STEAM TRAP MONITORING *A PERVASIVE SENSING™ STRATEGY*

ECONOMIC STUDY

EMERSON
Process Management

STEAM TRAP MONITORING OVERVIEW

Increases yield and product quality by assuring optimal temperature control and transfer of steam enthalpy

Improves plant reliability by reducing damage to equipment caused by water impingement, water hammer, corrosion & freezing

Reduces risk of safety incidents by minimizing water hammer, manual rounds and foot traffic in high risk areas

Optimizes productivity by enabling plant resources to focus on more critical activities

Reduces environmental impact by minimizing carbon emissions and water usage

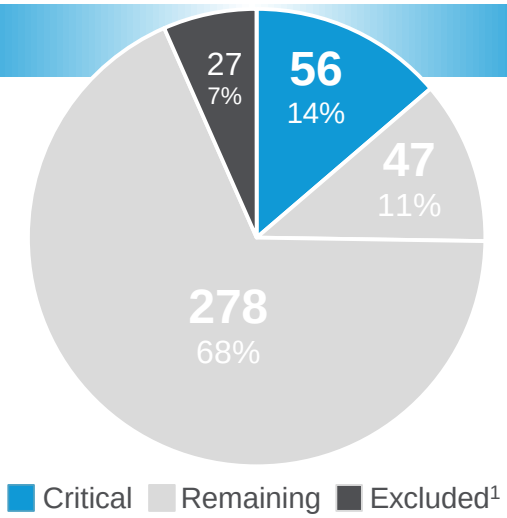
Improves energy efficiency by expediently addressing steam leaks and blow-thru failures to reduce boiler load & fuel use

Assumptions *used for analysis*
Total Trap Count
381
Steam Cost
$5.00 /1000lbs
Trap Failure Rate
15.0%
Annual Operating Hours
8,760
Boiler Fuel Type
Natural Gas
Remediation Cost
$800 /trap
Manual Audit Cost
$20.00 /trap

IMPLEMENTATION OPTIONS: *Short Term Payback, Long Term Savings*

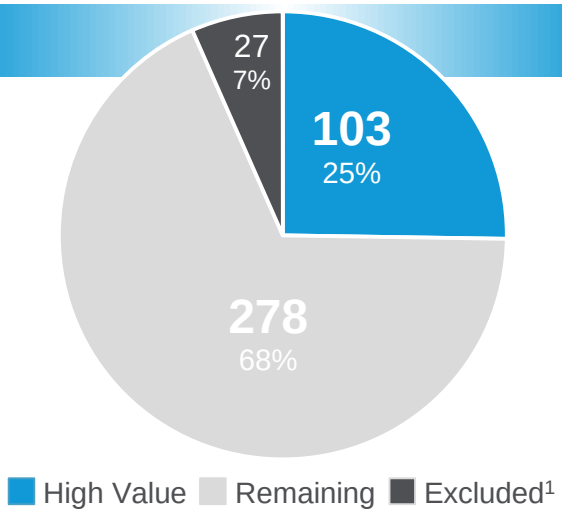
OPTION A: Critical Traps

Total Investment	$77,533
Annual Energy Savings	$55,696
Annual Manual Audit Savings	$1,120
Annual Emissions Savings	625 metric tons
Payback Period	18.6 months



OPTION B: Critical & High Value Traps

Total Investment	$143,338
Annual Energy Savings	$77,854
Annual Manual Audit Savings	$2,060
Annual Emissions Savings	861 metric tons
Payback Period	25.5 months



STEAM TRAP FAILURE MODE

	Risk	Reliability Impact	Process Impact	HSSE Impact	Energy Impact	Business Impact
CLOSED	Water Hammer	Piping & Equipment Repairs / Replacement	Unscheduled Shutdown	Increased Risk to Personnel Safety due to Event and Remediation	Increased Steam Production	Personnel Injury, Lawsuits, Lost Production, Capital Equipment Repair Costs
	Reduced Heat Transfer	Reduced Heat Exchanger Efficiency	Throughput Slow Down	Excessive Carbon Emissions for Increased Steam Production	Increased Steam Production	Increased Fuel Cost
	Poor Temperature Control	Reduced Heat Exchanger Efficiency	Poor Quality, Lost Batches, or Throughput Slow Down	Excessive Carbon Emissions for Increased Steam Production	Increased Steam Production	Lost Batches, Increased Scrap, Increased Rework Costs
	Water Impingement	Damage to Steam Turbines and Drives	Unscheduled Shutdown	Increased Risk to Personnel Safety due to Increased Maintenance	Increased Steam Production	Capital Equipment Repairs Purchase More Electricity
	Corrosion	Reduced Life of System Components, Pipe Scaling, Plugging Issues	Reduced Heat Transfer Throughput Slow Down Unscheduled Shutdown	Increased Risk to Personnel Safety due to Increased Maintenance	Increased Steam Production	Increased Maintenance and Equipment Costs
	Freezing	Steam Coils, Heat Plates Damaged by Condensate Freezing	Line Plugging Throughput Slow Down	Increased Risk to Personnel Safety due to Increased Maintenance	Increased Steam Production	Capital Equipment Repair and Higher Energy Costs
	Erosion	Premature Piping Failure	Reduced Heat Transfer Throughput Slowdown Unscheduled Shutdown	Increased Risk to Personnel Safety due to Increased Maintenance	Increased Steam Production due to Leaks	Potential Fines and Energy Expenses
OPEN	Leaking / Blowing Steam	Increased Condensate Return Pressure Lowers Trap Capacity & Risks Water Hammer	More Energy Required Increased Boiler Load	Excessive Carbon Emissions for Increased Steam Production	Increased Steam Production	Potential Fines and Energy Expenses

ANNUAL POTENTIAL ENERGY LOSS

Energy Loss	Pressure (psig)		
Orifice Diameter (in)	**65**	**165**	**600**
0.094			$3,585
0.125		$1,863	$6,373
0.188	$1,859		$14,340
0.250	$3,305		
0.344	$6,249		
0.500	$13,221		

Critical *High Value* *Remaining*

PROJECT DETAIL ▸ TOTAL SAVINGS

	All	High Value	Critical
Steam Traps to be Monitored	**381**	**103**	**56**
Average Annual Energy Loss /trap	$4,735	$10,078	$13,261
Energy Savings Percentage	50%		
Average Energy Savings /trap	$2,368	$5,039	$6,630
Annual Failure Rate	15%		
Annual Energy Savings	**$135,309**	**$77,854**	**$55,696**
Annual Manual Audit Cost Savings	**$7,620**	**$2,060**	**$1,120**
Total Projected Annual Savings	**$142,929**	**$79,914**	**$56,816**

STEAM TRAP POPULATION COUNT

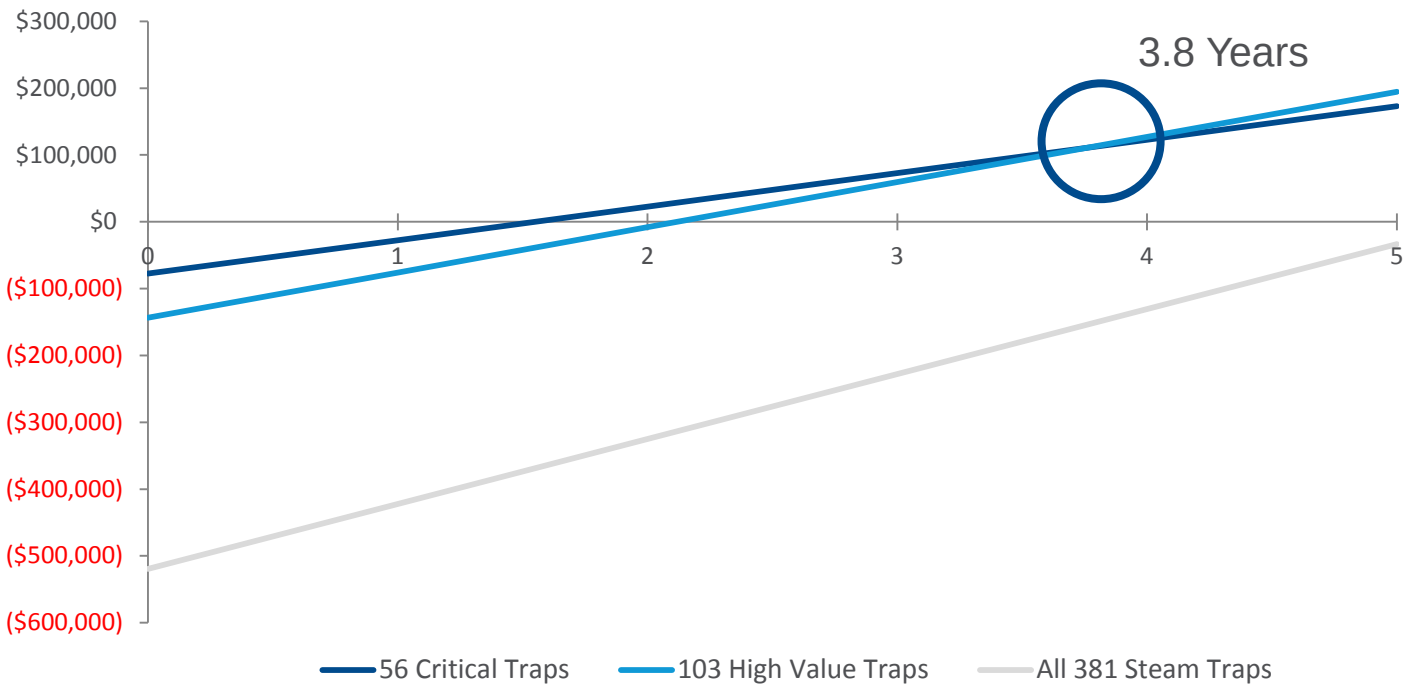
Trap Selection	Pressure (psig)		
Orifice Diameter (in)	**65**	**165**	**600**
0.094			1
0.125		52	14
0.188	54		2
0.250	171		
0.344	33		
0.500	54		

Critical *High Value* *Remaining*

PROJECT DETAIL ▶ RETURN ON INVESTMENT

	All	High Value	Critical
Steam Traps to be Monitored	**381**	**103**	**56**
708 Acoustic Transmitter Cost Estimate	$1,218		
1420 Gateway Cost Estimate	$4,554		
Installation & Commissioning Labor Estimate	$32,385	$8,755	$4,760
Total Installed & Commissioned Cost	**$519,290**	**$143,338**	**$77,533**
Expected Failures /year	57.15	15.45	8.4
Average Cost to Repair or Replace	$800		
Total Annual Cost to Repair or Replace	$45,720	$12,360	$6,720
Payback Period	**64.1 months**	**25.5 months**	**18.6 months**
5 Year Internal Rate of Return	-2%	38%	58%
Net Present Value @ 12% Cost of Capital	$350,415	$243,517	$180,584

CASH FLOW ANALYSIS



ENVIRONMENTAL IMPACT

	All	High Value	Critical
Steam Traps to be Monitored	**381**	**103**	**56**
Average Annual CO_2 Emissions Released /trap	$4,735	$10,078	$13,261
Emissions Reduction Percentage		50%	
Average Emissions Reduced /trap	$2,368	$5,039	$6,630
Annual Failure Rate		15%	
Annual Reduction of CO_2 (85% boiler efficiency)	**1,505 metric tons**	**861 metric tons**	**625 metric tons**
Annual Reduction of CO_2 in Passenger Cars	321.9 cars	184.1 cars	133.6 cars
Annual Reduction of CO_2 in Trees Planted	3,304 trees	1,890 trees	1,372 trees
Annual Water Savings	**3,243,000 US gal**	**1,866,000 US gal**	**1,335,000 US gal**
Annual Water Savings in Olympic Pools	4.9 pools	2.8 pools	2 pools

EMERSON Process Management

PRIORITIZED TRAP LIST SUMMARY

Area	Location	Trap Tag	App	Line Size (in)	Pressure (psig)	Orifice Diameter (in)	Blow-Thru Cost ($/yr)	CO_2 (ton/yr)
RU 2ND FLOOR	North of Zeolite Tanks	RU019	Drip Leg	1	600	0.188	$14,340	131.22
RU 1ST FLOOR	Aisle by Dump Tank A3 1068	RU143	Drip Leg	1	600	0.188	$14,340	131.22
41 MACHINE	W20	41M005	Shell and Tube Heat Ex	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, 2ND	East Hood Steam Coil	41M077	Heating Coil	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, 2ND	East Hood Steam Coil	41M078	Heating Coil	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, 2ND	East Hood Steam Coil - Future	41M079	Heating Coil	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, 2ND	East Hood Steam Coil - Future	41M080	Heating Coil	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, 2ND	West Hood Steam Coil	41M082	Heating Coil	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, 2ND	West Hood Steam Coil - Future	41M083	Heating Coil	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, 2ND	West Hood Steam Coil	41M084	Heating Coil	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, 2ND	West Hood Steam Coil - Future	41M085	Heating Coil	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, MEZZ	X35 AHU	41M101	Heating Coil	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, DRY	Rail Car Unloading Area - D26.9	41M148	Unit heater	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, DRY	G.5 Supertrol HX	41M164	Process Type?	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, DRY	G.5 Supertrol HX	41M167	Process Type?	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, PROD	Northwest Rail door	41M212	Heating Coil	5 1/2	65	0.500	$13,221	149.41
41 MACHINE, PROD	Northwest Rail door	41M213	Heating Coil	5 1/2	65	0.500	$13,221	149.41
RAIL TRACKS	UNIT HEATER	PM 201	Unit heater	5 1/2	65	0.500	$13,221	149.41
BLEACH PLANT	MUA-3 Pump/Trap	PM003	Process Type?	2	65	0.500	$13,221	149.41
BLEACH PLANT	SE MUA MEZZ. F- 20 MAKE UP AIR UNIT	PM021	AHU	2	65	0.500	$13,221	149.41
BLEACH PLANT	SE MUA MEZZ. F- 20 MAKE UP AIR UNIT	PM022	AHU	2	65	0.500	$13,221	149.41
CHEM PREP	ABSORPTION CHILLER - NORTH (B4)	PM039	Heating Coil	2	65	0.500	$13,221	149.41
CHEM PREP	ABSORPTION CHILLER - NORTH	PM040	Heating Coil	2	65	0.500	$13,221	149.41
CHEM PREP	MUA - CHEM PREP	PM053	AHU	2	65	0.500	$13,221	149.41
40 MACHINE	F11 Heat Exchanger	PM071	Process Type?	3	65	0.500	$13,221	149.41
LIME KILN	Lime Kiln Air Handler	PM080	AHU	5 1/2	65	0.500	$13,221	149.41
LIME KILN	MUA - A5	PM083	AHU	2	65	0.500	$13,221	149.41
LIME KILN	GREEN LIQUOR HEATER - D5	PM085	Shell and Tube Heat Ex	2	65	0.500	$13,221	149.41
LIME KILN	AHU - AIR MAKE UP	PM091	AHU	2	65	0.500	$13,221	149.41
BROWN STOCK	NE MAKE-UP AIR (A7.1)	PM116	Process Type?	2	65	0.500	$13,221	149.41
RU 2ND FLOOR	Southwest Make- Up Air System	RU005	AHU	2	65	0.500	$13,221	149.41
RU 2ND FLOOR	Southeast Corner	RU012	Process Type?	2	65	0.500	$13,221	149.41
RU 5TH FLOOR	MUA-7 Pump/Trap	RU040	AHU	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up air for Boiler - P6	RU047	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up air for Boiler -	RU048	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up air for Boiler - P1	RU049	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up air for Boiler - P4	RU050	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up air for Boiler - S1	RU051	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up Air for Boiler - S6	RU052	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up Air for Boiler - S7	RU053	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up Air for Boiler - S4	RU054	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up Air for Boiler	RU056	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up Air for Boiler	RU057	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up Air for Boiler	RU058	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up Air for Boiler	RU059	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up Air for Boiler	RU060	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up Air for Boiler	RU061	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up Air for Boiler	RU062	Heating Coil	2	65	0.500	$13,221	149.41
RU 4TH FLOOR	Make-Up Air for Boiler	RU063	Heating Coil	2	65	0.500	$13,221	149.41
RU 2ND FLOOR	Northeast MUA Condensate Pump	RU075	AHU	2	65	0.500	$13,221	149.41
RU 2ND FLOOR	Package Boiler Entrance (Above)	RU076	Unit heater	5 1/2	65	0.500	$13,221	149.41
RU 1ST FLOOR	MUA-2	RU101	AHU	2	65	0.500	$13,221	149.41
RU 1ST FLOOR	Trim Heater	RU115	Heating Coil	2	65	0.500	$13,221	149.41
RU 1ST FLOOR	East Overhead Door	RU119	Unit heater	5 1/2	65	0.500	$13,221	149.41
RU 1ST FLOOR	MUA-3	RU129	AHU	2	65	0.500	$13,221	149.41
RU 1ST FLOOR	East of Control Room	RU146	Heating Coil	5 1/2	65	0.500	$13,221	149.41

NOTES

1) Excluded steam traps consist of those with inlet (or differential) pressures below 20 psi. At inlet pressures below 20psi, the acoustic energy generated from steam and condensate passing through the orifice is very low and can be difficult to distinguish from background noise. For this reason, we remove these from being considered for real-time monitoring.

2) Napier's equation was used to estimate the flow through the steam trap orifice:

$$24.24 \times P_a \times D^2 \times F$$

P_a = Absolute Inlet Pressure
D = Orifice Diameter
F = Correction Factor (typically 62.5%) to statistically model blowing & leaking traps

3) Orifice size was estimated using statistical averages using inlet pressure & line size.

		Pressure @ Trap (psig)								
		20	25	50	75	100	125	150	200	250
Pipe Size	3/8	0.188	0.188	0.125	0.125	0.125	0.094	0.094	0.094	0.094
	1/2	0.250	0.250	0.188	0.156	0.156	0.125	0.125	0.094	0.094
	3/4	0.375	0.313	0.250	0.219	0.188	0.156	0.125	0.125	0.125
	1	0.500	0.438	0.344	0.313	0.281	0.250	0.219	0.188	0.188
	1 1/2	0.500	0.500	0.469	0.438	0.375	0.375	0.344	0.313	0.281
	1 3/4	0.500	0.500	0.500	0.469	0.438	0.438	0.375	0.344	0.344
	2	0.500	0.500	0.500	0.500	0.500	0.500	0.469	0.438	0.375

4) CO_2 losses were estimated using 85% boiler efficiency and the US EPA's 117.08lbm of CO_2 per million BTU estimate when using Natural Gas boiler fuel.

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