ENERGY MANAGEMENT ASSOCIATION

WEBINAR

AIA Provider Number: 50111116

Course Number: EMA2006L

Revealing Hidden Costs In Hydronic Cooling And Heating Systems

With your speaker

Stephen Clinton, PE, LEED AP
Spirotherm, Inc.

AIA Continuing Education Provider

SPIROTHERM

30 YEARS | 1990 - 2020

The World Leader in High-Efficiency Air and Dirt Elimination for Hydronic Systems

The SPIROTHERM Solution

Superior Air and Dirt Elimination

SPIROVENT

Air Removal Only

SPIROTRAP

Dirt Removal Only

SPIROVENT DIRT

Combination
Air & Dirt Removal

SPIROVENT QUAD

Hydraulic Separator with
Air & Dirt Removal

All are available with or without removable heads
All are available in standard or high velocity models

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Discussion Topics

During this presentation, we will answer the following questions:

- How does air negatively affect hydronic cooling and heating systems?
- What is “dirt” in a hydronic system?
- What are some of the typical air and dirt elimination technologies and methods?
- How effective are they at removing air and dirt?
- How is the Spirotherm coalescing technology different?
- What are the “true” costs of air and dirt in hydronic systems?
- What are the benefits of effective air and dirt elimination in open and closed hydronic systems?
- Who bears the air-related costs from initial system planning, through the various phases of design, throughout construction / start-up, and for the life of the system(s)?
- Who benefits from hydronic systems that are free of air and dirt?

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Straight to the Point!

Air in Hydronic Systems:

Causes Corrosion

Reduces Heat Transfer

Reduces Pump Performance

What is Corrosion?

Corrosion is the result of the chemical reaction between iron and oxygen as shown below:

$$Fe + 2H_2O > Fe(OH)_2 + H_2$$

$$3Fe(OH)_2 > Fe_3O_4 + H_2 + 2H_2O$$

As a result, the magnetite FE_3O_4 is formed. This magnetite, with the lasting presence of oxygen, will then be transformed to hematite, FE_2O_3, as described in the next equation.

$$Fe_3O_4 + O_2 > 6Fe_2O_3$$

Chemical reactions between system water and system metal, and electrolysis between dissimilar metals are not the only sources of absorbed gasses.

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Does This Look Familiar?

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Heat Transfer in Fluids

Q_{Fluid} = Mass Flow Rate x Specific Heat x ΔT

In HVAC hydronics, this is typically calculated as:

$Q_{Water\ (BTUH)} = 500 \times GPM \times \Delta T$ *

*This equation assumes an air-free system.

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Air Negatively Impacts Heat Transfer

A fluid-air mixture cannot transfer heat as effectively as a fluid by itself.

Specific Heat Impacts Heat Transfer

Specific Heat (C) is one factor in effective heat transfer:

C_{Water} = 1.0 Btu / lbm - F

Whereas

C_{Air} = 0.24 Btu / lbm - F

However,

Specific Heat is only one part of the equation….

Density (Mass Flow Rate) Even More So!

Density is related to mass flow rate:

$$Density_{Water} = 62.4\ lbm / ft^3\ (8.33\ lbm / gal)$$

Whereas

$$Density_{Air} = 0.07967\ lbm / ft^3\ \ (0.0106\ lbm / gal)$$

Air is an insulator and transfers virtually NO HEAT when present in a hydronic fluid!

Three Forms of Air in Hydronic Systems

- Free Air (+ *Entrapped*)
  - Air collected at high points in piping systems and terminal units, such as AHU's, FCU's, VAV's, etc.
- Entrained Air
  - Air bubbles that are "pushed/pulled along" with the fluid
  - Often found at the highest points and the most remote parts in the system
  - Source of:
    - Noisy flow in piping systems
    - "Bouncing" pressure gauges
- Dissolved Air
  - Air dissolved in solution and the most challenging to remove
  - Point of Lowest Air Solubility (PoLAS) / Henry's Law

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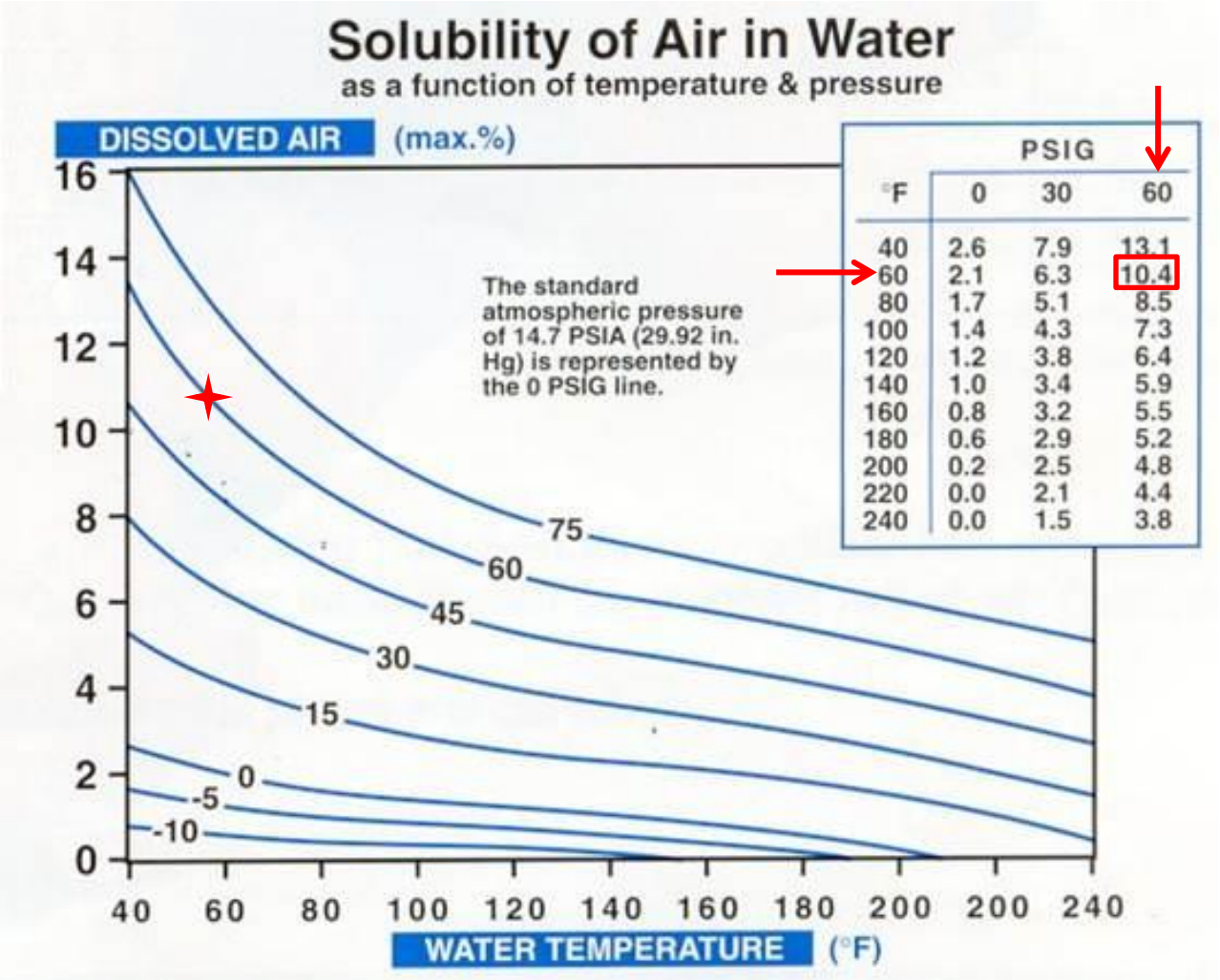
Dissolved Air: The Often - Overlooked Offender

Henry's Law:

"At a given temperature, the amount of gas absorbed by a liquid is proportional to its pressure."

Note: Entering domestic water may contain 10%-15+% air by volume.



°F	PSIG 0	30	60
40	2.6	7.9	13.1
60	2.1	6.3	10.4
80	1.7	5.1	8.5
100	1.4	4.3	7.3
120	1.2	3.8	6.4
140	1.0	3.4	5.9
160	0.8	3.2	5.5
180	0.6	2.9	5.2
200	0.2	2.5	4.8
220	0.0	2.1	4.4
240	0.0	1.5	3.8

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Sources of Air

- Initial System Fill
- Inaccessible / Closed Manual Air Vents
- Inoperable Automatic Air Vents
- Planned and Unplanned Maintenance
- Makeup Water Due to System Leaks
- Expansions and Renovations
- Dissolved Air Released From Solution

Negative Effects of Air

- System Corrosion as Air is ~20% Oxygen
- Increased Chemical Treatment Costs
- Reduced Heat Transfer Capability
- Increased Pump Energy
- Increased Supply Fan Energy
- Reduced System Energy Efficiency
- Increased Maintenance Costs and Life Cycle Costs For Equipment and the Overall System

Clues to Air in the System

- “Noisy” Piping
- “Jumping / Bouncing” Pressure Gauges
- Sounds of Cavitation in Pumps (Closed Systems)
- Reduced Pump Performance (Not Matching Curves)
- Chillers, Boilers, and Other Heat Transfer Equipment Not Meeting Scheduled Capacity
- System Corrosion and Observable Debris
- Low System ΔT’s
- Low Cooling and Heating Coil Discharge Air Temperatures

Entrained Air Impact on Pumps

- Not Traditionally Addressed in the HVAC Industry
- *Gould's Pump Manual:*

  "A mixture of only 2% gas by volume will cause a 10% reduction in capacity and 4% will cause a reduction in over 43%."

KEEP AIR OUT OF YOUR PUMP

Conventional Centrifugal Pumps are not designed to handle a mixture of liquid and gases. Pumping liquids containing a significant amount of entrained gas can lead to serious mechanical and hydraulic problems. A mixture of only 2% gas by volume will cause a 10% reduction in capacity and 4% will cause a reduction of over 43%. In addition to the loss of efficiency and wasted power the pump will probably be noisy and may vibrate excessively. Entrained gases can cause shaft breakage, seal failures and in some cases accelerate corrosion.

Air may be present in the liquid due to leaky suction lines on suction lift applications or a variety of other reasons. A free falling discharge into a tank or pit will also cause excessive gas entrainment and may cause problems for a pump drawing from that tank.

There are Centrifugal Pumps designed specifically for applications where entrained gases are encountered.

AIR POCKETS IN SUCTION PIPE

Air pockets can be a source of trouble on pump installations involving suction lift. They can cause a loss of prime on start-up as well as restrict flow in the suction pipe to the extent that a reduction in capacity is experienced. When installing piping, suction lines should always pass under interfering piping and where reducers are used, eccentric rather than straight reducers must be used.

Eccentric reducers are always installed with the horizontal side on top. Suction valves should be installed with the stems horizontal so that no air pockets are formed at the top of the valve near the bonnet. Figure 11 shows both the correct and incorrect method of installing piping.

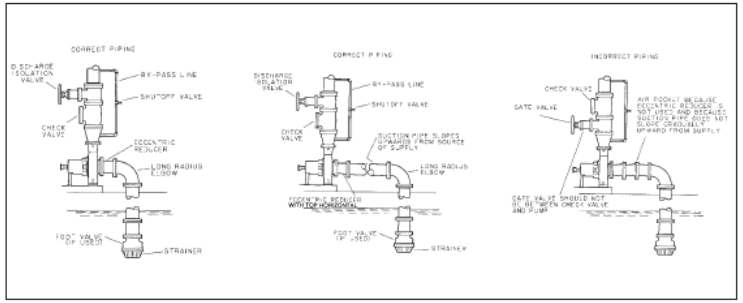
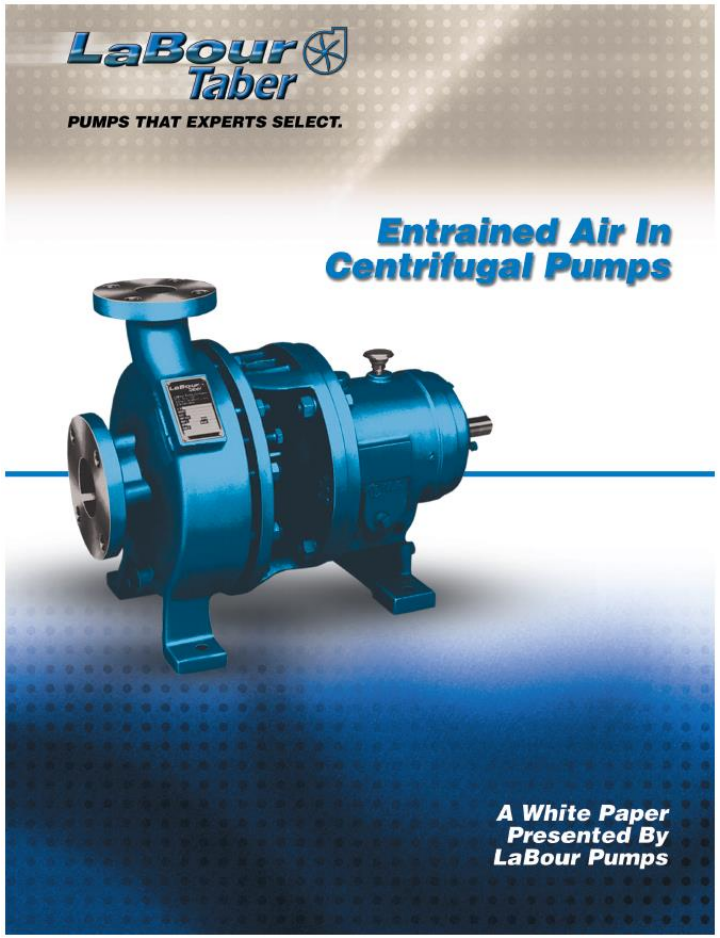


Figure 11

13



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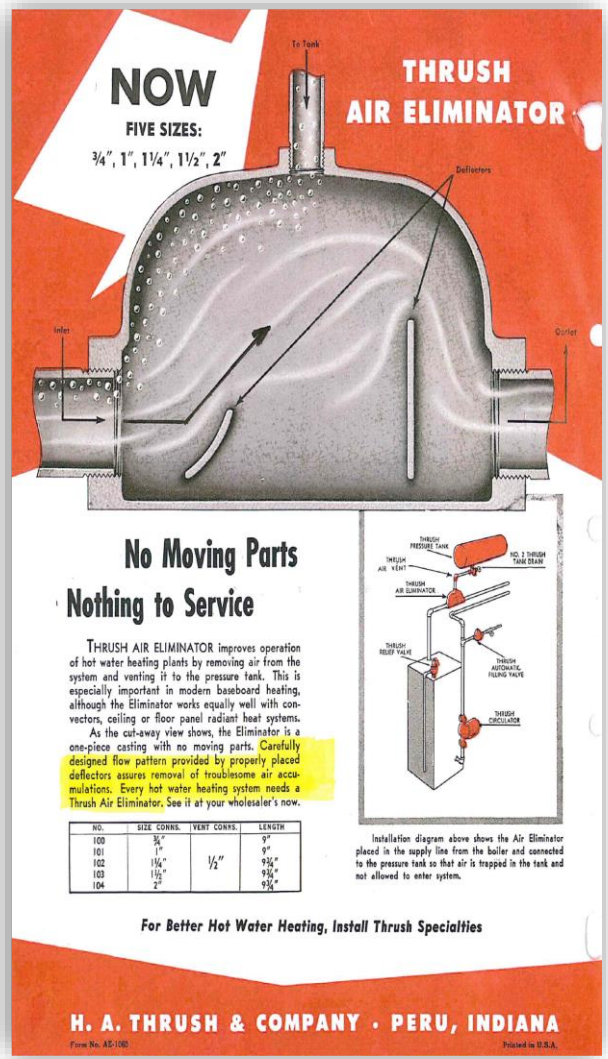
Air Scoops



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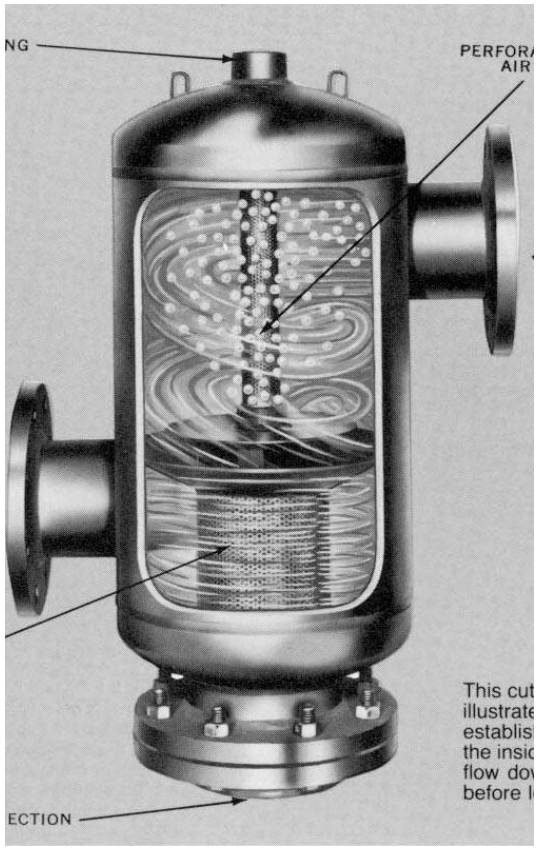
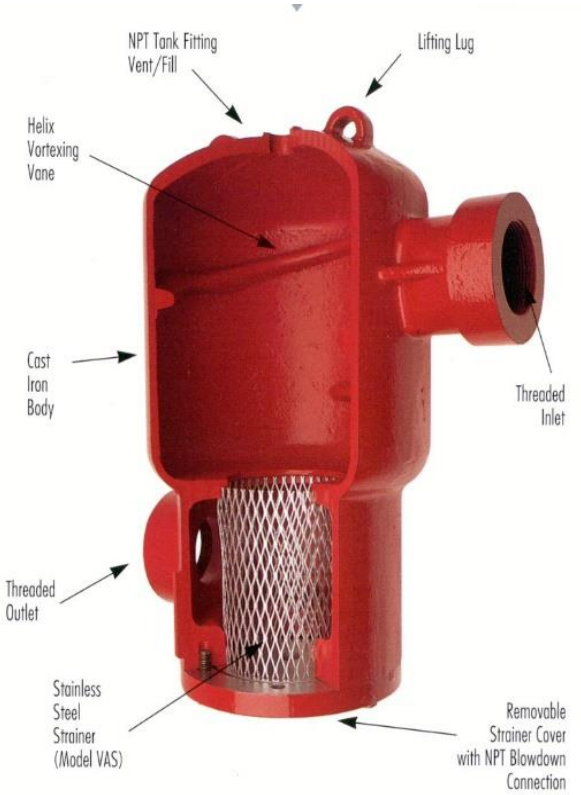
Traditional Tangential Air Separators





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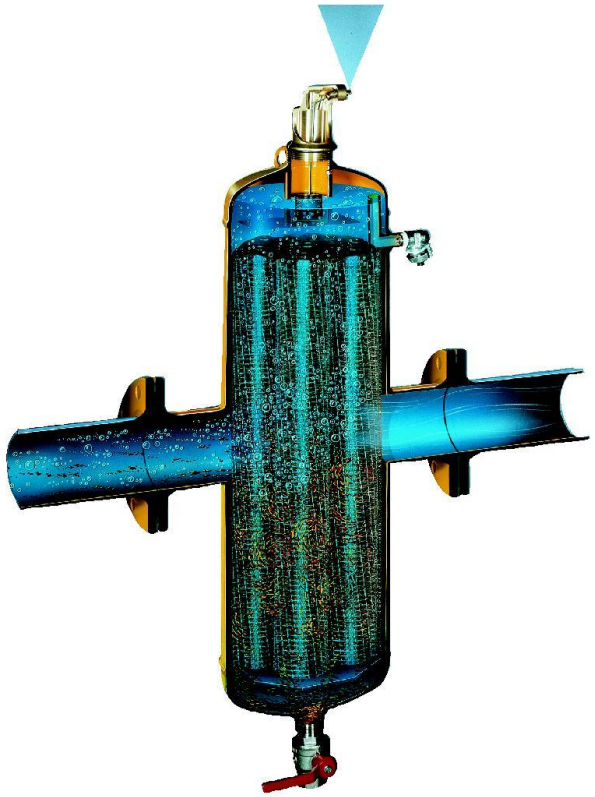
The Coalescing Solution – Invented by Spirotech 50 Years Ago

- Coalescing Technology
- Keys to Operation:
  - Reduced Velocity
  - Suppressed Turbulence
  - Maximized Collision and Adhesion
  - **Water in an Absorptive State**
- Proven to Remove:
  - 100% of Free Air
  - 100% of Entrained Air
  - Up to 99.6% of Dissolved Air
- Unsurpassed Air and Dirt Elimination Performance
- Effective in Glycol Solutions, too!



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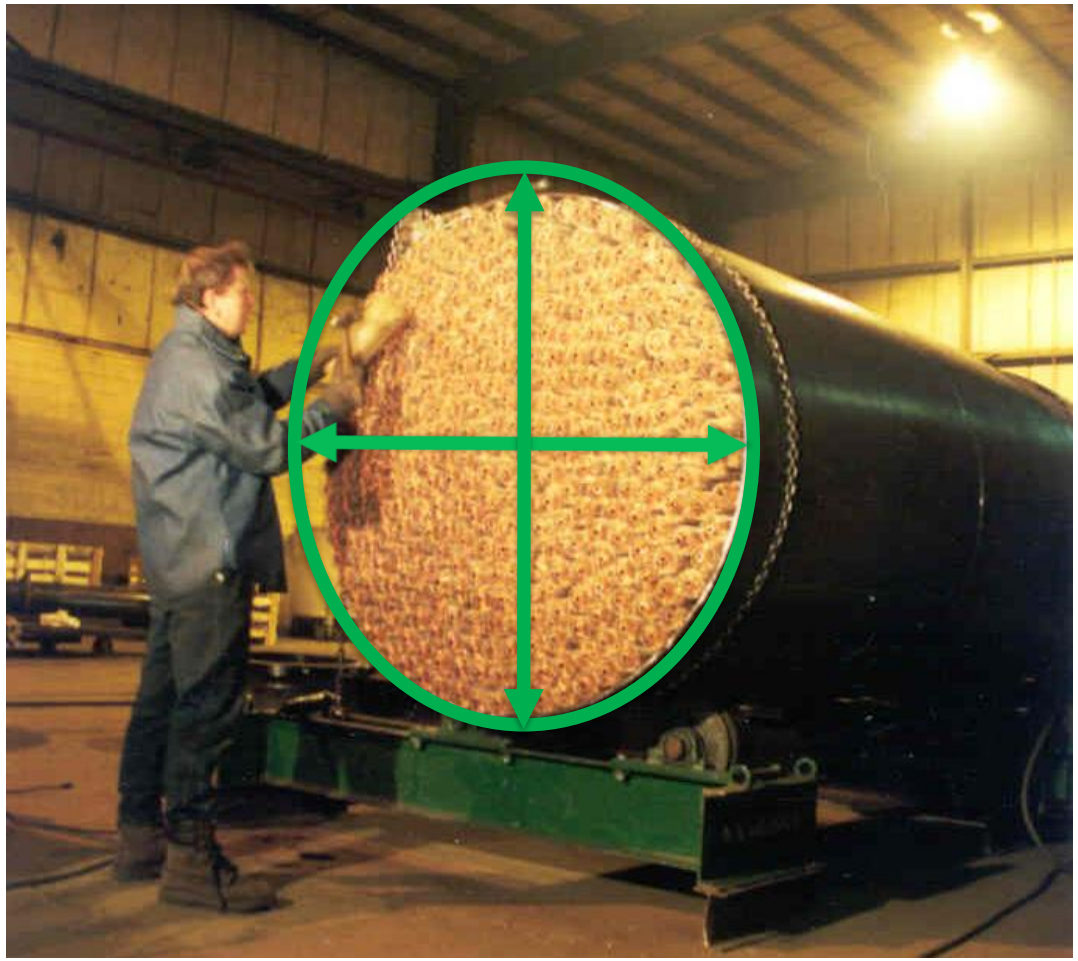
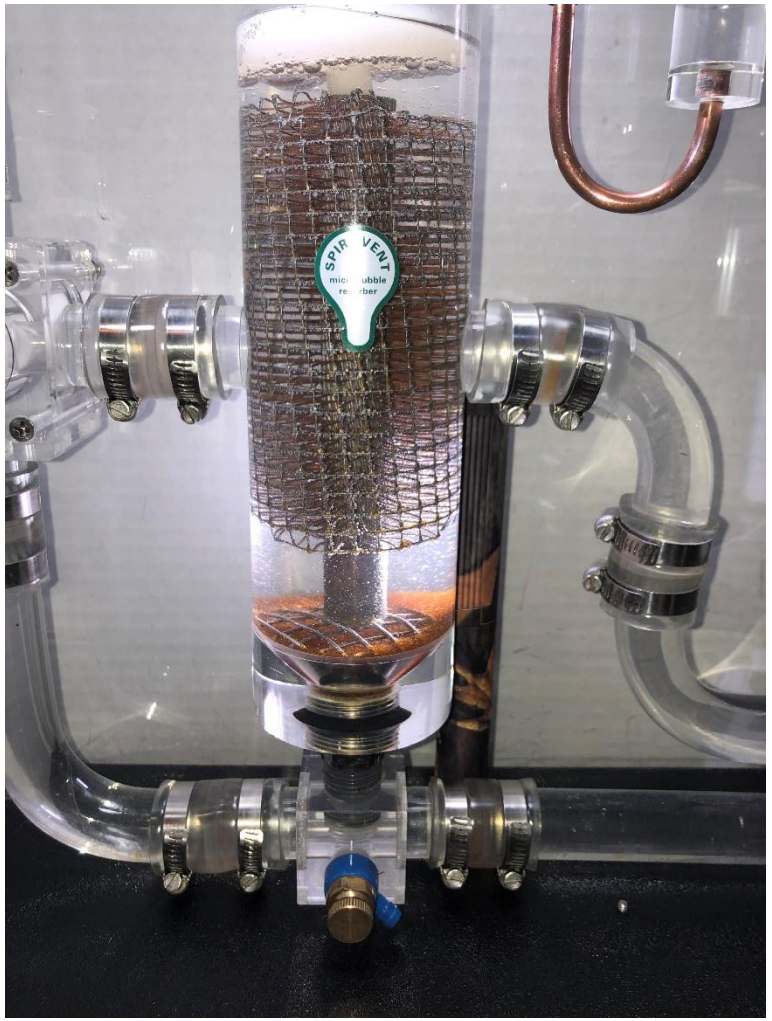
Spirotherm Coalescing Air and Dirt Separators



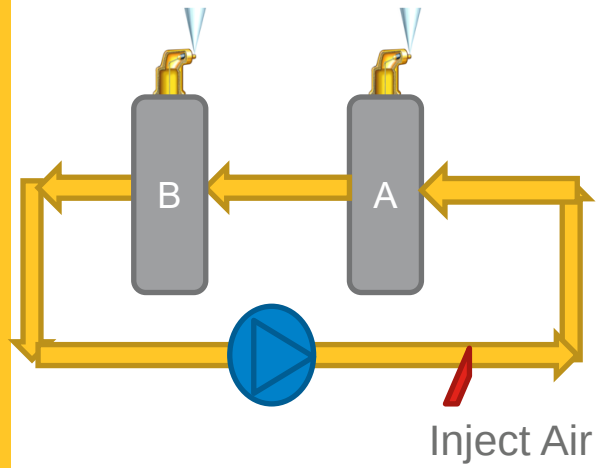
Spirovent Senior

(30” Pipe Size / 60” Shell Diameter)



Test Configuration

- Within a closed loop system, setup two air separators in series (A and B)
- Circulate water at a constant velocity
  - 240 GPM in 4” pipe → 6 feet/second
- Water temperature ~77 °F
- System pressure ~3 PSI
- Inject air bubbles into the water for an initial period of time (~15 minutes)
- Allow both air separators to operate
- Continually measure the volume of air removed by each air separator
- Compare results as initially free and subsequently entrained air is removed



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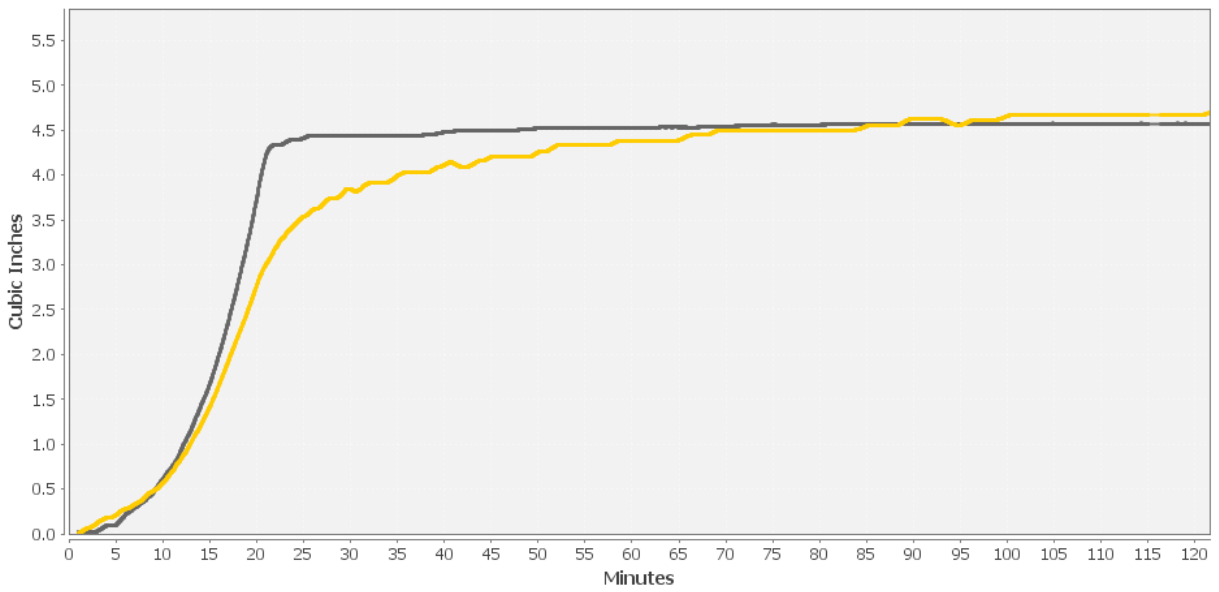
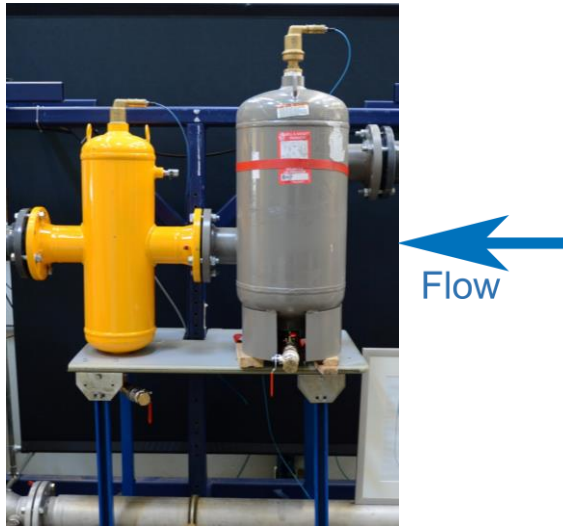
Spirovent vs. Tangential Air Separator - Air Elimination Test



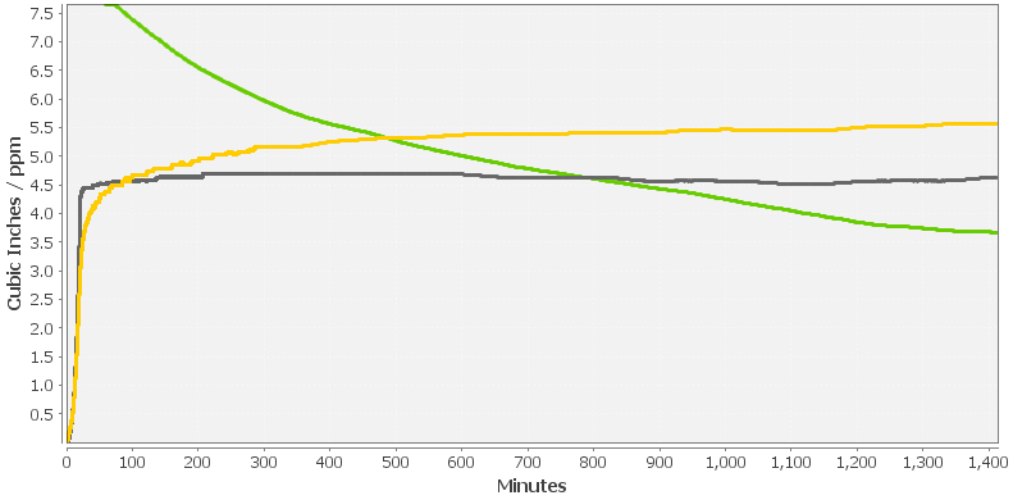


For the first 2 hours both air separators remove about the same amount of air.

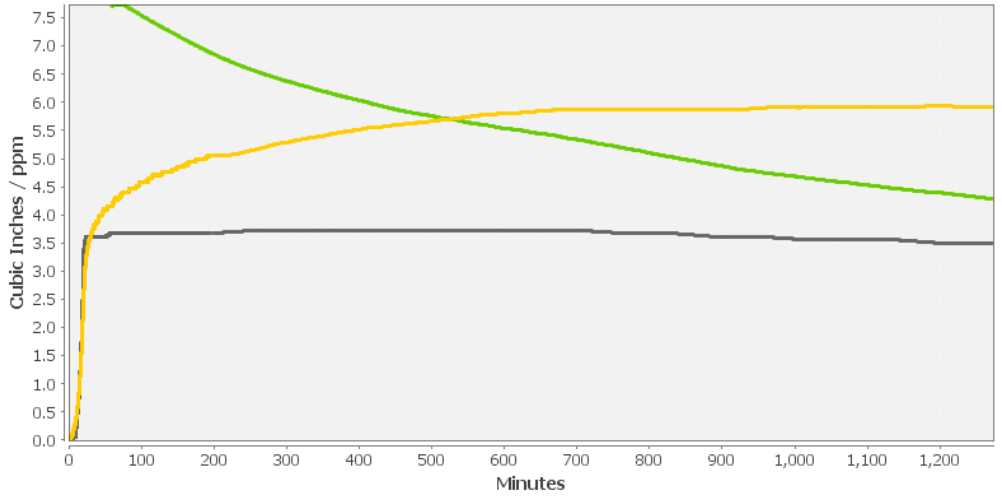
The removal rate is high because large air bubbles readily rise out of the water and are easily vented.

After 2 hours, large air bubbles have been vented and all that remains are microbubbles.

Spirovent vs. Tangential Air Separator or Tangential Air Separator vs. Spirovent Results Are the Same



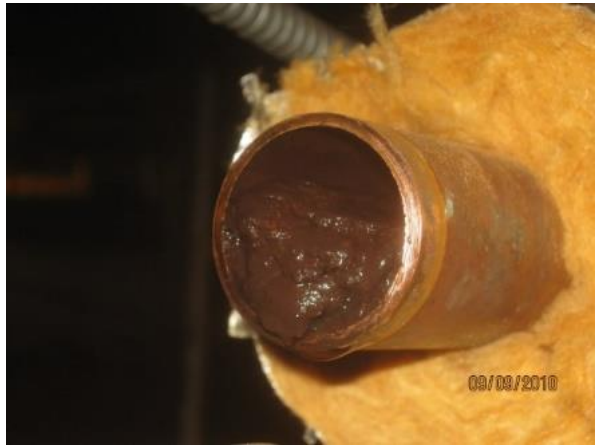
Tangential Air Separator 1st, Spirovent 2nd



Spirovent 1st, Tangential Air Separator 2nd

So What If Air (Oxygen) Is Not Removed?

"Dirt" and Scale Form!



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The Impact of Dirt on Systems and Equipment

Recirculated Dirt and Debris:

- "Liquid Sandpaper" Scouring the Entire System
- Cause Premature Failure of:
  - Pump seals
  - Control valves
  - Coils and heat exchangers
  - Metering equipment
  - Piping and fittings
- Is <u>NOT</u> Removed by Tangential Air Separators

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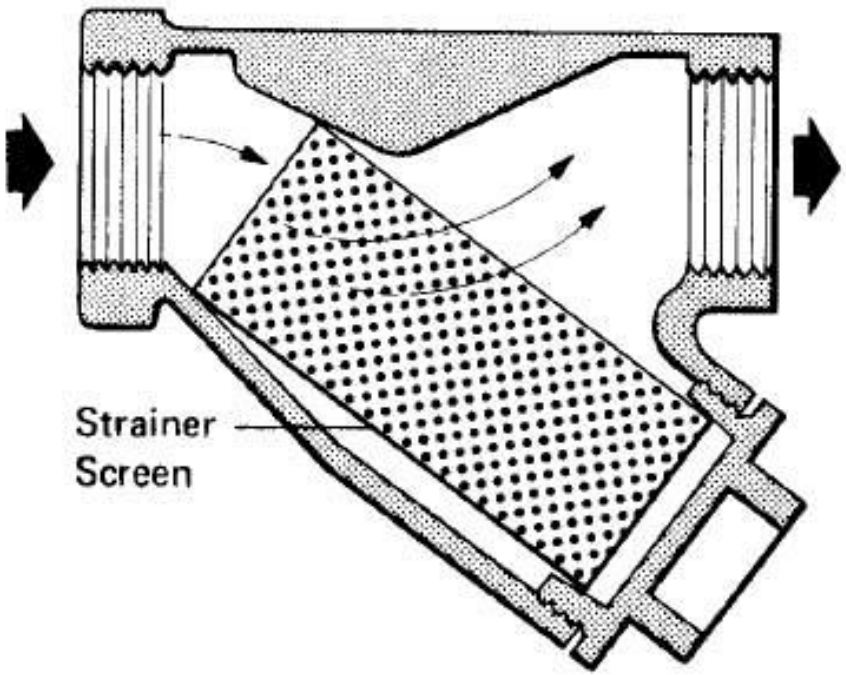
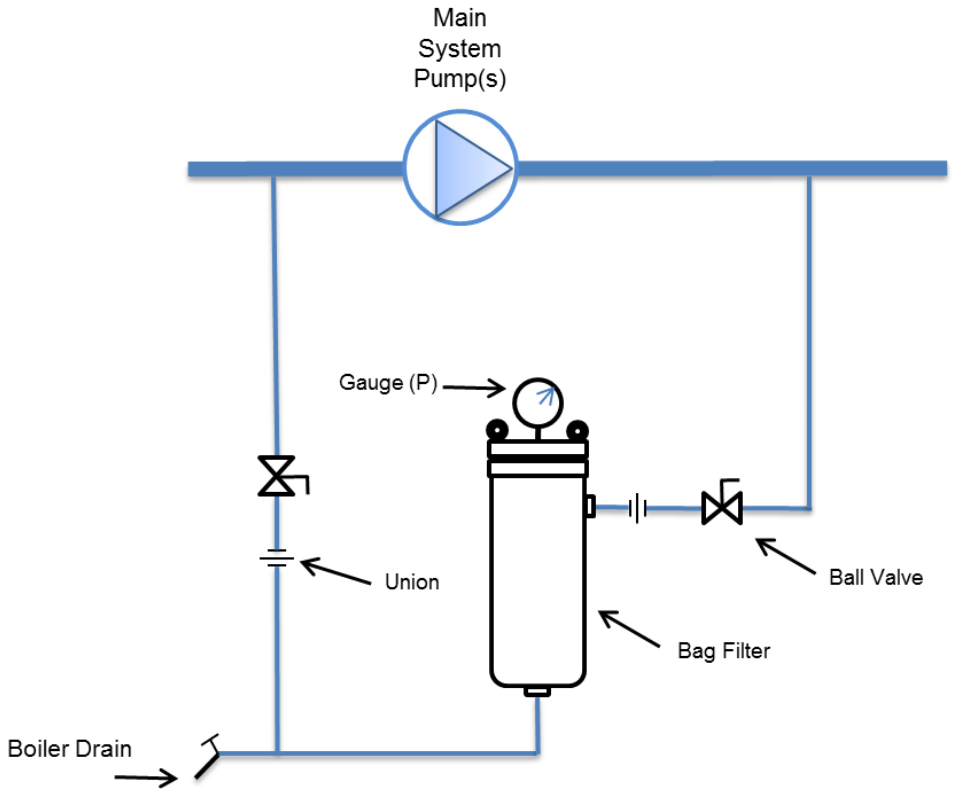
Dealing With Dirt

- Traditional Methods
  - Full Flow
    - **Strainers**
      - Used In-Line
      - Various Screen Mesh Sizes Available
      - As They Collect Debris, Pressure Drop Increases
        - » How Often Are They Serviced??



Dealing With Dirt

- **Traditional Methods**
  - Side Stream Filtration
    - **Bag Filters**
    - Typically Smaller Than Main Pipe
    - As Side Stream, They See <10% Flow



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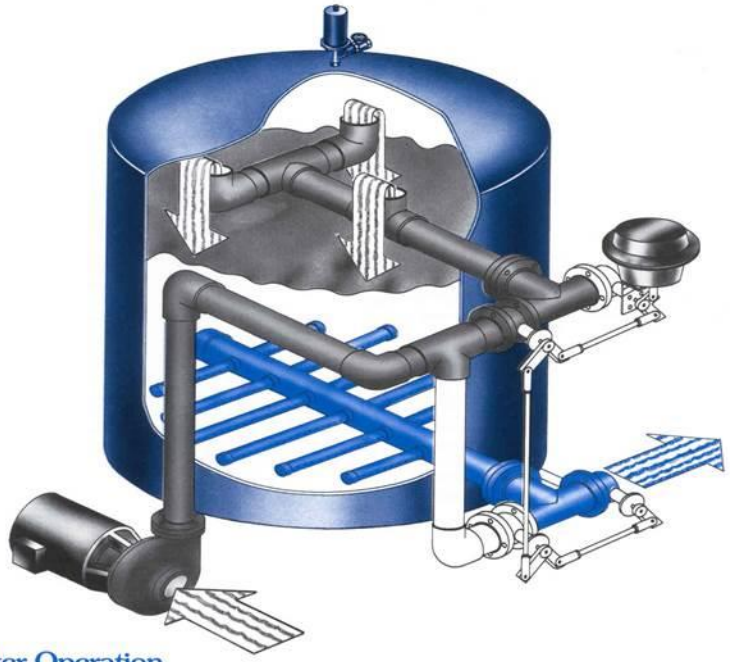
Dealing With Dirt

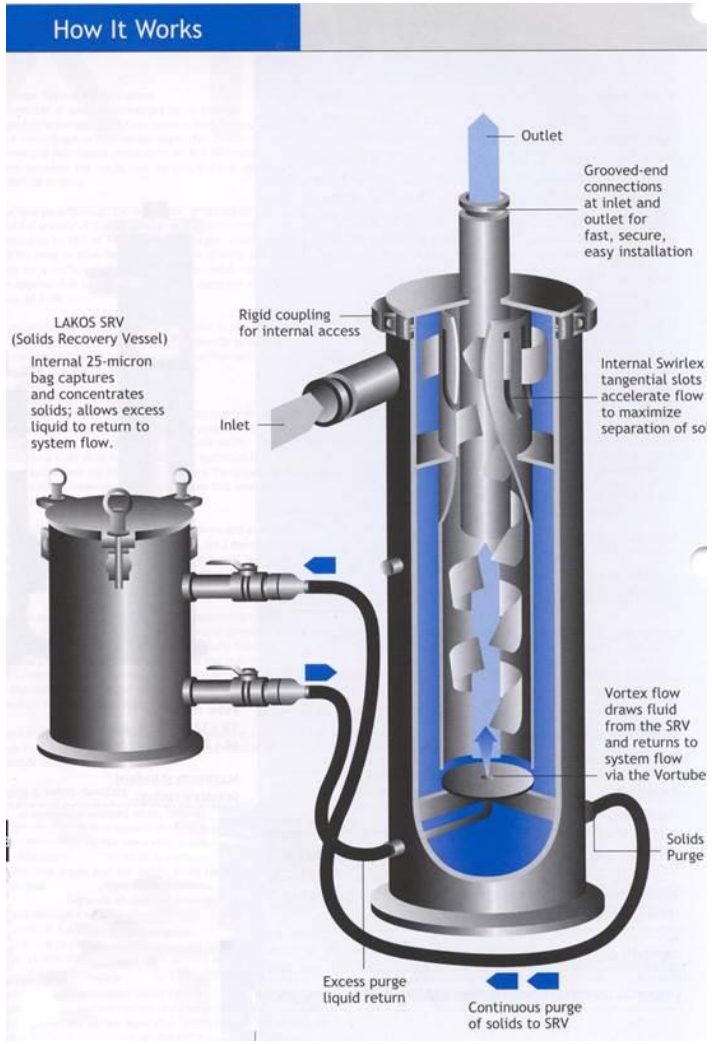
- **Traditional Methods**
  - Side Stream Filtration
    - **Sand Filters**
    - Typically Smaller Than Main Pipe
    - As Side Stream, They See <10% Flow
    - Back Washing Required
    - Can Achieve Small Size Separation
      - Necessary?
    - Pump Needed - High Pressure Drop



Filter Operation

Dealing With Dirt

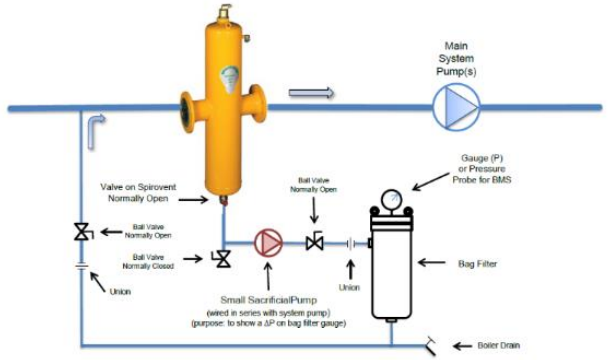
- Traditional Methods
  - Side Stream Separation
    - **Cyclonic Separators**
    - As Side Stream, They See <10% Flow
    - High Pressure Drops
    - Effective to ~ 70-micron
    - Particles with Specific Gravity > 2.5



Separation vs. Filtration / Straining

- Full System Flow Provides for Maximum Effectiveness in Open and Closed Systems
- Removal of Dirt Particles That Erode Piping and System Components
- Low Pressure Drop
- Lower Chamber Allows Particles to Sink and Not Be Re-Entrained
- 80% of Particles 30 Microns and Larger Removed within 100 Passes and to 5 Microns Over Time
- Blowdown May Be Manual, Automatic, or Constant

Blow Down with Bag Filter



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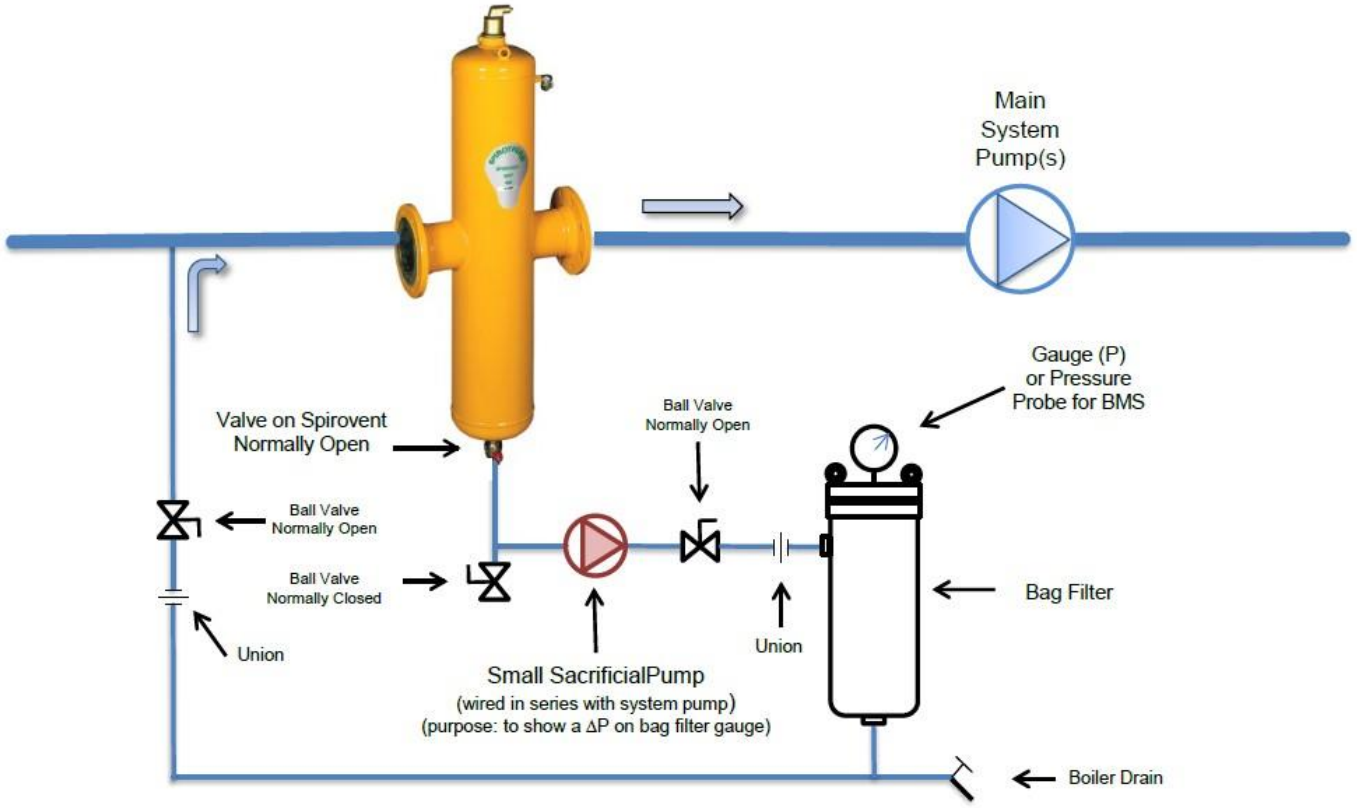
Recommended Continuous Blow Down: ZERO Water / Chemicals / Glycol Loss

Blow Down with Bag Filter



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Dirt Separation Results

Dirt Removal – Water and Glycol Systems

Before and After “Sludge” Removal

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Ease of Retrofit – Single Unit

BEFORE

AFTER

Youngstown State University – 20” Unit

New Construction – Multiple Units

Kansas State University – 20” Units

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Case Studies

Installation Profile

Over 1 million sold (Residential + Commercial Markets)
500+ Colleges and Universities
700+ K-12 School Districts
250+ Hospitals and Healthcare Facilities
250+ Central Utility Plants

SPIROTHERM

CASE HISTORY EXCERPTS

INSTITUTION / ORGANIZATION	SYSTEM TYPE	SPIROTHERM TECHNOLOGY -- IMPROVEMENTS SUMMARY
Youngstown State University Youngstown, Ohio	Chilled Water	15.9% increase in tonnage output (400 additional tons) Delta-T increase from 8.5°F to 10.0°F Remote building DAT's improved from 65°F to 55.0°F Projected 37.9% reduction in annual kWh required for pumps
University of Akron Akron, Ohio	Chilled Water	Similar increase in tonnage as achieved at Youngstown State University
Waukesha Memorial Hospital Waukesha, Wisconsin	Chilled Water	VFD speed reduced 22% 85% reduction in corrosion prevention chemicals
Missouri State University Springfield, Missouri	CHW / HHW	*10 chiller stations for common loop originally utilized, now only 7 required *10° rated coils now producing 14°F to 16°F *Significant reductions in gpm flow rates 45+ units on campus | *Integrated system updates involving Spirotherm, PIC valves, chemistry
University of Notre Dame South Bend, Indiana	Heating Hot Water	In a previously air-bound system Dissolved Oxygen levels reduced below 1ppm
Santa Fe College Gainesville, Florida	Chilled Water	Differential pressure switch reduction (#24 to #14; 23.1' less pump head) Reduction in # pumps running from "2 to 3" to "1 to 2"
Pennsylvania State University State College, Pennsylvania	CHW / HHW	Corrosion and sediment problems eliminated 250+ units installed on campus incl. individual buildings and central plants
University of Wisconsin Milwaukee, Wisconsin	Heating Hot Water	Steam utilization reduced from 830 kBtu to 460 kBtu on a degree day High concentrations of iron oxide & particulate eliminated
Kansas State University Manhattan, Kansas	CHW / HHW	Multiple central CHW plants retrofitted with Spirotherm air-dirt separators Air/dirt issues solved 60+ units on incl. individual buildings and central plants
North Memorial Health Care Robbinsdale, Minnesota	Chilled Water	Eliminated need for an additional chiller by reducing secondary-- loop supply temps from 47.1°F to 44.0°F design temperature Reduced start-up air purging time from 1-2 days to 1 hour Strainer clogging eliminated
Rochester (NY) Housing Authority	Heating Hot Water	Average 8% decrease in natural gas (fuel efficiency) in each building Consistent improvements measured across (16) buildings
Central Michigan University Mt. Pleasant, Michigan **University of Arkansas** Fayetteville, Arkansas	CHW / HHW	Corrosion coupons installed; rates of corrosion flat-lined 25+ units on each campus
University of California Santa Barbara, California	Chilled Water	Reduced run time of chillers and associated energy savings
University of Michigan Ann Arbor, Michigan	CHW / HHW	Solved two years' worth of air/dirt issues in 2 months 100+ units installed on campus
University of Nebraska Lincoln, Nebraska	CHW / HHW	Significantly reduced maintenance workloads campus-wide 100+ units on campus incl. individual buildings and central plants
Washington State Department of Transportation	Heating Hot Water	Noise and corrosion problems eliminated
University of Pittsburgh Pittsburgh, Pennsylvania	Chilled Water	Turbidity decreased from 282 to 12 units (< 8 weeks) Iron content decreased from 30 ppm to 2.17 ppm (< 8 weeks)
Eastern Illinois University Charleston, Illinois	Heating Hot Water	Eliminated "no heat" calls and reduced energy usage
Maryville University St. Louis, Missouri	Heating Hot Water	Reduced maintenance calls and costs
McClellan Park Sacramento, California	Chilled Water	Eliminated maintenance calls in systems with 20+ year old pipe 20 units installed throughout the complex

For additional information, contact your local Spirotherm Representative or visit http://www.spirotherm.com

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Case Study Highlights

- Increased chiller plant output (tonnage) by **15.9%**
- Decreased chilled water (CHW) pump speed by **22%** and pump motor HP by **50%+**
- Increased CHW system ΔT's by **1.5°F**
- Reduced cooling coil discharge air temperatures by **7°- 10°F**
- Reduced CHW system DP sensor set point by **35 psig**
- Flattened rate of decay charts for corrosion coupons and reduced corrosion prevention chemicals by **85%**
- Removed **20,000 gallons** of free, entrained, and dissolved **air** from a 250,000 gallon CHW system (**8% air**)
- Decreased heating hot water (HW) plant natural gas usage by **8%**
- Reduced start-up air purging time from **1-2 days** to **1 hour**
- Eliminated **water flow noise** problems
- Eliminated "no heat" calls in HW systems
- Improved **sustainability** by reducing water and energy usage

For case studies or more information, contact your local Spirotherm, Inc. sales representative: http://www.Spirotherm.com/sales-service/ or call (630) 307-2662.

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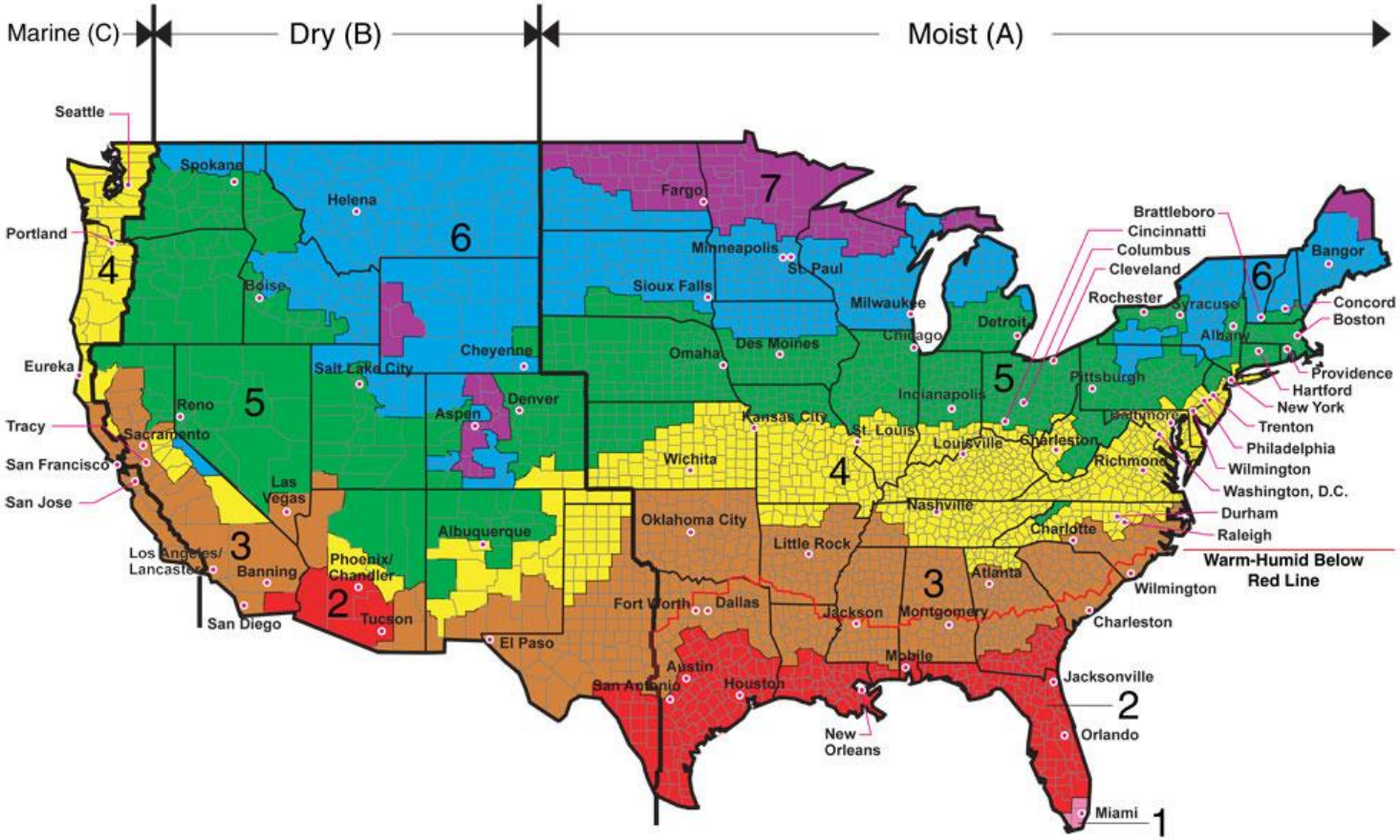
One Way to Analyze Cost Savings

Focus on:

U.S. Climate Zone Map



All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands

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Substantial ROI / Payback

FINANCIAL: Simple Payback Periods are less than one year in virtually all cases. Savings-to-Investment Ratios are based on the demonstrated life expectancy of a Spirovent® Air & Dirt Separator of 25 years.

		Nashville	Boston	Tampa	Phoenix	San Francisco
Increased Annual Energy Costs Due to Inefficiency of Air (%) [1]	CHW System	12.4 %	12.3 %	12.4 %	12.4 %	12.2 %
	HW System	10.7 %	10.3 %	11.6 %	10.3 %	7.5 %
Simple Payback Period (SPP) in Years [2]	CHW System	0.32	0.38	0.17	0.25	0.48
	HW System	0.32	0.17	4.72	0.65	0.52
Savings-to-Investment Ratio (SIR) [3,4]	CHW System	78.9	66.6	150.7	98.5	52.6
	HW System	77.2	150.6	5.3	38.5	47.8

[1] Energy modeling assumed system inefficiencies attributed to chiller kW/ton, boiler efficiency, and pump efficiencies with data correlated to case study data.
[2] Calculated by the equipment-only cost difference of a Spirovent Air & Dirt and a tangential air-only separator divided by the calculated annual energy cost savings.
[3] Calculated by dividing the total energy savings over the lifetime of the Spirovent (assuming 25 years) divided by the upfront cost of the upgraded investment.
[4] SIRs > 1 are considered desirable and are typically approved and funded for energy projects in the public and private sectors.

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Cost – Benefit Analysis

- Air and Associated Corrosion in a Hydronic System Fluid Impact the Entire Project Team
- System Owners / Managers
  - Delayed Openings / Lost Revenue
  - Customer Complaints
  - Increased Operating Expenses (OPEX): Energy, Maintenance, Replacements
  - Future Increased Capital Expenses (CAPEX) to Mitigate Issues
- System Operators
  - Premature Equipment Failures
  - “Too Hot / Too Cold” Calls
  - Increased Labor Hours to Address Issues
  - Customer Complaints

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Cost – Benefit Analysis

- General Contractors / Mechanical Contractors / TAB Contractors / Cx Agents
  - Issues and Expenses “Chasing Air” During Start-Up, TAB, and Cx
  - Substantial Completion Delays Due to the Above and to Repair Ceiling Tiles Damaged When Accessing Manual Air Vents
  - Multiple Rounds of TAB and Cx Reports
  - Warranty Issues and Premature Equipment Failures During Warranty Period
  - Labor Hours Required for On-Site Meetings, Remedial Work, and Correspondence to Address Issues Related to Air and Related Corrosion
  - Reduced Profit Margin Due to Additional Expenses
  - Damaged Reputations and Relationships with Owners, Architects & Engineers

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Cost – Benefit Analysis

- Consulting Engineers and Architects
  - "Time is Money" / Limited Fees Available for CA at the End of the Project
  - Labor Hours Required for On-Site Meetings, Remedial Work, and Correspondence to Address Issues Related to Air and Related Corrosion
  - Avoidable Issue if "Value Engineering" Substituted Tangential Air Separator
  - Damaged Reputations and Relationships with Owners and Others
- Equipment Manufacturers and Manufacturer's Local Representatives
  - Labor Hours Required for On-Site Meetings, Remedial Work, and Correspondence to Address Issues Related to Air and Related Corrosion
  - Damaged Reputations and Relationships with Owners and Everyone Else
  - Possible Replacement of Equipment or Components, Even if Corrosion-Related

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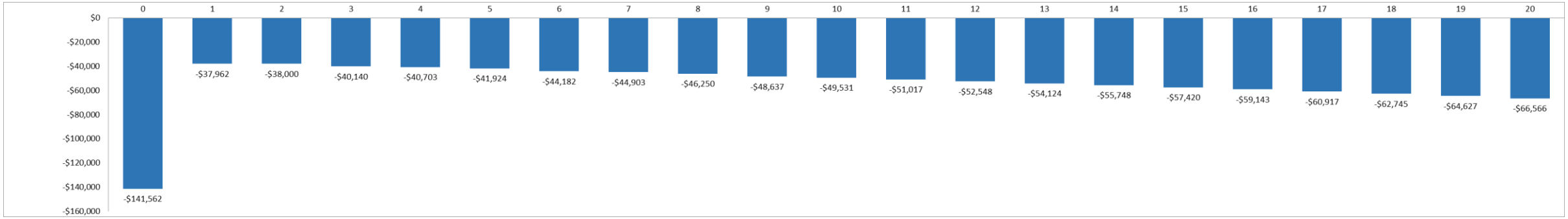
Cost – Benefit Analysis

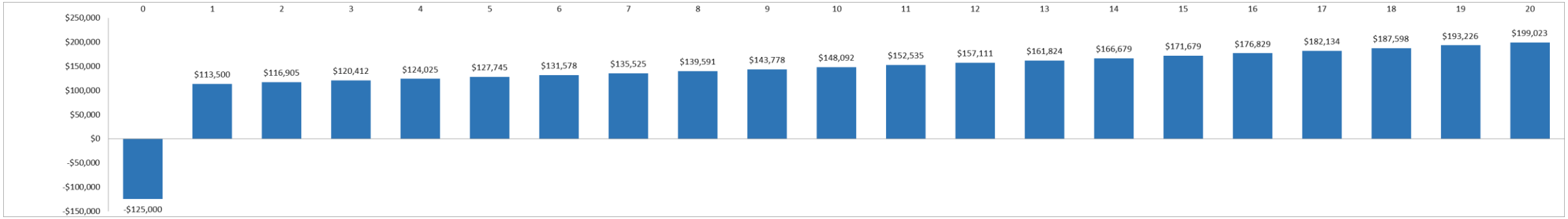
- Who Benefits From An Air- and Dirt-Free System?
  - System Owners / Managers
  - System Operators
  - General Contractors and Mechanical Contractors
  - Test and Balance Contractors
  - Commissioning Agents
  - Consulting Engineers
  - Architects
  - Equipment Manufacturers
  - Manufacturer’s Local Representatives

An Important Financial Principle – Look Long Term

Cash Flow by Year Example #1 – Sidestream Filters with Tangential Air Separators



Cash Flow by Year Example #2 – Spirovent Combination Air Eliminator and Dirt Separators



Contact us for assistance with a financial analysis of your facility or upcoming project!

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ENERGY MANAGEMENT ASSOCIATION

QUESTIONS?

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AIA Provider Number: 50111116

Course Number: EMA2006L

Thanks to our Associate Member:

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Virtual EMP Seminar

November 9-10 @ 2pm - 4pm Eastern

www.energymgmt.org/empseminars

Energy Benchmarking as a Service with ENERGY STAR's Portfolio Manager

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