven"***

Applied The Fenton Chemistry

Result:

- Immediate Color Change
- Very Fast Reaction
- Significant Odor Remains

Conclusion:

- Reaction Too Rapid = Incomplete Oxidation

Experimentation with Stabilizers to Control Reaction Speed Results in Staying Power that Fully Penetrates the Treatment Target Zone.

Patent Application Filed

"Radox-23 Fenton's Treatment System"

Steen Research Full Scale Test

Case Study 1:

High Intensity Scrubber

Scrubber pulled from the cooker and presses.

Non-Methane Organic Carbon (NMOC) ermined using US EPA Method 25A

Scrubber efficiency needed to be better then 80 percent removal.

Three continuous samples, each 45 minutes in duration.

RADOX Destroyed Over 90% of NMOC's

	RUN 1	RUN 2	RUN 3	Average
Inlet				
Flow Rate,				
dsfm	523	519	520	521
acfm	565	559	560	561
Total Non-Methane Hydrocarbon,				
ppm, as C_1	1131	1035	1126	1097
lb/hr, as CH_4	1.474	1.338	1.454	1.422
Outlet				
Flow Rate,				
dsfm	845	845	845	845
acfm	906	905	906	906
Total Non-Methane Hydrocarbon,				
ppm, as C_1	39.5	41.4	36.6	39.1
lb/hr, as CH_4	0.0832	0.0872	0.0771	0.0825
DESTRUCTION EFFICIENCY, %	**94.4**	**93.5**	**94.7**	**94.2**

Poultry Renderer

Case Study 2:

Feather Dryer Scrubber

60K SCFM Packed Bed Air Scrubber

USDA Compared ClO_2 to RADOX-23 Fenton Treatment System

Gas chromatography ("GC") and mass spectrometry ("MS") was used to determine destruction efficiency

RADOX is More Effective in Reducing Odor than ClO_2

Results From USDA Study:

"Samples from Radox-treated air streams had **(1)** 42 % higher concentration of carbon dioxide (CO2); **(2)** 69 % lower concentrations of the highly aldehyde compounds, and **(3)** 52 % lower total VOC when compared to untreated, or ClO2-treated samples."

"The RADOX treatment reduced the total perceived odor intensity by 74 while the ClO2 treatment did not significantly alter the odor intensity."

"The RADOX catalyst was shown to be significantly more effective than chlorine dioxide (ClO2) for reducing the concentration of malodorous VOC and total VOC emitted from poultry rendering.

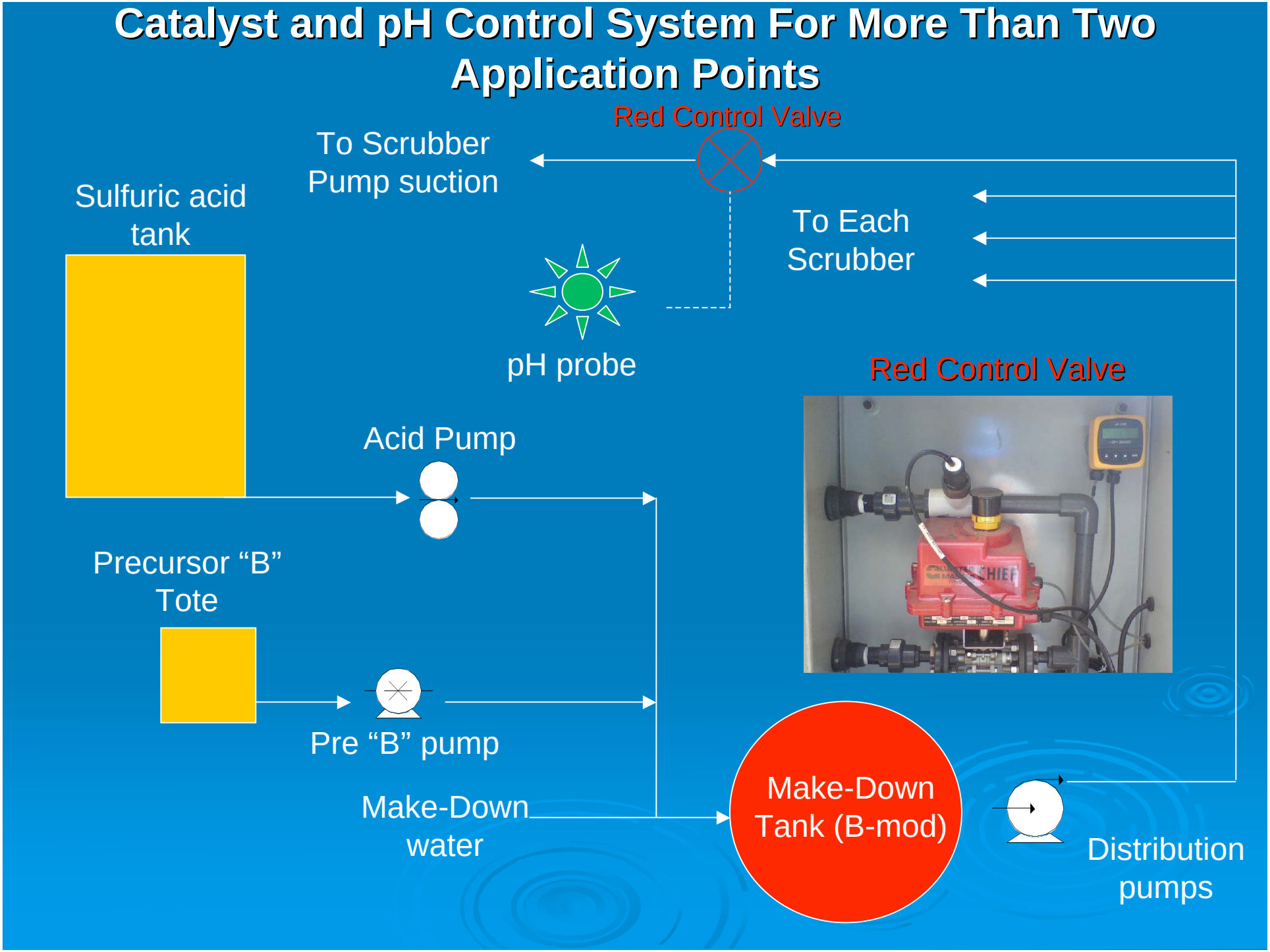
"The concentration of highly malodorous aldehyde compounds, which were responsible for a majority of the poultry rendering odor, were not changed by the ClO2 treatment."

"Additionally, there was a 5-fold higher concentration of indole in the ClO2 samples when compared to RADOX-treated samples."

Application of the Radox-23 Fenton Chemistry System

- ✓ **Simple Implementation**
- ✓ **Low Set-Up Cost**
- ✓ **Bullet-Proof Systems**
- ✓ **Low Maintenance**
- ✓ **Cost Competitive**
- ✓ **Typically 10% to 25% Less than Bleach/Caustic and ClO2**
- ✓ **No Toxic By-Products**

Catalyst and pH Control System For More Than Two Application Points

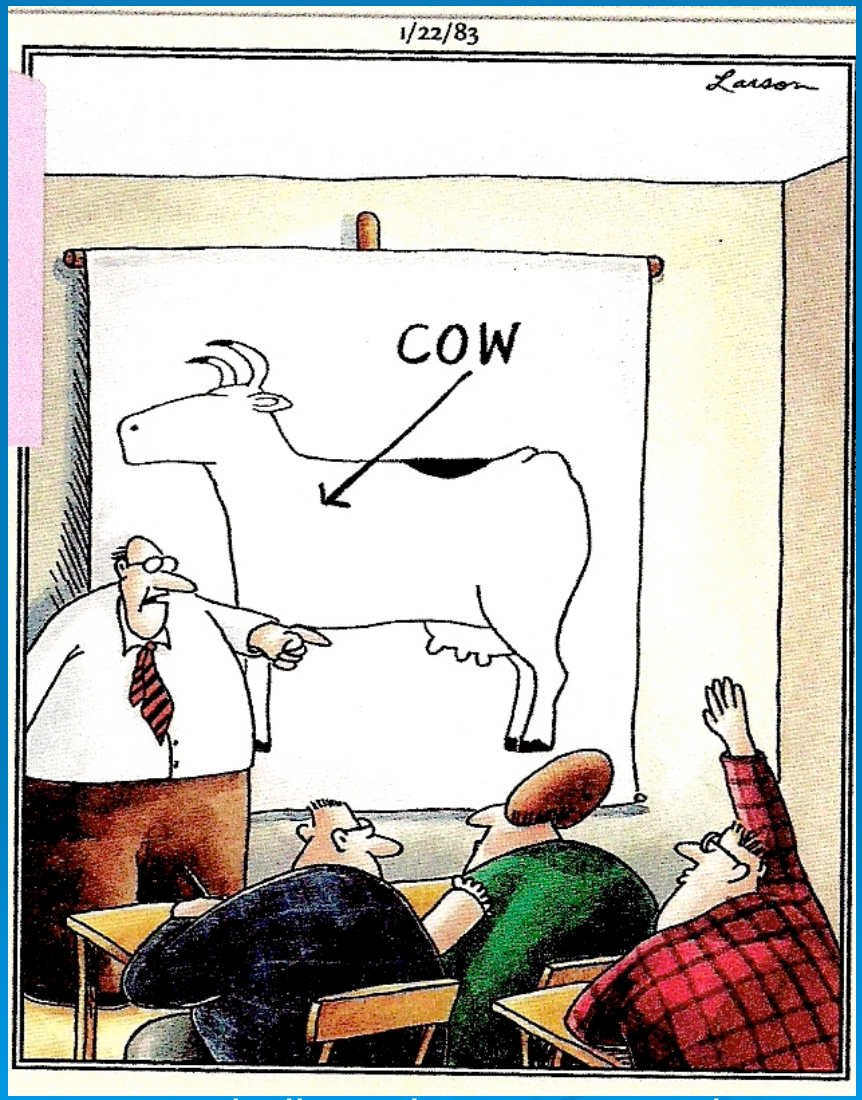


Radox-23 Fenton System Applied to Multiple Scrubbers

Modified Peroxide Metering For Multiple Application Points

Radox-23 Fenton System Single Scrubber Application

Question and Answers



"Yes …I believe there's a question there in the back."

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