

WPS Energy Efficiency & Sustainability Summit

Wednesday, June 10
7:30 am–11:10 am

Lambeau Field
Green Bay, Wisconsin



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Raffle

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Welcome

Greg Smedema
Manger, Key Accounts
WPS



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Focus on Energy Business Program Updates

Dave Nyquist
Outreach Manager,
Focus on Energy



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2026 FOCUS ON ENERGY® OVERVIEW

June 10, 2026



FOCUS ON ENERGY



Wisconsin utilities' statewide energy efficiency and renewable energy program.

- Help Wisconsin residents and businesses manage rising energy costs.
- Provide education, information, and incentives.
- Promote in-state economic development.
- Protect our environment.
- Control Wisconsin's growing demand for electricity and natural gas.

OVERVIEW



- Provide financial incentives for energy-saving projects which would not otherwise occur.
- Technical assistance, including:
 - Estimate savings and payback for potential projects.
 - Provide best practice information and support for various industries.
 - On-site support to identify energy saving opportunities.

MISSION STATEMENT



Focus on Energy
empowers the people
and businesses of Wisconsin
to make smart energy
decisions with enduring
economic benefits.

FOCUS BY THE NUMBERS



Served nearly 172,000 residential participants 

 Served 4,000 business participants

Achieved \$4.17 in benefits for every \$1 invested 

Wisconsin's official resource for

smart energy solutions

Works with residents and businesses to complete

smart energy projects

Provides rebates, technical assistance, and

smart energy resources

PROGRAMS FOR BUSINESSES



focus on energy[®]

Partnering with Wisconsin utilities

WE SERVE ALL BUSINESS TYPES

Helping energy-efficient improvements be more affordable and achievable.



SMART ENERGY OPTIONS

Energy Efficiency Technologies

- Refrigeration.
- Process Systems.
- HVAC.
- Lighting.

Renewable Energy Technologies

- Solar Electric.
- Solar Thermal.
- Biomass & Biogas.
- Wind.
- Hydroelectric.

SMART ENERGY SERVICES

Our services help single-building and large portfolio holders make energy-efficient decisions to save money and energy.

- Optimize building energy use.
- Assess energy-using systems.
- Retrocommissioning.
- Energy management services.
- New construction and renovations design assistance.

BUSINESS OFFERS



- What's considered a business?
 - Commercial.
 - Industrial.
 - Agribusiness.
 - Government.
 - Education.
- Other considerations
 - Must be on a business meter/rate.
 - New construction or existing building.



INCENTIVE PATHS



Rebates

- Set dollar amounts.
- Covers commonly installed equipment.
- Applied for after installation.

Instant Discounts

- Work with participating Trade Ally or distributor.
- Purchase qualifying equipment.
- Receive instant discount on purchase.

Custom Incentives

- Incentive based on energy saved.
- Typically for less common equipment replacements.
- Requires pre-approval before getting started.

Design Assistance

- For new construction and major renovation projects only.
- Evaluate different equipment configurations.
- Incentive based on energy saved.

REBATES



- Standard equipment retrofits.
- Generally, 1-for-1 replacements.
- Fixed rebate rates.
- Preapproval not required unless specified.
- Rebate amount and requirements listed in rebate catalogs.
- Visit [focusonenergy.com/catalogs](https://www.focusonenergy.com/catalogs) to view current catalogs.



REBATE APPLICATION PROCESS

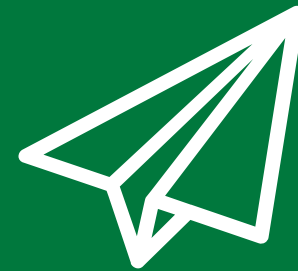


1. Confirm equipment eligibility.

- Review requirements in rebate catalog.
- Obtain pre-approval if required.
- Contact an Energy Advisor for additional support.

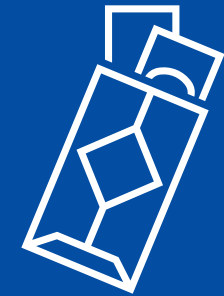


2. Install qualifying equipment.



3. Submit application, invoices, and required documentation.

- Must be submitted within 60 days of project completion.
- Send to Energy Advisor or business@focusonenergy.com



4. Receive check within 6-8 weeks.

- A post-installation inspection may be required prior to payment.

INSTANT DISCOUNTS



Distributor provides point of sale discount or post sale credit.

Installing contractor installs equipment and collects basic customer data.

Contractor passes discount to customer as a credit on final invoice.

INSTANT DISCOUNTS FOR BUSINESSES



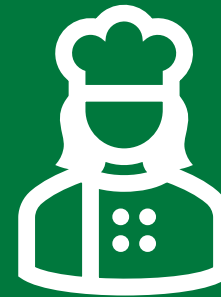
HVAC

- Air Source Heat Pumps <5.4 tons
- Boilers <300 MBh
- Furnaces
- Smart Thermostats



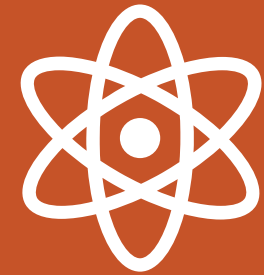
Water Heating

- Heat Pump
- Indirect
- Tankless
- Storage



Commercial Kitchens

- Cooking Equipment
- Dishwashers
- Hood Controls
- Ice Machines



Life Sciences

- Lab-grade refrigerators and freezers
- Ultra-low-temp freezers
- Ice Machines

HOW TO PARTICIPATE



Ask your contractor if they offer instant discounts.

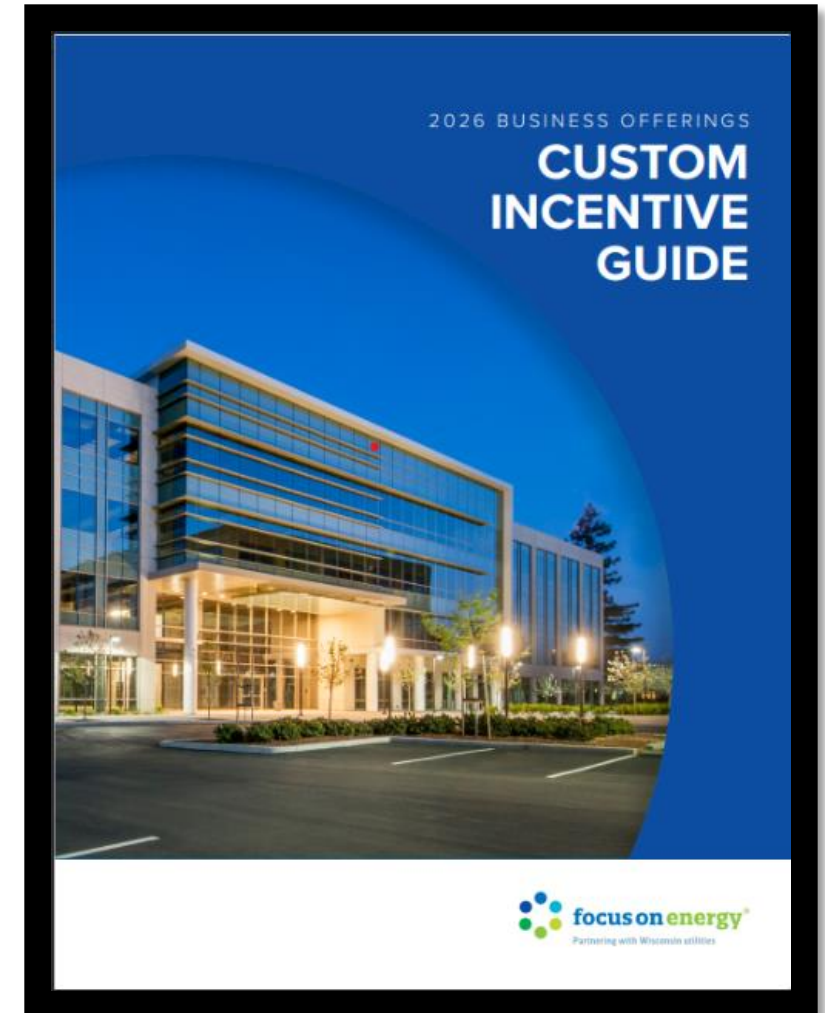
Confirm equipment eligibility and provide your contractor basic business details.

Receive the discount on your invoice.

CUSTOM INCENTIVES



- Offered for projects where a rebate does not exist.
- E.g., non-standard equipment or operating conditions, not a 1-for-1 replacement.
- Incentive is based on the estimated first year gas and electric energy savings.
- Projects must pay back between 1 and 10 years.



CUSTOM APPLICATION PROCESS



1. Engage Energy Advisor.

- Pre-approval is required prior to project starting for all Custom projects.



2. Provide project information.

- Work with your Energy Advisor and Trade Ally.
- Include proposal, specifications, and utility data.



3. Obtain pre-approval.

- Your Energy Advisor will use project information to calculate energy savings and incentive.



4. Install equipment.

- Equipment can be purchased and installed after signing the Incentive Agreement.



5. Notify Energy Advisor of completion.

- A post-installation inspection may be required.
- Receive your incentive check within 6-8 weeks.

CUSTOM INCENTIVES







All custom incentives require pre-approval from the program before equipment is purchased or work begins. This includes signing purchase orders or proposals.

Contact an Energy Advisor before purchasing equipment if you are unsure whether your project requires a custom incentive.

BUSINESS NEW CONSTRUCTION OFFERINGS AND TIMING



Incentives and technical support available at any step during the design and construction process.

PLANNING AND DESIGN	CONSTRUCTION DOCUMENTS	BIDDING/ ESTIMATING	CONSTRUCTION	MOVE-IN
<p>Optimal Timing</p>  <p>Energy Design Assistance including income-qualified housing consulting</p>	<p>Opportunities Still Available</p>  <p>Energy Design Review</p>		<p>Fewer Opportunities</p>  <p>Rebates and Incentives</p>	<p>Contact Us*</p>  <p>*for opportunities within 60 days of occupancy</p>

SOLAR PHOTOVOLTAIC (PV)



- Solar PV incentives available based on system size.
- Customer incentive is based on system kW (DC Rating) and limited to \$25,000 for businesses.

OTHER RENEWABLE TECHNOLOGIES



- Up to \$300,000 per project.
- Incentive based on expected system production.
- Available for:
 - Biogas.
 - Biomass.
 - Solar Thermal.
 - Wind.
 - Hydroelectric.
- Uses the Custom Incentive Application and Guide.



BUILDING PERFORMANCE OPTIMIZATION (BPO)



- Common tune-up and controls system changes.
- Tune-up measures:
 - Boiler Tune-Up - \$0.05 per MBh.
 - Chiller Tune-Up - \$1 per Ton.
- Optimization measures:
 - Receive \$500 per installed measure.

System	Building Performance Optimization Measure
Tune-Ups	<ul style="list-style-type: none"> • Boiler Tune-Up • Chiller Tune-Up
Cooling	<ul style="list-style-type: none"> • Chiller schedule optimization. • Chilled water reset controls.
Heating	<ul style="list-style-type: none"> • Hot water supply reset. • Hot water system cutout optimization.
Valve & Damper Repair	<ul style="list-style-type: none"> • Chilled water valve repair. • Economizer repair/upgrade. • Hot water valve repair. • Triple-duty valve optimization.
Ventilation	<ul style="list-style-type: none"> • Adaptive optimal start. • HVAC fan static pressure reset. • Morning warm-up optimization. • Outside air intake control optimization. • Schedule optimization, temperature setback. • Zone-based scheduling.

RETROCOMMISSIONING (RCx)



- Optimize performance and efficiency of existing system.
- Work with a Registered Service Provider to complete an audit of the facility.
- Select energy-saving measures to implement.
- Focus on Energy provides an incentive for completing the audit and implementing selected measures.

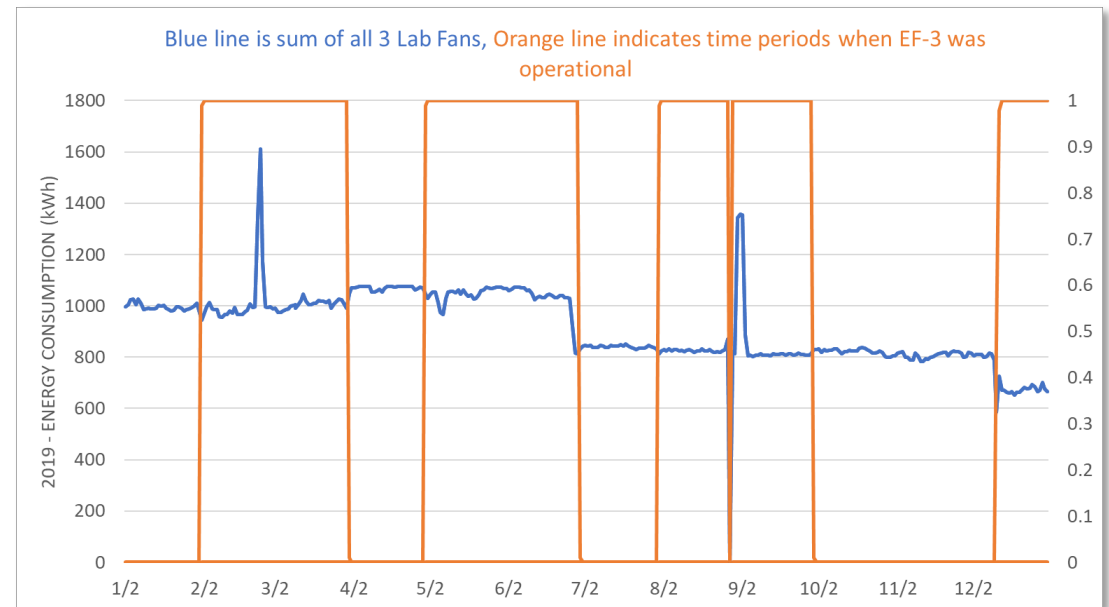


RETROCOMMISSIONING REQUIREMENTS

- Facilities must be at least six years old, with no major renovations or new construction occurring within last six years.
- Facility must have direct digital controls (DDC).
- Must work with a Focus on Energy Registered Service Provider. Service providers register by applying online at focusonenergy.com/forms/ta-application.

RETROCOMMISSIONING COMMON MEASURES

- Outside Air Optimization.
- Chilled/Hot-water Reset.
- Valve Optimization.
- Scheduling and Setbacks.
- Supply Air Temperature Reset.
- Variable Air Volume (VAV) Control.



PRACTICAL ENERGY MANAGEMENT (PEM)



Work with an Energy Advisor to:

1. Establish an energy baseline and set energy-saving goals.
2. Investigate opportunities for efficiency and develop an energy management plan.
3. Implement energy-saving projects and verify impact.

Incentives are available for:

- Entering monthly utility data into a benchmarking program or software.
- Attending energy-related trainings.
- Communicating and celebrating energy-saving successes.

GETTING STARTED WITH FOCUS ON ENERGY



WORKING WITH AN ENERGY ADVISOR



- Identify energy-saving opportunities.
- Create, maintain, and monitor energy management plans.
- Verify measure eligibility and assist with paperwork.
- Complete energy-saving estimates and apply for custom incentives.
- Coordinate media opportunities.



WORKING WITH A TRADE ALLY



- Registered Trade Allies provide additional support.
- Familiar with the rebates their equipment qualifies for.
- Assist with completing paperwork.
- Can elect to receive rebates and incentives on behalf of the customer, reducing first-cost.
- Find a Trade Ally at [focusonenergy.com/trade-allies](https://www.focusonenergy.com/trade-allies).

THANK YOU



Recovering Industrial Waste Heat: Real-World Strategies for Steam Recovery and Energy Savings

Tom Tucker, P.E.
Principal
Kinergetics LLC



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2026 WPS Energy Efficiency and Sustainability Summit

Recovering Industrial Waste Heat: Real World Strategies for Heat Recovery and Energy Savings

June 10, 2026



Tom Tucker, P.E., Principal

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Topic Areas...

1. Some basic thermodynamics (1st and 2nd Law) and “temperature matching”.
2. Heat exchanger performance screening.
3. Heat pumps and related applications.
4. Questions?

About Kinergetics...

1. Founded in 2006, was the first to provide energy investigations to ethanol plants for the U.S. DOE.
2. Industrial sectors have been ethanol, bio-products, seed oil extraction, pulp/paper, chemicals, food processing.
3. Expertise in power and thermal optimization
4. Thermal optimization, waste heat recovery (including vapor recompression), construction oversight, commissioning and startup.

Thermodynamics – Energy & “Quality” of Energy Sources

- 1st Law:
 - Essentially energy in = energy out (no exceptions).
 - Considers quantity only – Treats ALL sources the same.
- 2nd Law:
 - Considers quantity & quality – Recognizes all energy sources are NOT the same.
 - Focus is on conservation of *work potential rather* than only on conservation of energy.

Thermodynamics – Energy & “Quality” of Energy Sources Cont’d:

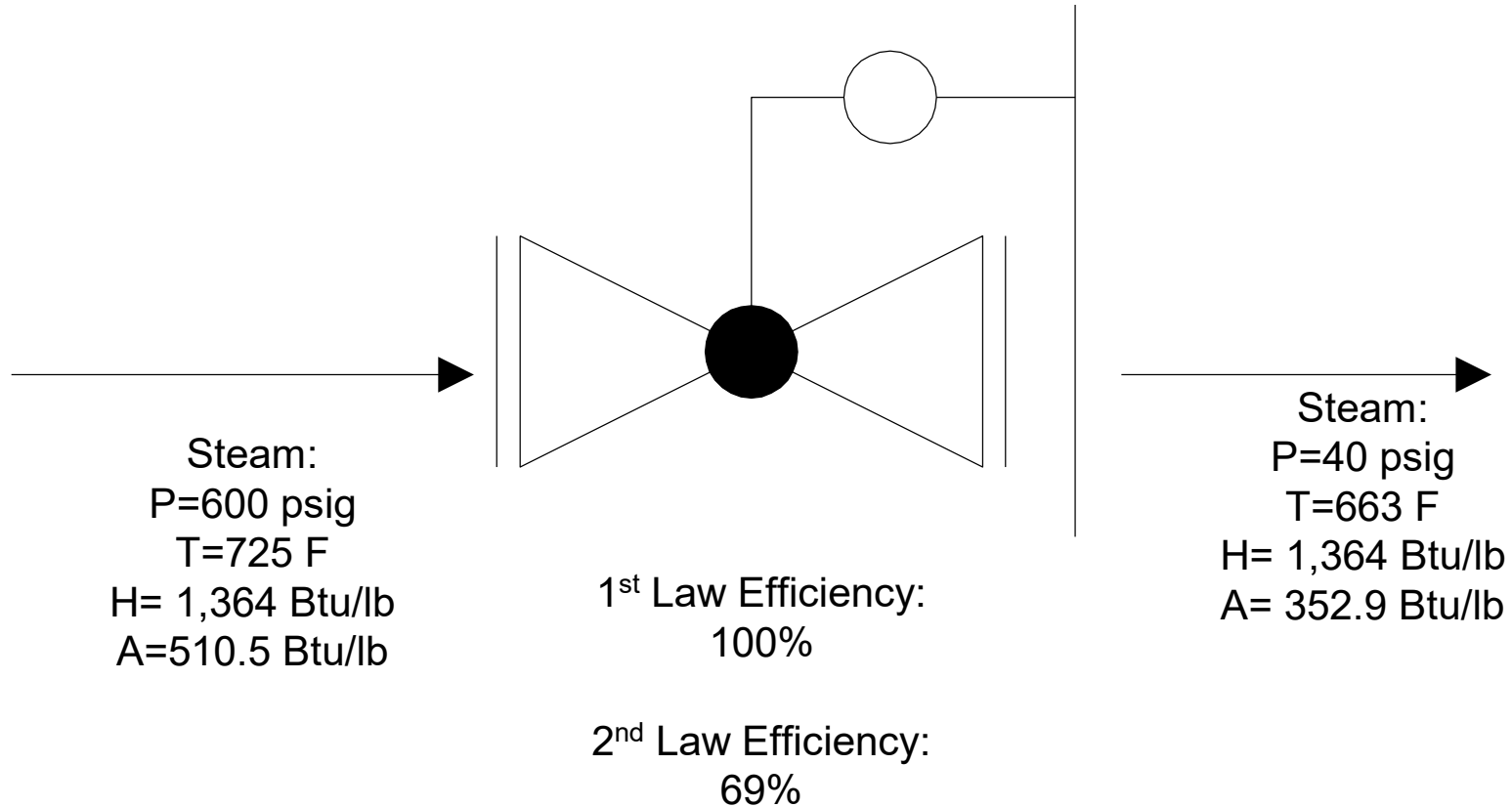
The “Source” is any energy source and the “Approx. % Relative Availability” is the potential of the resource to do work.

Note the Hot Water. A domestic water heater has an “operating” 1st law efficiency of ~65% to 75%, commonly cited.

The 2nd law efficiency is ~2%!!

“Source”	Approx. % Relative Availability
Electricity	100
Fuel (nat gas)	75
Hot Oil	45
600-psig Steam (725°F)	32
125-psig Steam (353°F)	22
50-psig Steam (298°F)	15
15-psig Steam (250°F)	7
Hot Water	~2

Thermodynamics – Energy & “Quality” of Energy Sources Cont’d:



ALL energy conversions destroy potential to do work, even with no energy loss.

Thermodynamics – Energy & “Quality” of Energy Sources Cont’d:

- From a temperature focused perspective, implies that during heat transfer, the heat source (supply) and heat sink (stream to be heated) should be as close in temperature as reasonable.
 - Example: Don’t use cooling tower water (~95°F) to condense process vapor (~160°F) if hot water (~130°F) is needed.
 - The above concept is a peek into detailed thermal analysis and design

Thermodynamics – Energy & “Quality” of Energy Sources Cont’d:

- Systematic methods for temperature matching are “Pinch Analysis” and “Availability Analysis”.
 - Pinch Analysis is more concerned with counting energy and Availability Analysis is more concerned with conservation of work.
- Kinergetics developed “PseudoPinch™”, approach blends Pinch and Availability Analysis with practical design.

Case Study 1: Temperature Matching

Process Heat Recovery in Soybean Oil Extraction

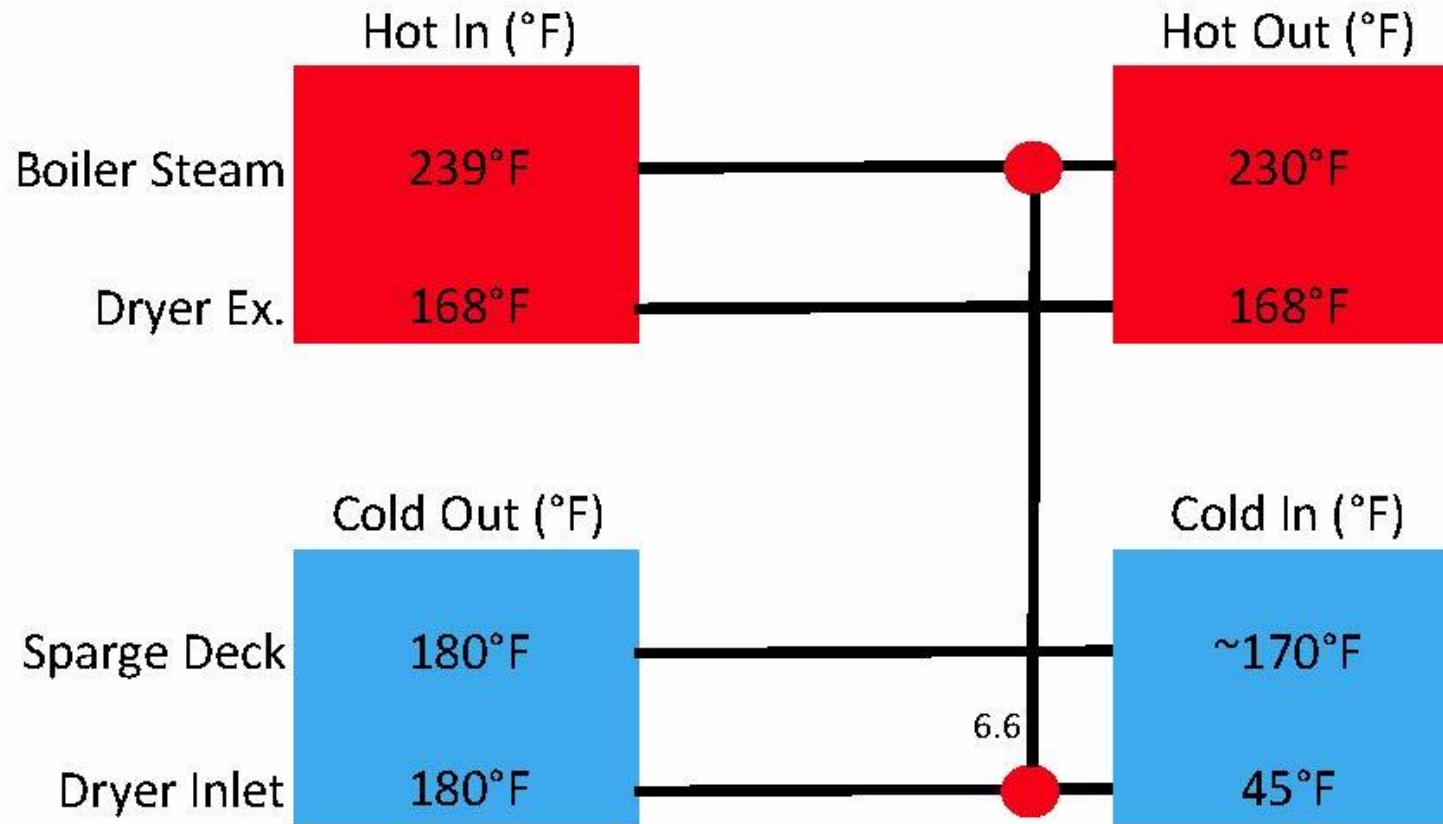
CS 1: Temp. Matching:

- Seed oil extraction uses a dryer and sparge steam to remove hexane and “toast” the meal after oil removal.
- Facility 10 PSIG (~239°F) flash steam venting from the steam system and wet dryer exhaust leaving at ~168°F.
- Plant originally decided to use the flash steam to preheat dryer inlet air from 45°F (easy & inexpensive).
- Problem – Now there is no “sink” for the 168°F exhaust & flash is not available to offset 5 PSIG sparge steam.

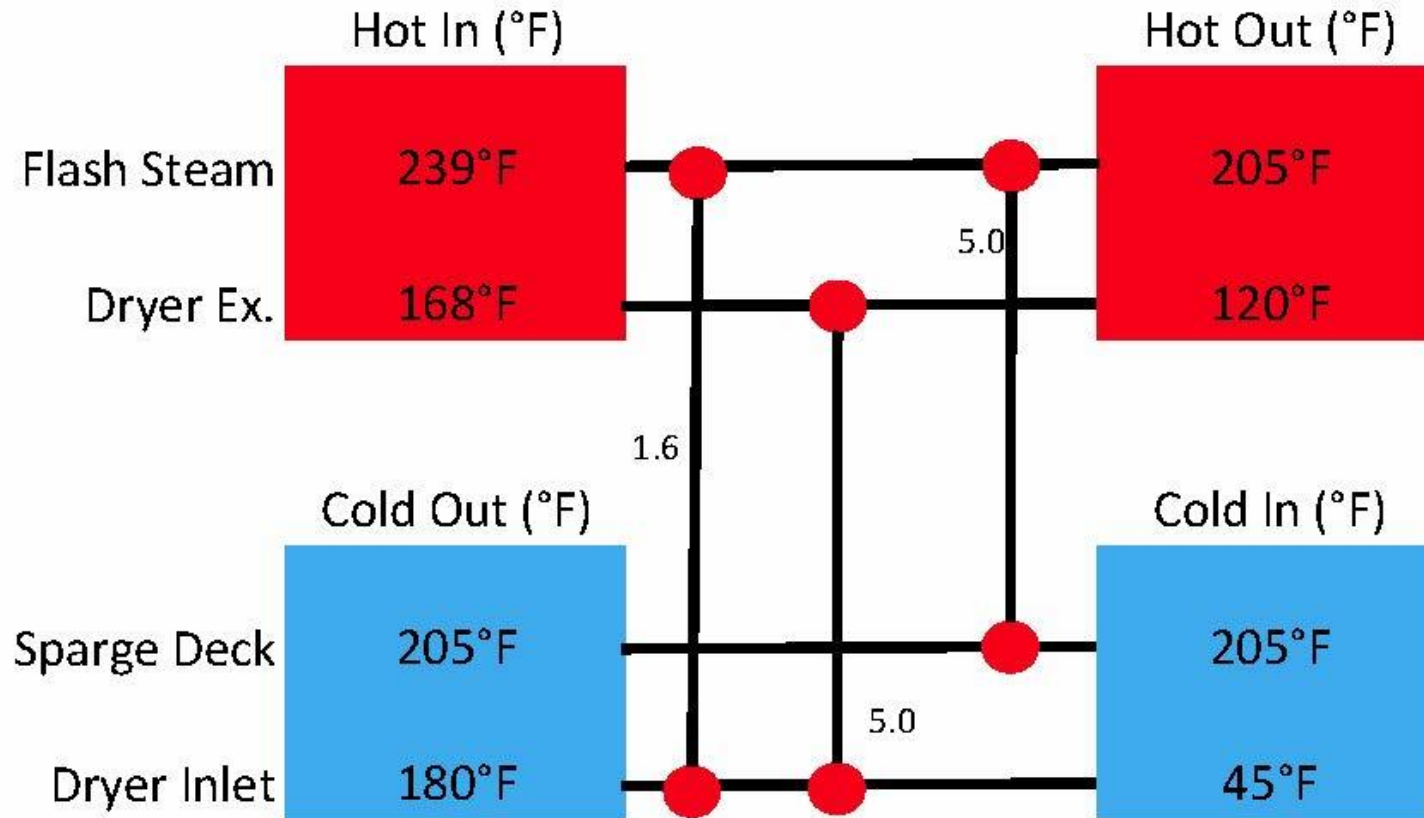
CS 1: Temp. Matching Cont'd:

- If temperature matching had been considered, the indicated approach would have been:
 - Use the flash 10 PSIG flash steam for the sparge.
 - Use the nearly saturated process exhaust at $\sim 168^{\circ}\text{F}$ to preheat dryer inlet air (from outdoors).
 - The “grid” or “spaghetti” diagram is a good way to

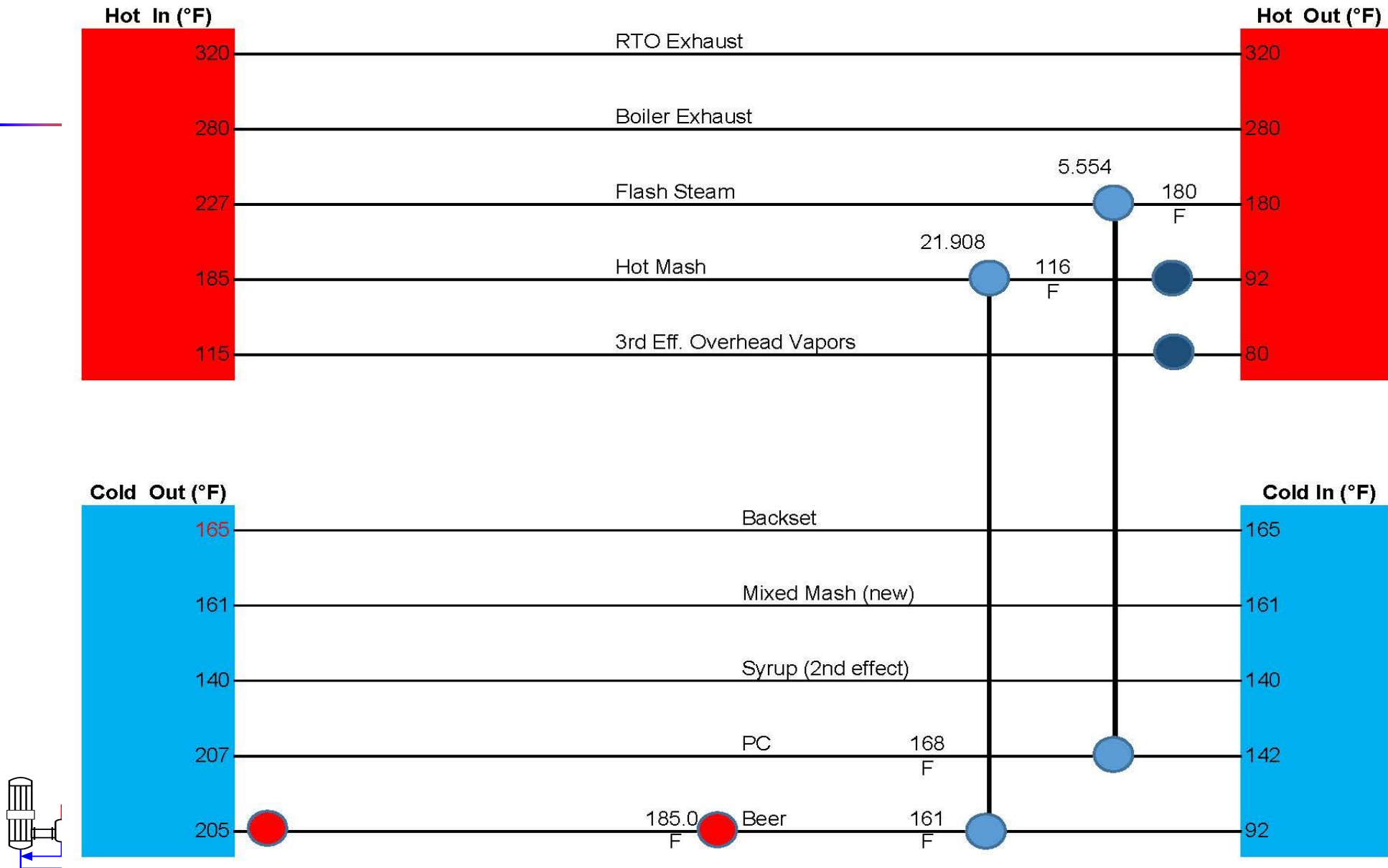
Existing Heat Recovery Grid



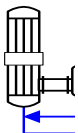
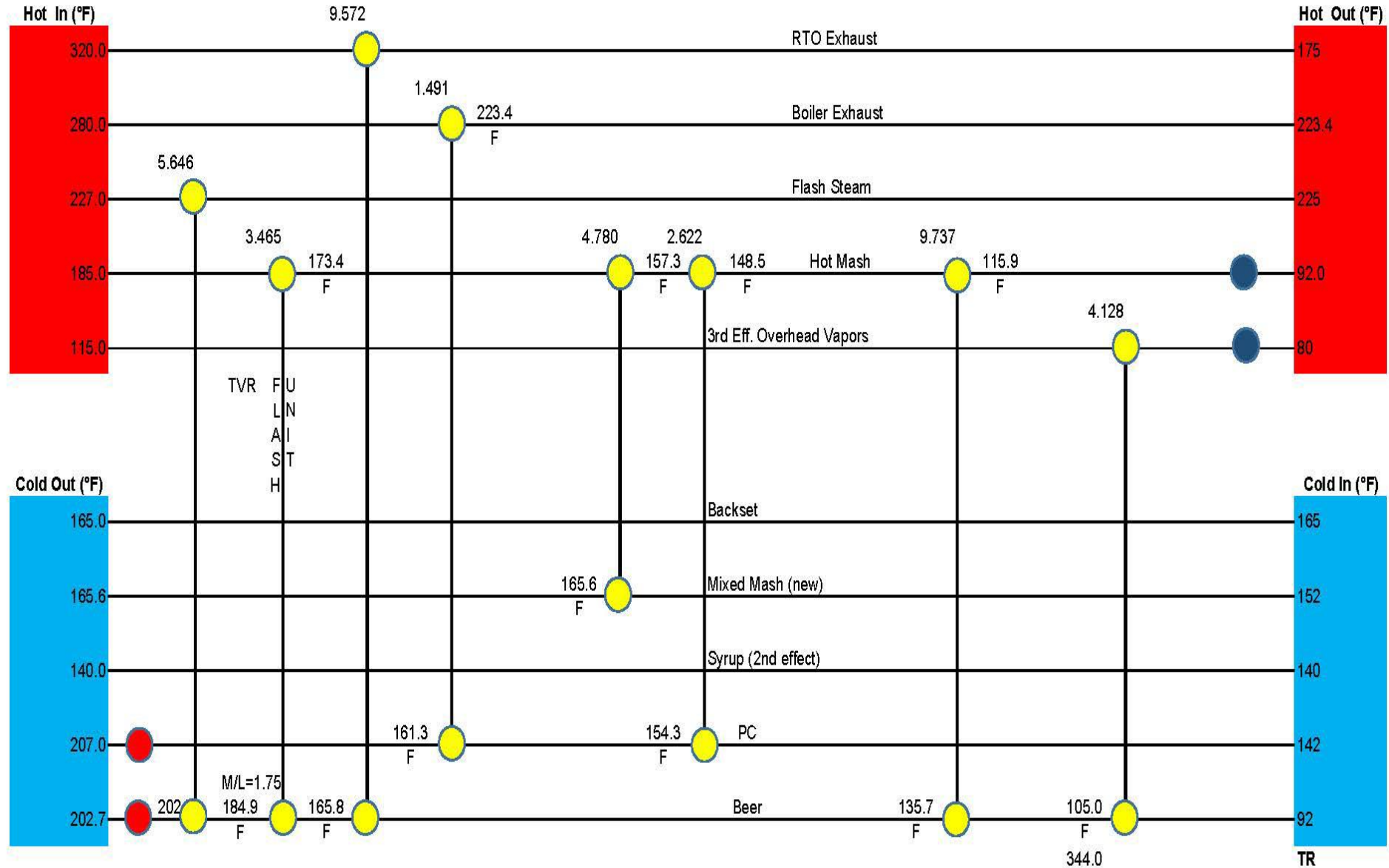
Improved Heat Recovery Grid



Existing Recovery Network Grid



Optimized Recovery Network Grid



Temperature Matching - Parting Comments:

- Aside from temperature matching of the heat source and heat sink, heat exchanger selection can have a big impact on thermal performance.
- Low exchanger pressure drop usually sacrifices heat transfer for a given exchanger selection.

INDIRECT CONTACT HEAT RECOVERY

Indirect Heat Recovery:

- The NTU method is a relatively simple method good for screening.
 - E is defined as the “Effectiveness”
 - E: $C_h/C_c \times (T_{hi}-T_{ho})/(T_{hi} - T_{ci})$
 - C_h, C_c : heat capacity x mass flow
 - C_{min} is smaller of C_h & C_c .
- Above is for no phase change (condensing or evaporation), but there are other forms to handle such applications.

Case Study 2

Micro-CHP (mCHP) Heat Recovery Loop

CS 2: mCHP Heat Recovery Loop



Recovery Exchanger Spec.

PROJECT DATA SHEET

INPUT DATA	Side 1	Side 2	UNITS
Heat load		336000,0	BTU/h
LMTD		34,8	°F
Min oversizing		0,00	%
Fluid	Water	Water	
Inlet temperature	180,00	120,00	°F
Outlet temperature	150,00	140,00	°F
Mass flow	186,97	280,90	lb/min
Inlet volume flow	23,09	34,09	USGal/min
Outlet volume flow	22,88	34,27	USGal/min
Max pressure drop	5,0	5,1	psi
Design pressure	43,5	43,5	psi
Design temperature	180,0	140,0	°F
HEAT EXCHANGER	Side 1	Side 2	UNITS
Heat transfer area		33,8	ft ²
Fouling factor		0,00239396	ft ² h°F/BTU
OHTC clean		902,8	BTU/ft ² h°F
OHTC fouling		285,6	BTU/ft ² h°F
Oversize		216,1	%
Calc. press. drop	2,4	5,0	psi

CS #2: mCHP Ht Recovery Loop Cont'd:

- $T_{hi} / T_{ho} = 180^{\circ}\text{F} / 150^{\circ}\text{F}; T_{ci} / T_{co} = 120^{\circ}\text{F} / 140^{\circ}\text{F}$
- Hot flow: ~ 23 GPM with $C_p \sim 1$ BTU/LB- $^{\circ}\text{F}$
- Cold flow: 34 GPM with $C_p \sim 1$ BTU/LB- $^{\circ}\text{F}$
- $C_h = 11,500$ LB/Hr x 1 BTU/LB- $^{\circ}\text{F} = 11,500$ BTU/Hr- $^{\circ}\text{F}$
- $C_c = 17,000$ LB/Hr x 1 BTU/LB- $^{\circ}\text{F} = 17,000$ BTU/Hr- $^{\circ}\text{F}$
- $C_{\min} = 11,500$ BTU/Hr- $^{\circ}\text{F}$
- $E = 11,500 / 11,500 \times (180 - 150)^{\circ}\text{F} \div (180 - 120)^{\circ}\text{F}$
- $= 0.50 = 50\%$ (a bit low, generally speaking)
- **BUT**, pressure drop is low: 2.4 PSI hot and 5.0 PSI cold

Indirect Heat Exchange Examples...



Wood Fired Boiler
Exhaust Heat Recovery



Scrubber Exhaust Heat for Makeup
Air Preheating



RTO Exhaust Heat Recovery

Heat Pumps

Heat Pumps:

- Make an un-useable lower temperature source useful through a compression process of some sort. General types:
 - Closed, open and semi-open cycle are the most common.
 - Mechanical (MVR) and Thermal (TVR) vapor recompression can be used.
- However, most heat pump applications incorporate an electric motor driven compressor.

Heat Pumps Cont'd:

- Performance is defined by (COP_{HP}), the Coefficient of Performance.
- Theoretical COP_{HP} :

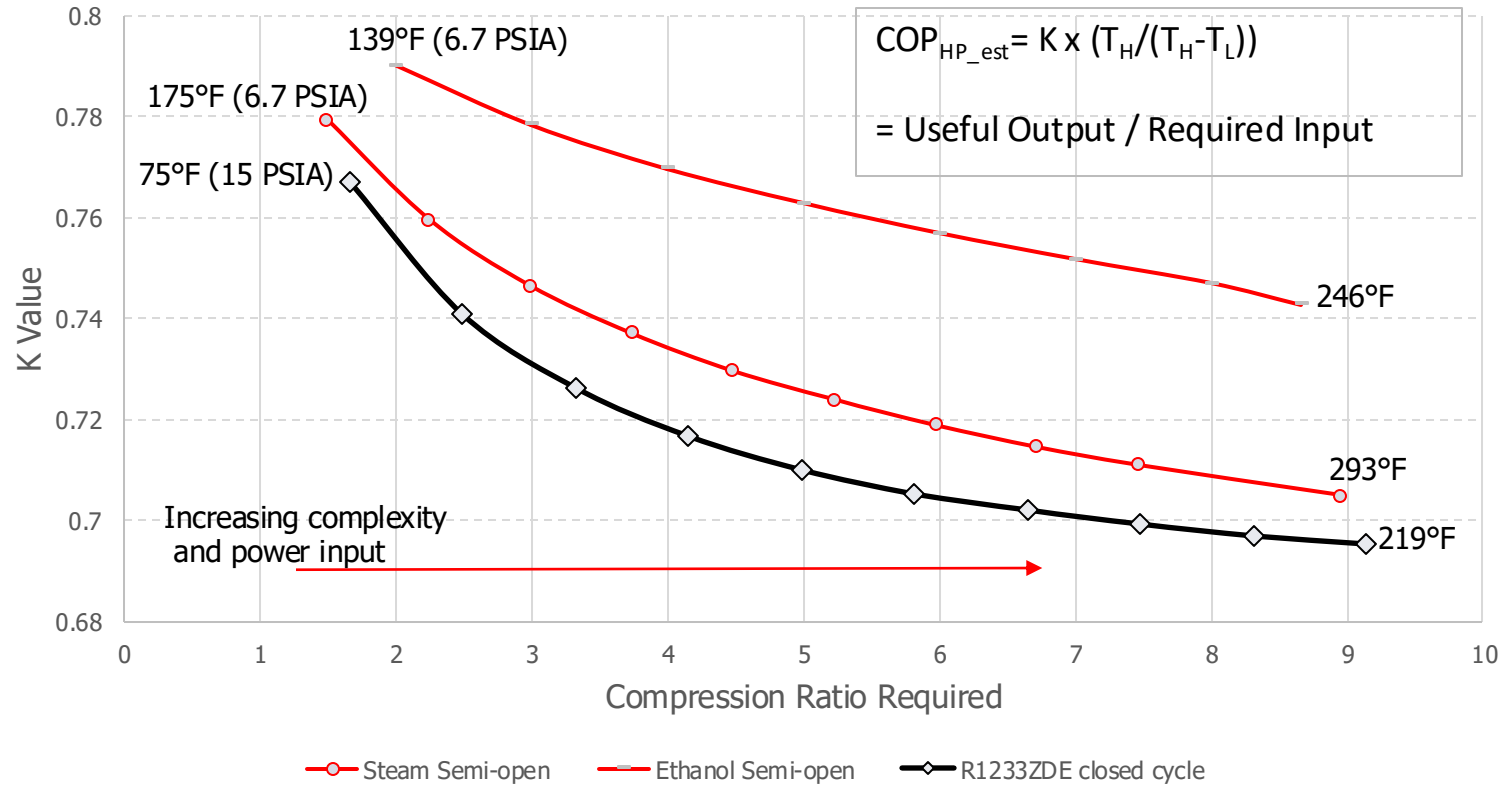
$$COP_{HP_theor} = T_H / (T_H - T_C) = Q_H / (Q_H + Q_C)$$

- The practical $COP_{HP} = K \times COP_{HP_theor}$
- “K” is the ratio of “practical” COP_{HP} to theoretical COP_{HP}

Heat Pumps Cont'd:

K Value is the ratio of "practical" COP_H to theoretical COP_H

Heat Pump COP_H "K" Values



Heat Pumps Cont'd:

- T_H = Absolute temp of heat sink (Rankine)
- T_C = Absolute temp of heat source (Rankine)
- Rankine (R) = $^{\circ}\text{F} + 459$
- Absolute temperature (R) MUST be used
- So, how do you conduct a preliminary evaluation of a heat pump opportunity?

Heat Pumps Cont'd:

- Select a heat source and heat sink, determine heat loads and process temperatures required.
- For closed cycle heat pumps:
 - Subtract 15°F from the lower *source* temp.
 - Add 15°F to the higher *sink* temp.
- For semi-open cycle heat pumps:
 - Follow the above for the source or sink
- The temperatures are an approximation to heat exchangers. A Case Study example...

Case Study 3

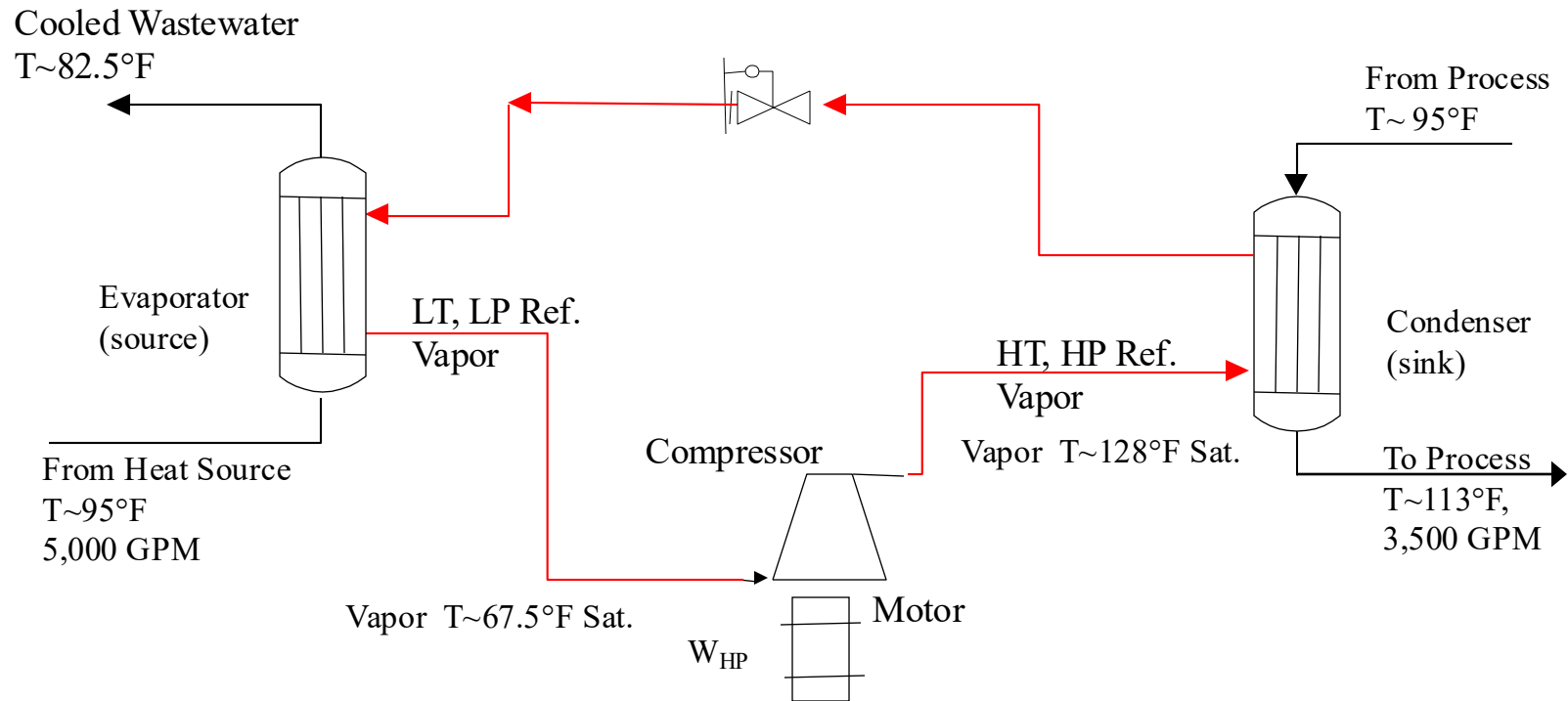
Wastewater Heat Recovery at a Eastern US Pulp and Paper Mill

CS 3: Pulp and Paper Mill:

- PM dryers have heat recovery, but stock was still only $\sim 105^{\circ}\text{F}$ on average.
- Ideal temp for vacuum dewatering is $\sim 125^{\circ}\text{F}$.
- River water temperature varies from about 36°F to 75°F seasonally, and the average water from treatment to the river is $\sim 95^{\circ}\text{F}$.
- Incoming river water (makeup) needed to be $\sim 113^{\circ}\text{F}$ for stock target of $\sim 125^{\circ}\text{F}$.
- Preliminary Project: Indirect heat exchange and closed-cycle heat pump were selected.

CS 3: Pulp and Paper Mill Cont'd:

(paper mill wastewater heat recovery)



Project evaluation from eastern US paper mill to preheat stock to the paper machines. Compliments existing condensing heat recovery system.

CS 3: Pulp and Paper Mill Cont'd:

- Estimate $COP_{HP_theor} = T_H / (T_H - T_C)$
- Select a “K” Value. Recommend 0.70 as first approximation.
- Estimate preliminary target COP_{HP}
 - $COP_{HP} = K \times T_H / (T_H - T_C)$
- Referring back to the example:
 - $T_C = 85^\circ F - 15^\circ F = 70^\circ F$
 - $T_H = 113^\circ F + 15^\circ F = 128^\circ F$

CS 3: Pulp and Paper Mill Cont'd:

- $T_H = 128^\circ\text{F} + 459 = 587\text{R}$
- $T_C = 67.5^\circ\text{F} + 459 = 526.5\text{R}$
- $\text{COP}_{\text{HP_theor}} = 587\text{R} / (587\text{R} - 526.5\text{R}) = 9.7$
- $\text{COP}_{\text{HP}} = 0.70 \times 9.7 = 6.8$
- Estimate the heating demand, Q_H :
 $= 3,500 \text{ GPM} \times 8.3 \text{ LB/Gal} \times 60 \text{ min/Hr} \times (113-100)^\circ\text{F}$
 $= 31,374,000 \text{ BTU/Hr}$

CS 3: Pulp and Paper Mill Cont'd:

- Estimate the compressor shaft power, W_{BHP} :

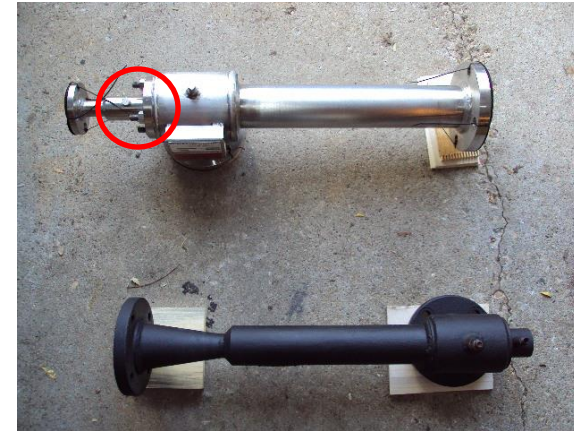
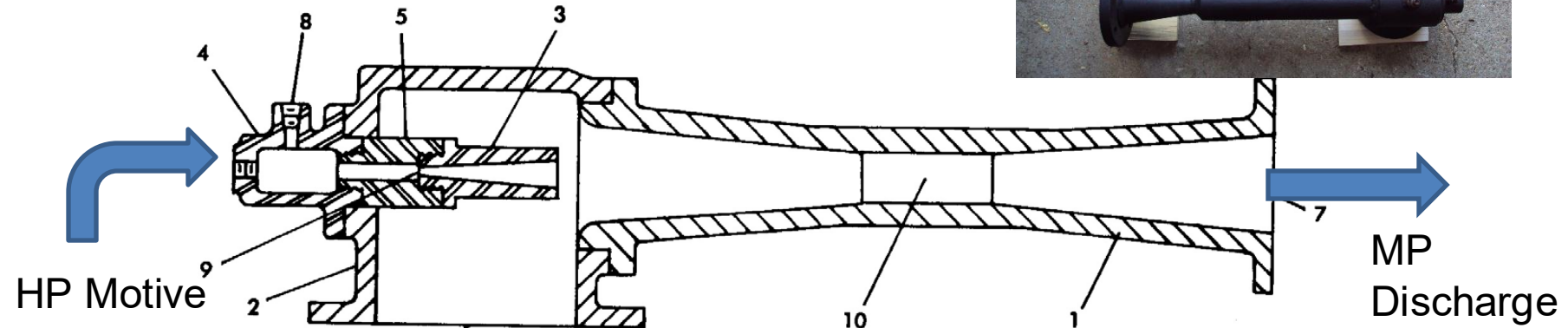
$$\begin{aligned}W_{\text{BHP}} &= Q_{\text{H}} \div \text{COP}_{\text{H}} \\ &= 31,374,000 \text{ BTU/Hr} \div 6.8 \\ &= 4,613,823 \text{ BTU/Hr} \\ &= 4,613,823 \text{ BTU/Hr} \times (1 \text{ kW} \div 3,412 \text{ BTU/Hr}) \\ &= 1,352 \text{ kW}\end{aligned}$$

- Electrical power required based on 95% efficient motor = $1,423 \text{ kW}_e$
= $1,908 \text{ HP}_e$

Thermal Vapor Recompression (TVR)

- A TVR is essentially a thermal heat pump that uses steam instead of electricity for the compression.
- Historically common to improve the steam economy/efficiency of evaporators and as the primary driver on many vacuum systems.
- A steam TVR uses high pressure “Motive” steam to compress a lower pressure “Load” steam to a medium pressure “Discharge” steam.
- Device is called thermo-compressor, steam jet ejector or eductor depending on the application, but they all compress a “Load” vapor.

TVR Cont'd:



- 1. Diffuser
- 2. Suction Chamber
- 3. Steam Nozzle
- 4. Steam Chest
- 5. Extension (if used)

- 6. Suction
- 7. Discharge
- 8. Steam Inlet
- 9. Nozzle Throat
- 10. Diffuser Throat

NOTE!!! $M + L = D$
Watch the Heat Balance!!

Heat Exchange Institute

TVR Cont'd: Ejector Classes-

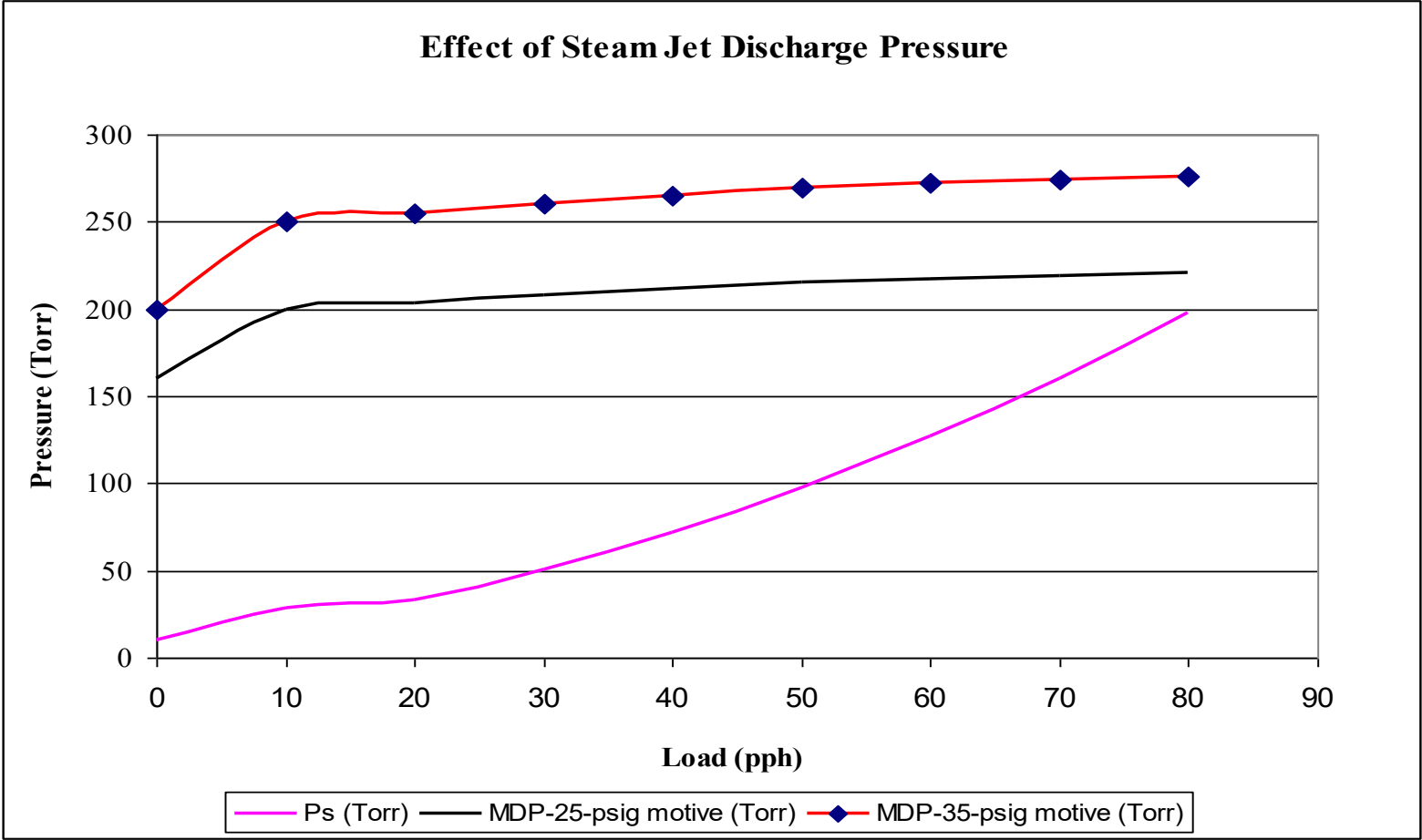
1. Sub-critical flow

- Compression ratio is $< \sim 2$
- Changing motive pressure can be used to vary Load to some degree (Note: fixed vs variable orifice)

2. Critical flow

- Compression ratio $> \sim 2$
- Load cannot be controlled by throttling motive steam
- Raising motive pressure increases discharge pressure and can make an ejector stable. **It can also waste steam if discharge pressure (temperature) is not an issue.**

TVR Cont'd:



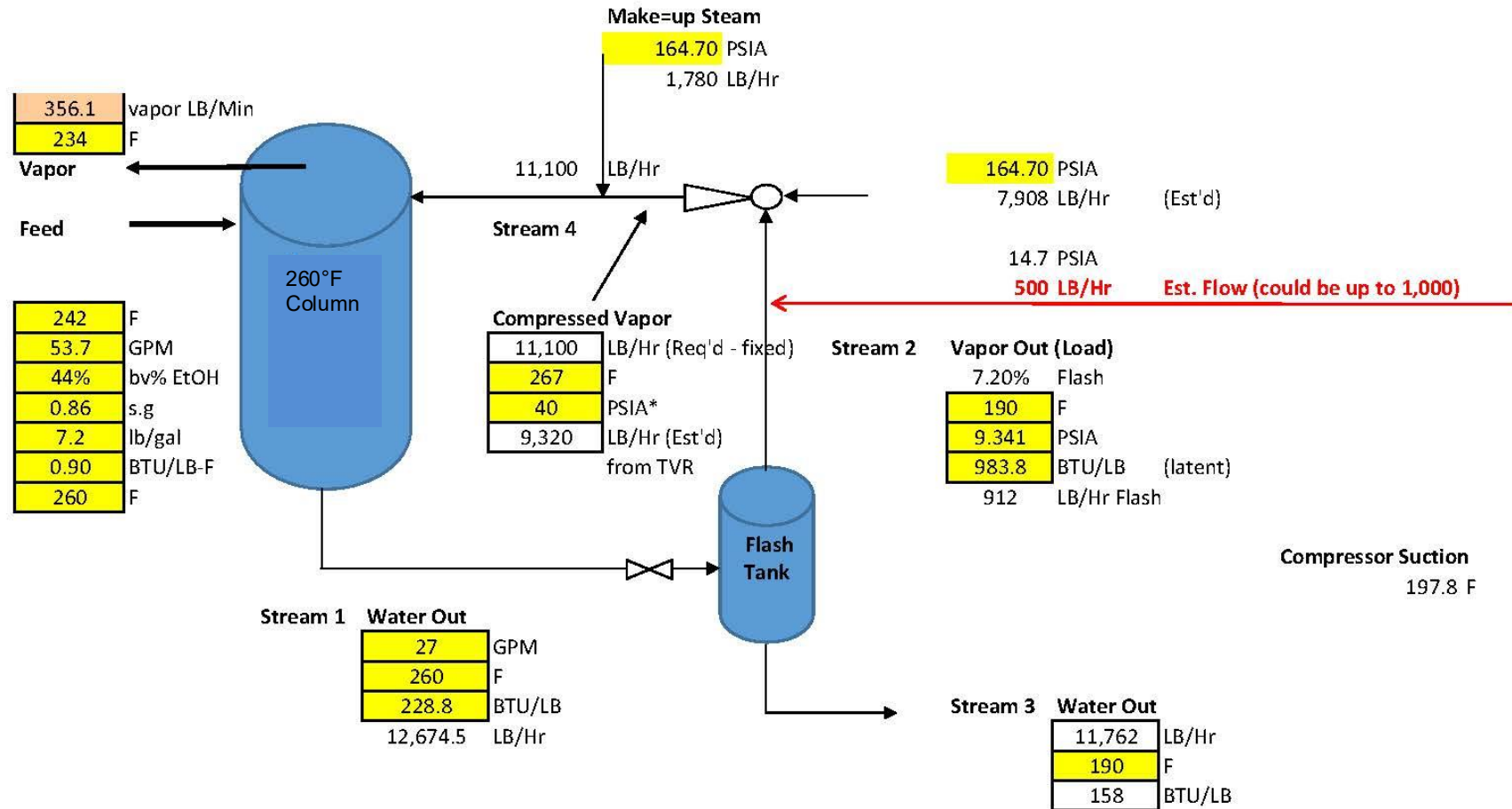
Case Study 4

TVR Heat Pump for Flash Cooling Process Condensate (PC) to Produce Low Temperature Process Steam

CS 4: TVR Heat Pump for Flash Cooling PC:

- Hot process condensate (PC) was cooled with tower water before wastewater treatment (a heat loss).
- Indirect heat recovery was not an option due to the temperatures involved.
- Solution: Use a steam TVR to flash cool the PC with the discharge to heat water and reduce the boiler steam needed.
- System can be considered open-cycle.

CS 4: Open Cycle Heat Pump (TVR)



2,500 HP MVR Evaporator (Electric Semi-open)



Closed Cycle Heat Pump as could be Used in Paper Mill



(Photo courtesy of Greg Walthers, Affiliated Steam)

Waste Heat Integrated Recompression ("WHIR", patent pending)



← Multistage MVR section under construction.

ExFactor™ heat recovery system →
under construction



Waste Heat Integrated Recompression ("WHIR", patent pending):



ExFactor™ heat recovery system with multi-stage MVR for process steam generation.



Kinergetics Slurry Heater eliminates need for high temperature steam and reduces PC.

- System started November 2025, and was exceeding expectations as of February 2026.

Case Study 5

How Does a Heat Pump Compare to Electrification?

CS 5: Electrify Versus Heat Pump

- During an assessment, we were asked to make savings and cost secondary to environmental benefits and electrify 3 kLB/Hr of steam generation.
- Steam is raised at an efficiency of ~83% fuel to steam.
- ~300 Ton of refrigeration is in use during normal operation at about 1 kWe/TR (~3.6 MMBTU/Hr).

CS 5: Electric Boiler Cont'd:

- Estimated gas boiler fuel cost is: ~\$129,000/Yr
- Estimated electric boiler “fuel” cost is:
~\$448,800/Yr
- Estimated heat pump ($COP_H \sim 5.4$) is: \$82,560/Yr
- Estimated Emissions:

Electric Boiler - 3,506 Ton-CO₂/yr

Gas Boiler - 1,260 Ton-CO₂/yr

Heat Pump - 643 Ton-CO₂/yr

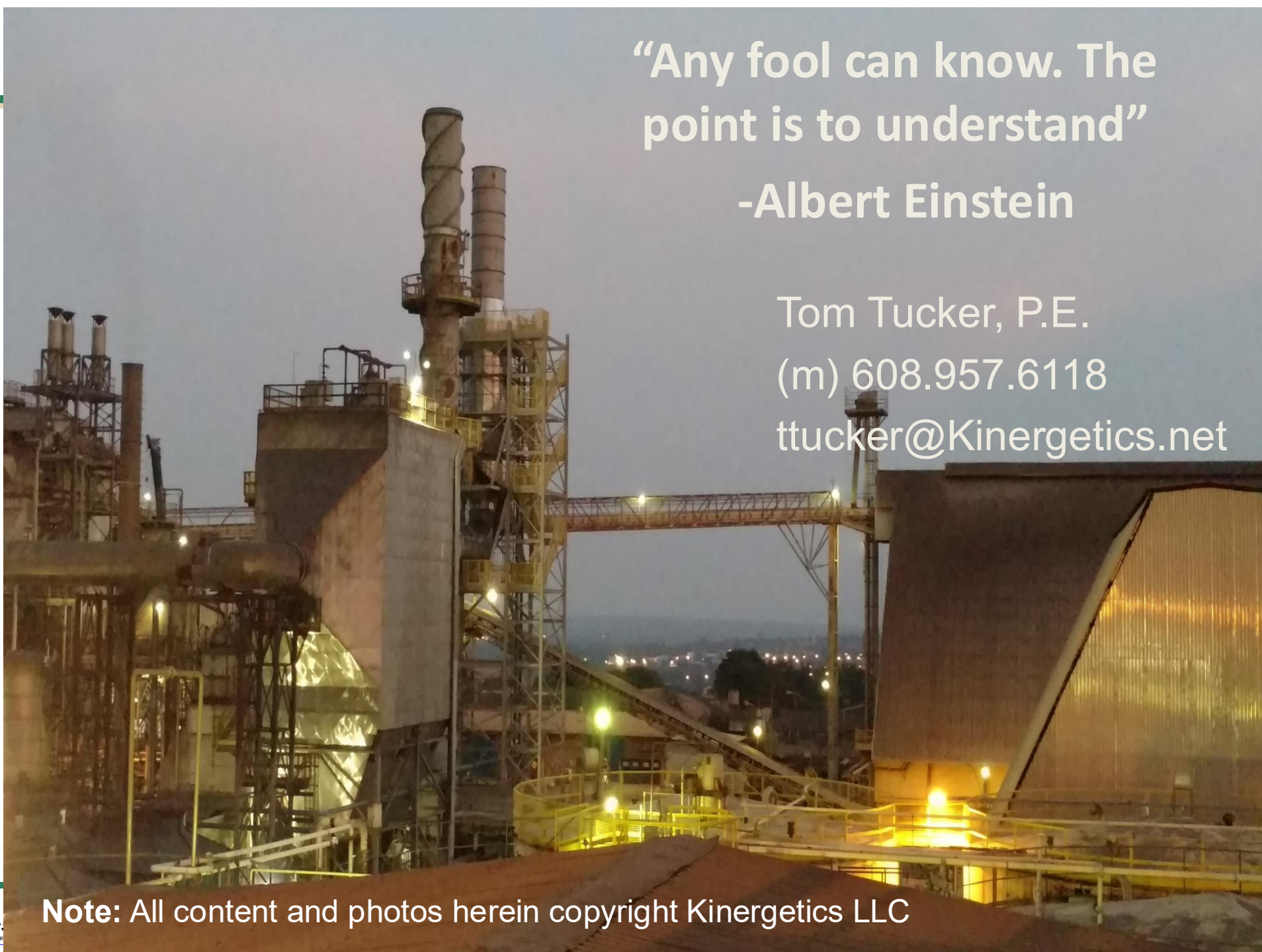
“Any fool can know. The
point is to understand”

-Albert Einstein

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Improving the Performance of Industrial Process Cooling

Annelise Tucker
Energy Engineer
Kinergetics LLC



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2026 WPS Energy Efficiency and Sustainability Summit

Improving Process Cooling Efficiency

June 10, 2026



Annelise Tucker, BSBME

Agenda

- Overview Air Cooled Chiller Systems
- Opportunities to Increase Efficiency
 - TXV/EXV
 - Compressors
- Cooling Towers
 - General Overview
 - Common Issues & their effects
 - Prevention
- Pump Cavitation & Air Locking
- Case Study: Low Refrigerant Level
- Case Study: Parallel Pumps on Cooling Tower

About Kinergetics...

- Energy efficiency investigations ranging from screening to investment-grade.
- Waste heat recovery system design and complete engineering, construction oversight, commissioning and startup.
- Waste heat recovery expertise including custom equipment, process heat exchangers, and heat pumps.
- Primary industrial focus has been in ethanol, bio-products, seed oil extraction, pulp/paper, chemicals, food processing and dairy.

"Typical" Air Cooled Chiller System

Schematic

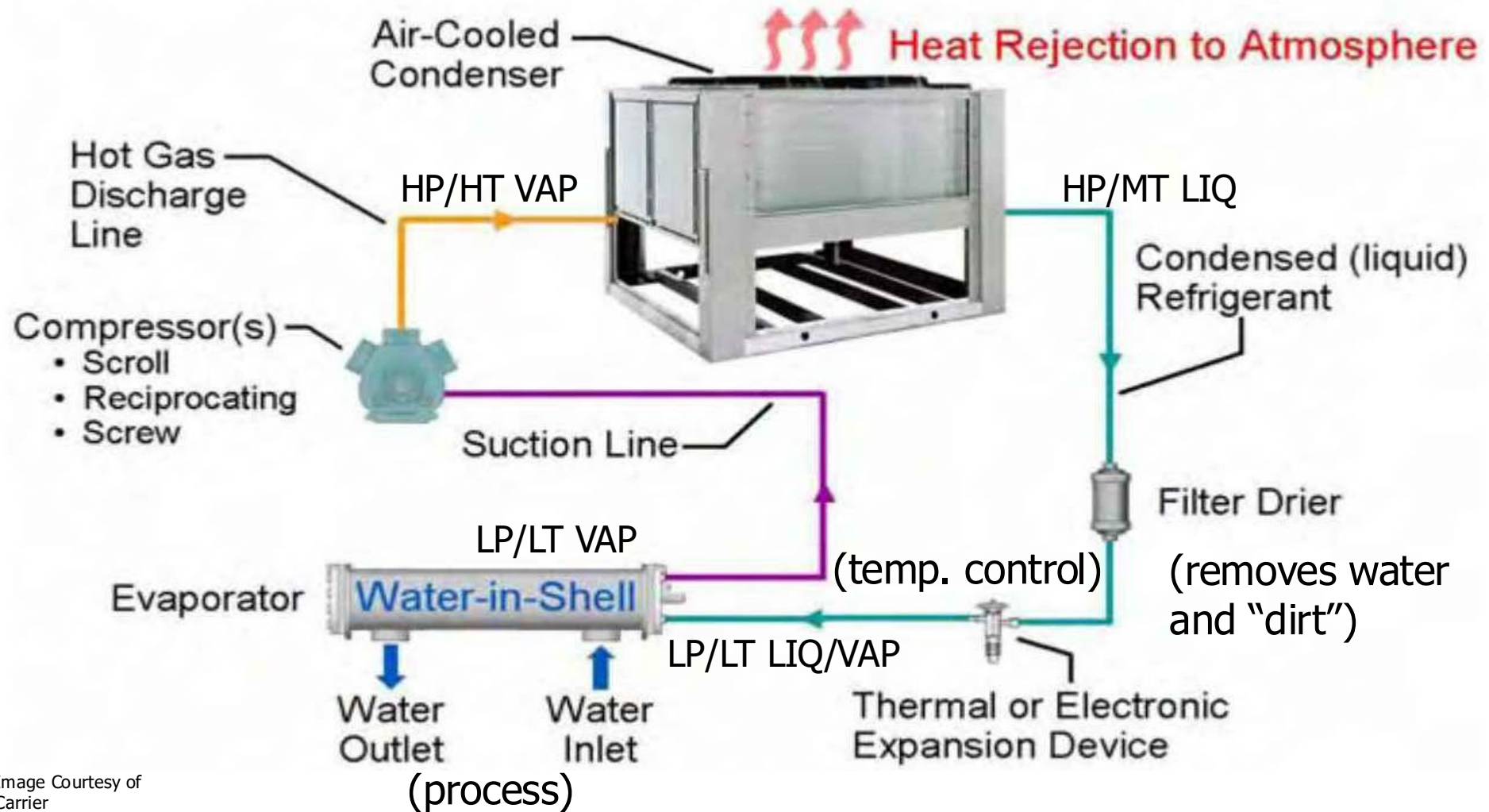


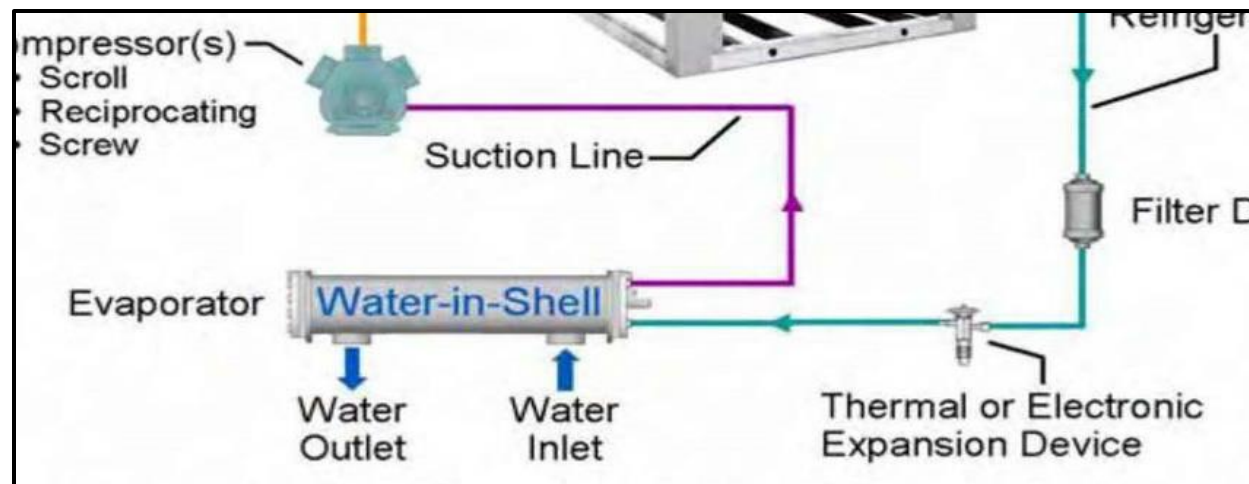
Image Courtesy of
Carrier

Opportunities to Increase Efficiency



Expansion Valves

- Expansion valves are used to control the flow of refrigerant in a cooling step
- Two main types: Electronic and Thermal Expansion Valves



Thermal Expansion Valve (TXV)

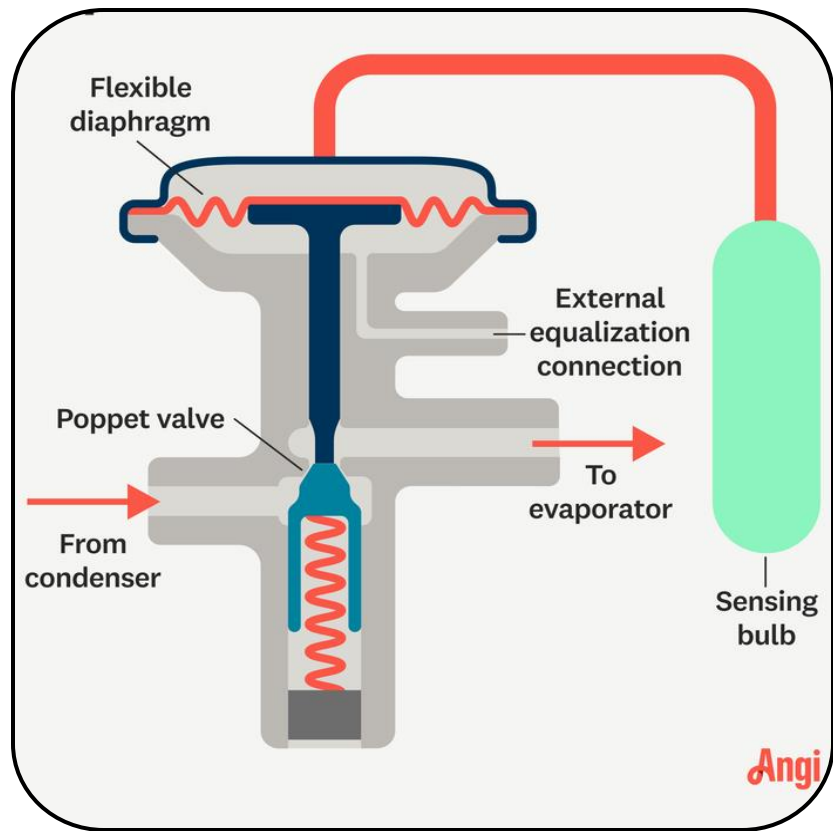
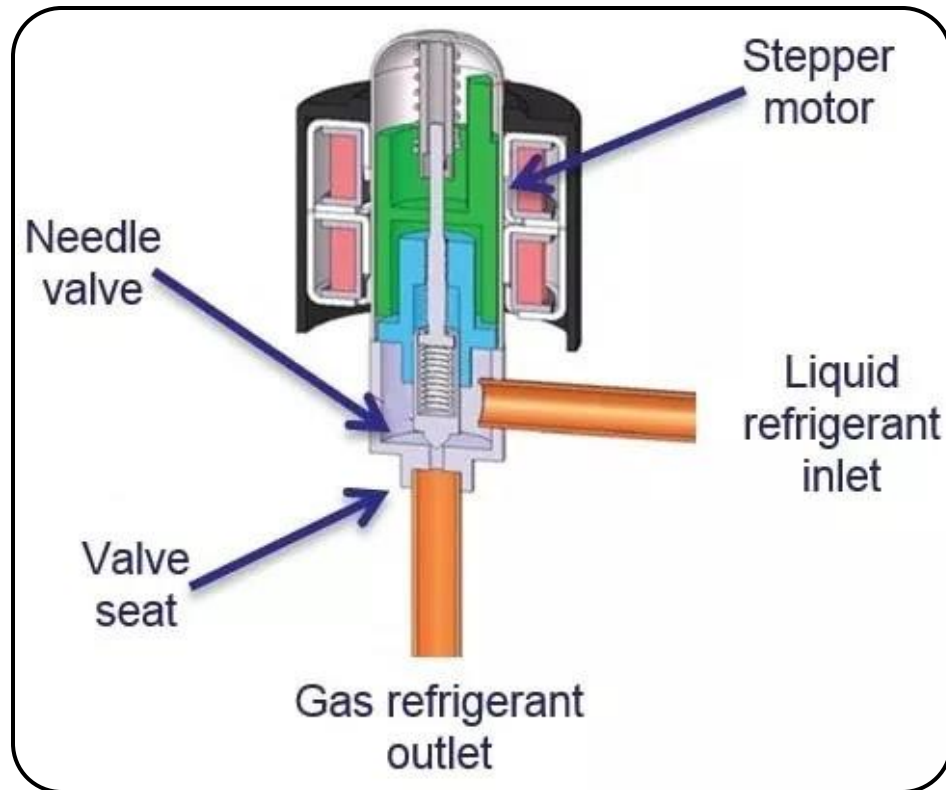


Diagram courtesy of Angi.com

- The sensing bulb is filled with a small portion of refrigerant that pushes on diaphragm
- Both the spring and pressure from the evaporator work to close the diaphragm at the same time

Electronic Expansion Valve (EXV)



- Valve operation is controlled electronically with “step” gear motor
- Due to the electronics and gear drive, valve position can be very precise
- EXV’s tend to provide an efficiency gain due to reduced vapor generation

Diagram courtesy of RST Valves

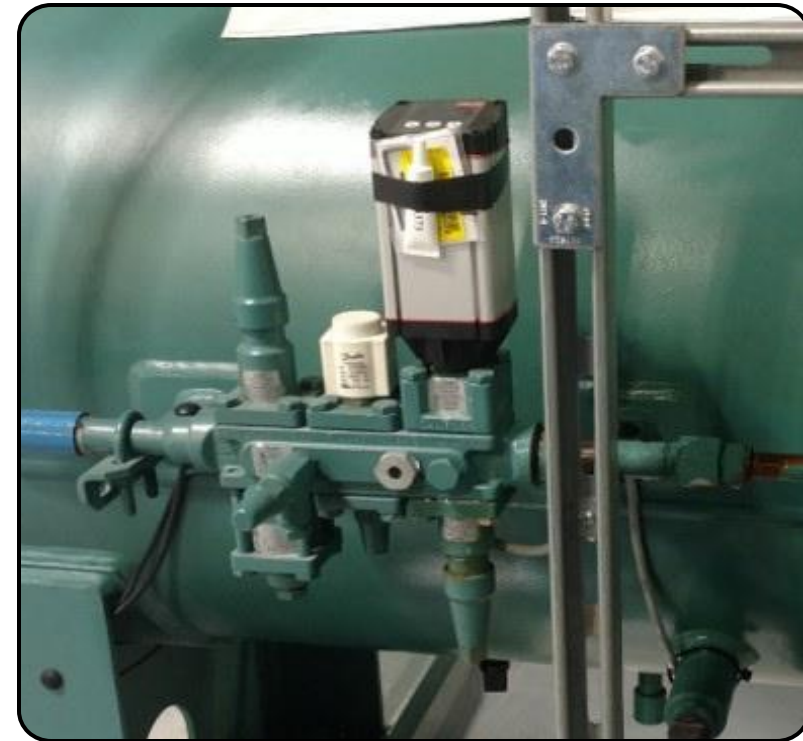
Is one better than the other?

Comp. (400 HP)	Percent FLA (%)	Ammonia Flow (GPM)	Oil Temp (F)	Suction (PSIG)	Discharge (PSIG)
SC-8 (EXV)	89.5	3.99	160	27.3	155
SC-12 (TXV)	92	5.45	129	27.7	153

In the field



TXV

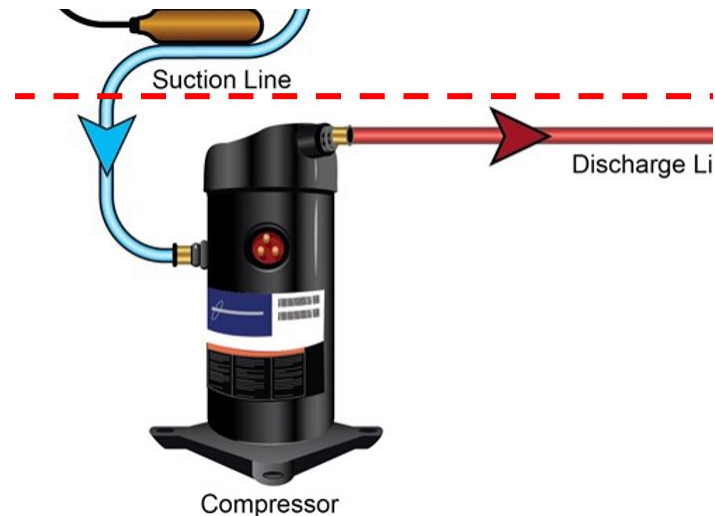


EXV

Increasing Efficiency at the Compressor

For efficiency and lower operating cost:

1. Set suction pressure as high as possible
2. Set head pressure low and have it “float” as ambient conditions will allow.

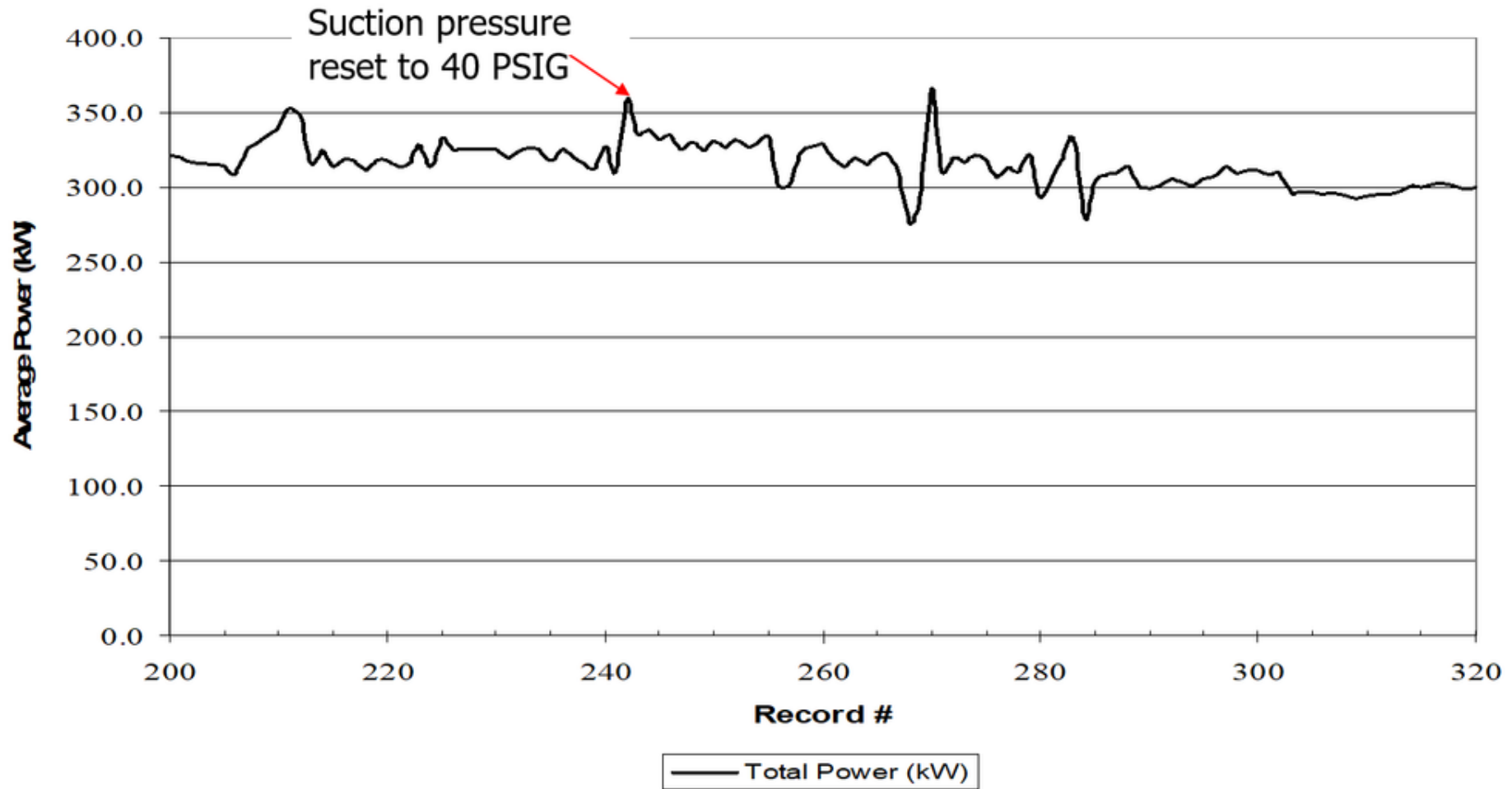


Compressor Operation and Pressure

When considering head (discharge) or suction pressure changes, check:

- How oil circulation is provided
- How refrigerant is distributed; is it pumped?
- The capacity of the condenser
- The design differential pressure of the refrigerant control valve
- How the condenser fans are controlled

Refrigeration Compressor Power (1:58 pm to 2:58 pm; 2/6/08)



Cooling Towers

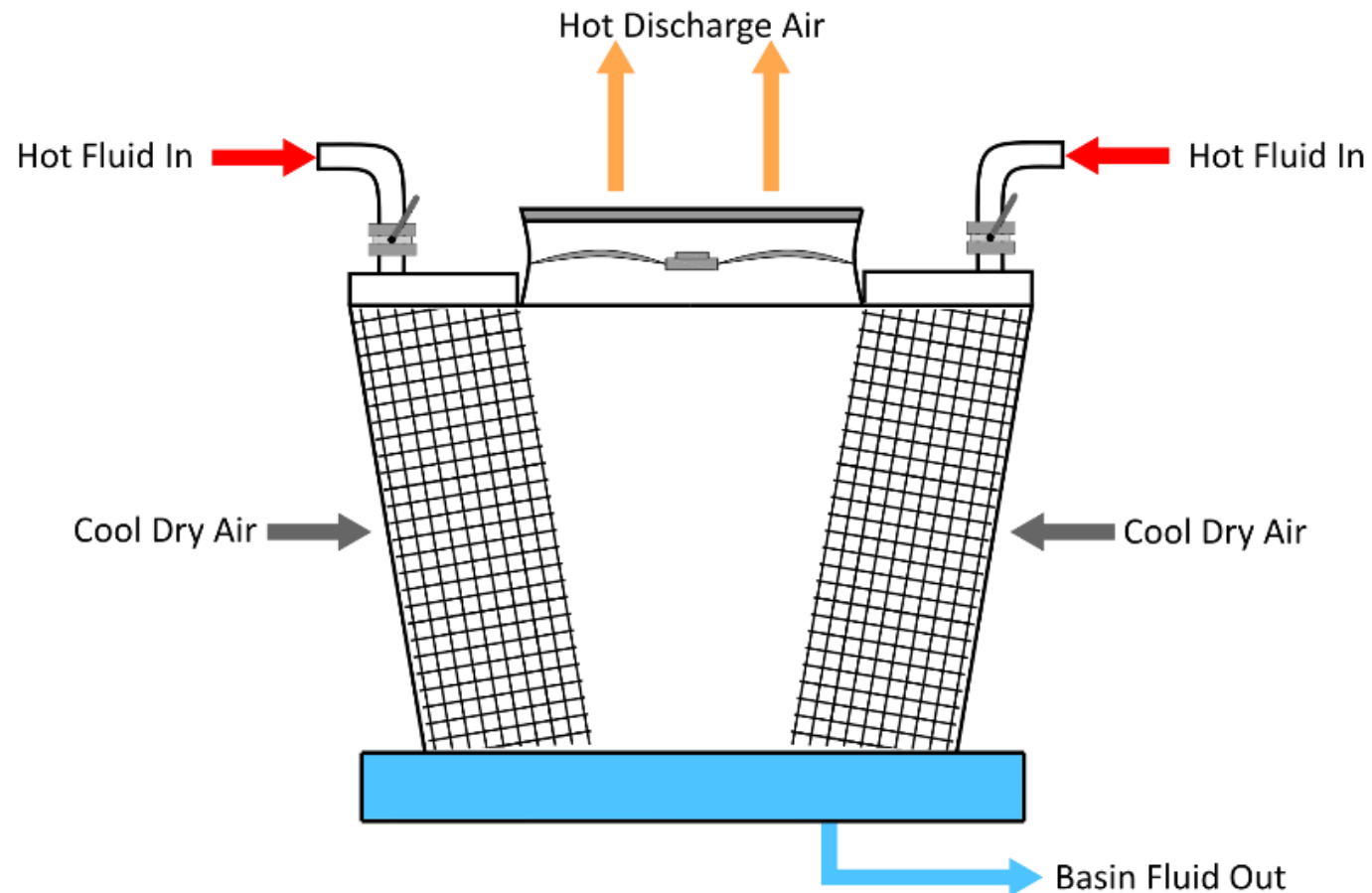


Cooling Towers

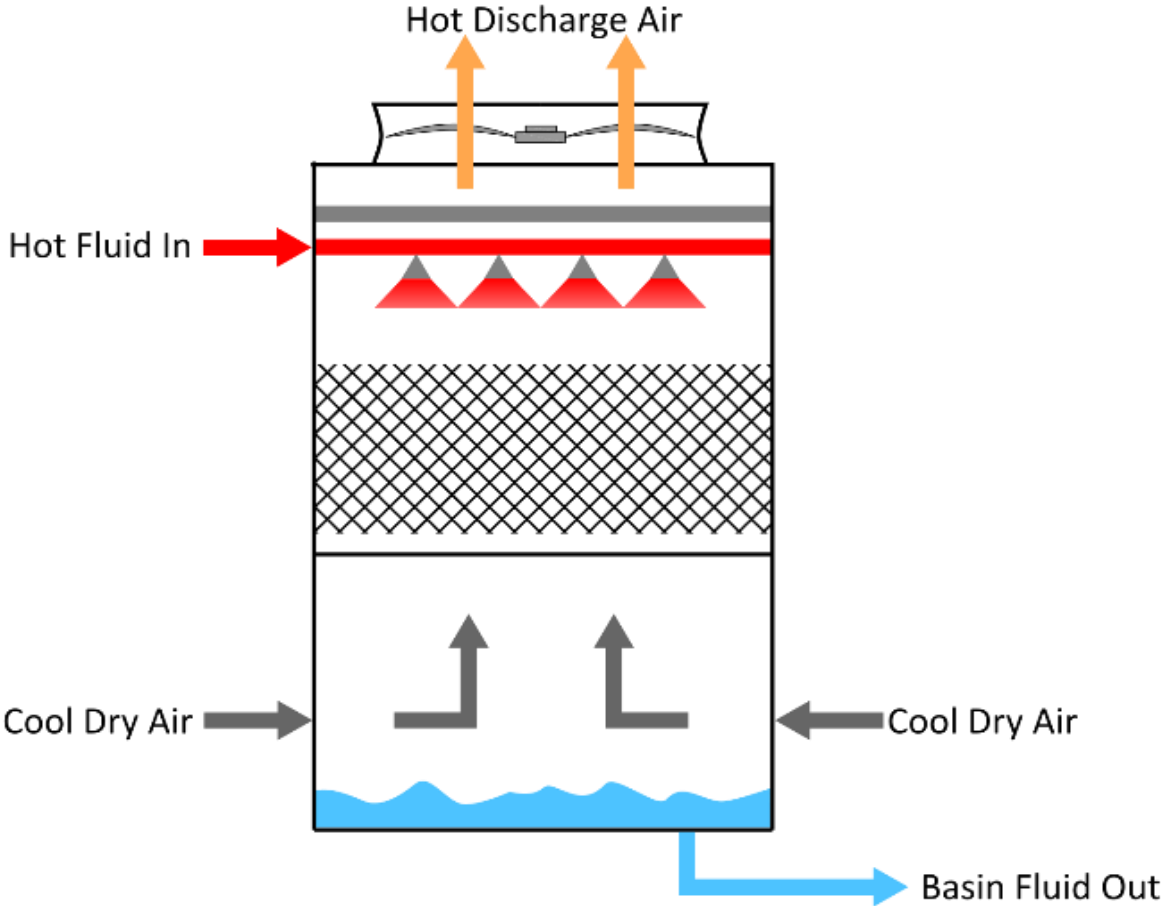
- Cooling towers (CT) rely on evaporative cooling, require less air than a dry-cooler and are smaller
- The air-cooled unit in our example requires more than *double* the air flow for the same capacity



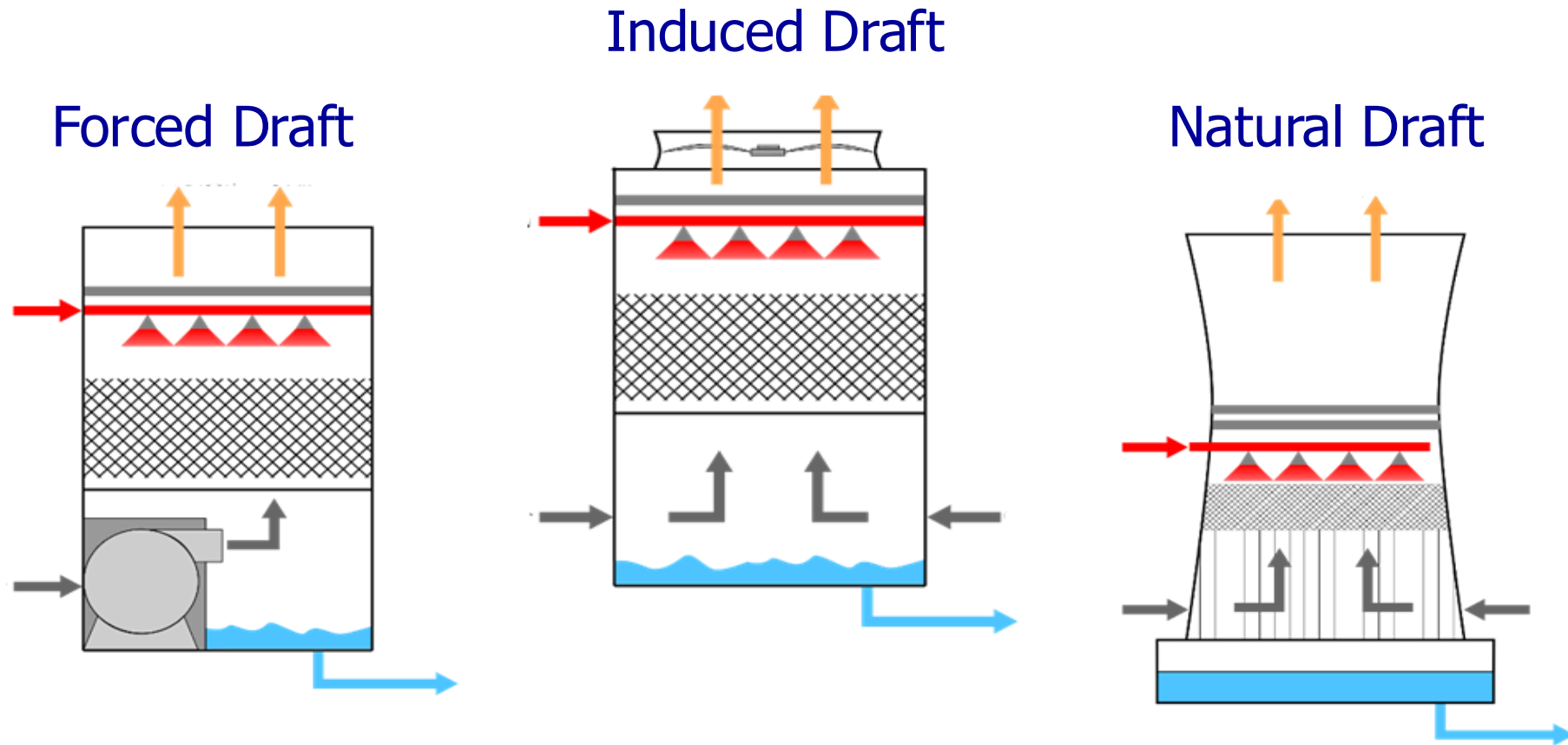
Cross-Flow Cooling Towers



Counter-Flow Cooling Towers

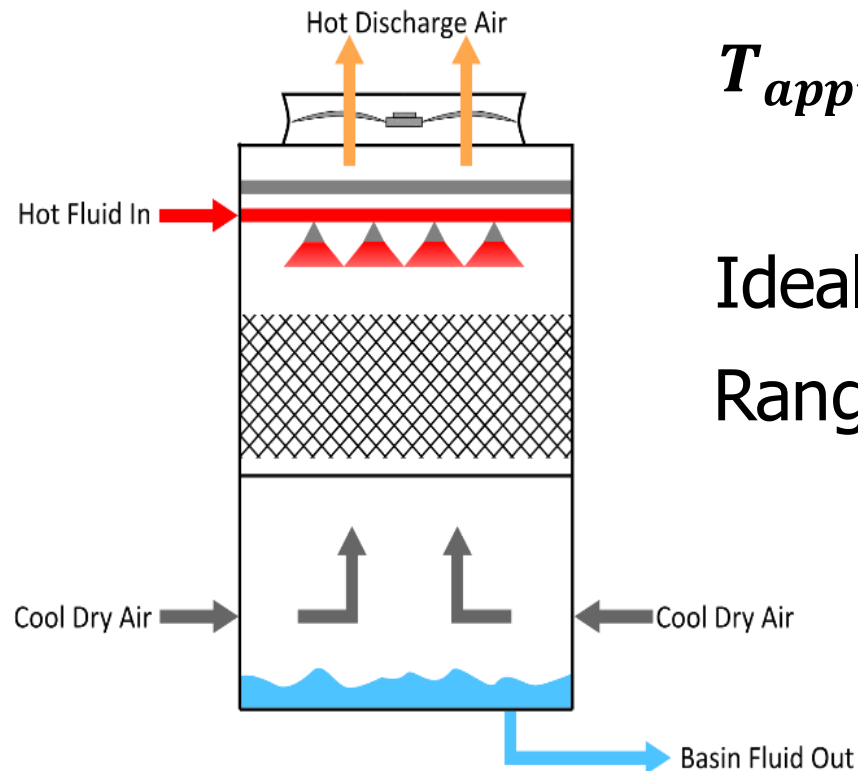


Different Air Flow Options



So.. how do you know if a CT is operating well?

Look at the tower approach temperature

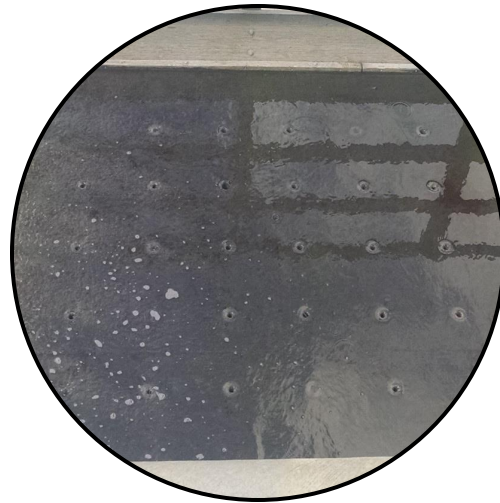


$$T_{approach} = T_{Basin} - T_{WB_InletAir}$$

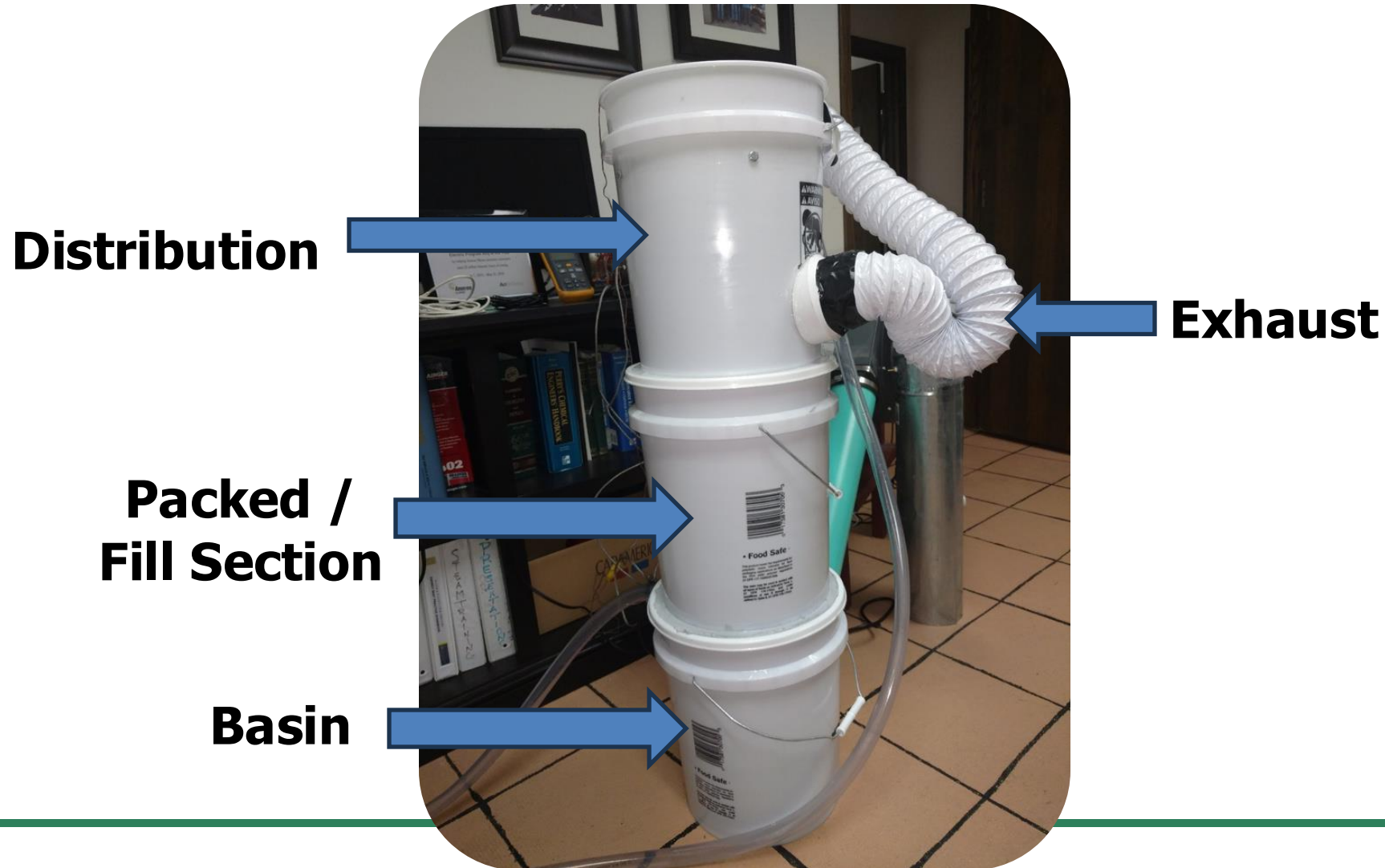
Ideal approach $\sim 10^{\circ}\text{F}$

Range seen in field $\sim 6^{\circ}\text{F} - 28^{\circ}\text{F}$

Some Causes for Poor Cooling Tower Approach Temps



Kinergetics' Investigation Into Causes Of Poor Cooling Tower Approach Temps



Compromised/Plugged Fill



Potential Causes:

- Poor maintenance
- Scale building up, plugging, degradation and more

Can heavily influence heat exchange capabilities and water flow

Poor Water/Fill Distribution



Potential Causes:

- Lack of packing/fill media
- Low water flow across packing

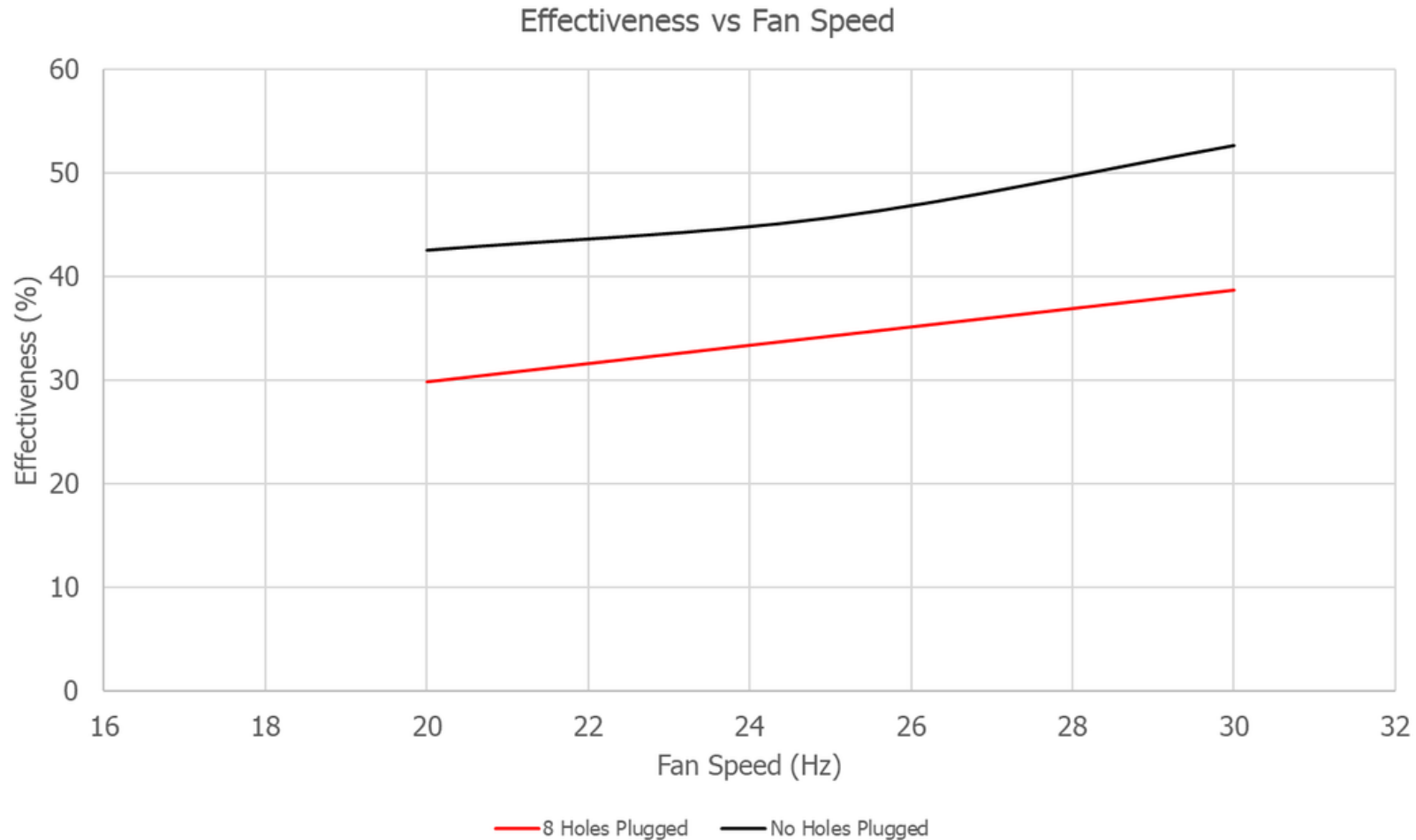
May Present As:

- Overflow or Underflow

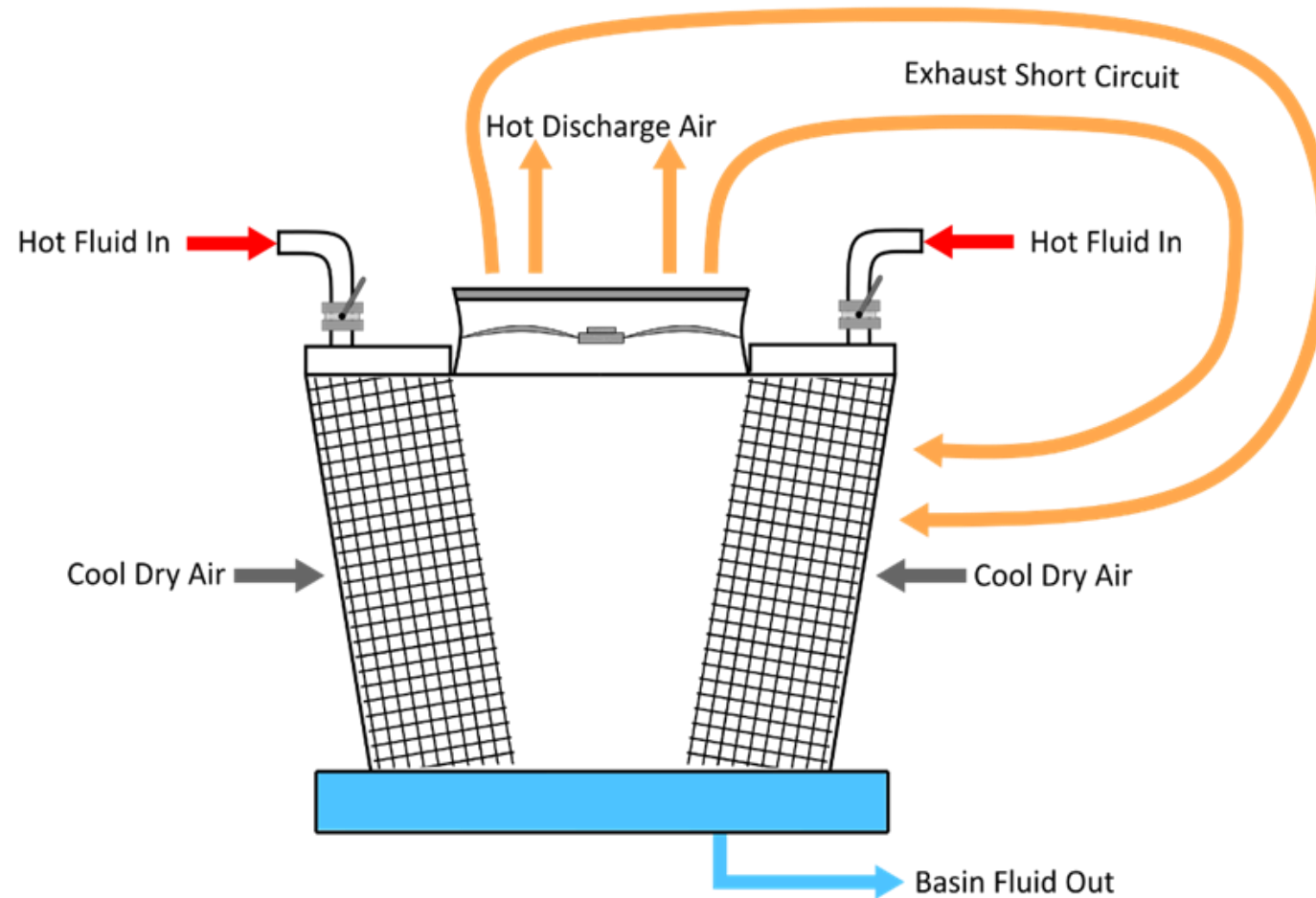
Cooling Tower Demo: Distribution Impact

35 Hz, With Packing					
Inlet Drybulb (F)	Inlet Humidity (F)	Inlet Wetbulb (F)	Measured dTa (F)	Design dTa (F)	Basin Temp (F)
72.4	58.3	62.6	14.0	12.5	76.5
72.8	62.7	64.0	12.6	11.0	76.6
73.5	71.4	66.9	11.5	8.1	78.4
74.4	74.5	68.5	11.2	6.5	79.7
35 Hz, No Packing					
73.1	58.2	63.1	24.5	11.0	87.6
73.4	66.8	65.6	21.9	8.1	87.5
74.7	73.5	68.5	19.5	6.5	88.0

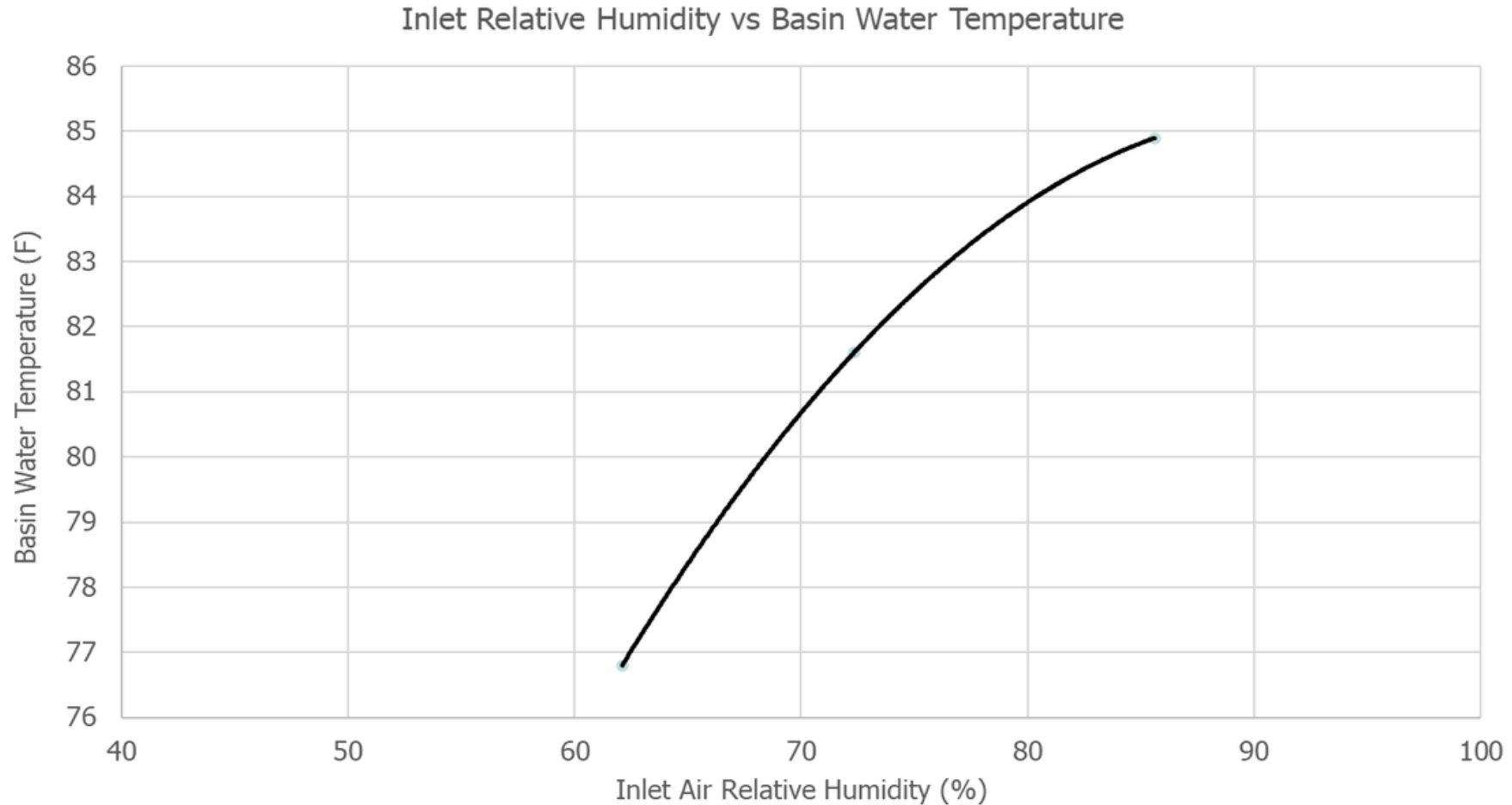
Cooling Tower Demo: Air Flow Impact



Exhaust Short Circuitting



Cooling Tower Demo: Short Circuiting Impact



How can you help prevent these issues?

- Schedule fill cleanings
- Run the design flow - water cycling can lead to dry spots/plugging in fill
- Ensure proper fan blade pitch
- Ensure proper distribution & water pickup
- Manage short circuiting (extend stack or, increase fan speed)

Pump Performance: Cavitation and Air Locking



Pump Performance: Cavitation vs. Air Locking

	Cavitation	Air Locking
Causes	Low suction pressure relative to liquid vapor pressure	Air entrainment from falling water, an improper pump suction connection, and/or vortex formation*
What's happening?	Liquid boils due to pressure difference, bubbles collapse and cause damage/pitting	Air is trapped within the line/pipe, and can block the normal flow of liquid
Sound/Signals	Gritty sound in the pump	Pulsing, rushing, rumbling or gurgling sound

Air Locking...



Air Locking on MultiCell Tower

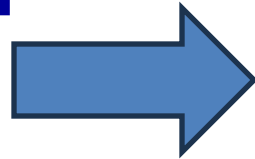
Signs of Potential Problem:

- Pump flow always short of capacity by ~20% for no obvious reason
- Some water pressure fluctuation was noted, but was attributed to process behavior

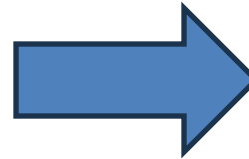
Air Locking on MultiCell Tower

Underlying problem: cooling tower basin depth

**Air from
water
falling**



**Air in
Pump
Lines**



**Limited water
flow &
increase in
pump power**

The Solution: Installation of open trough between each tower basin & pumps

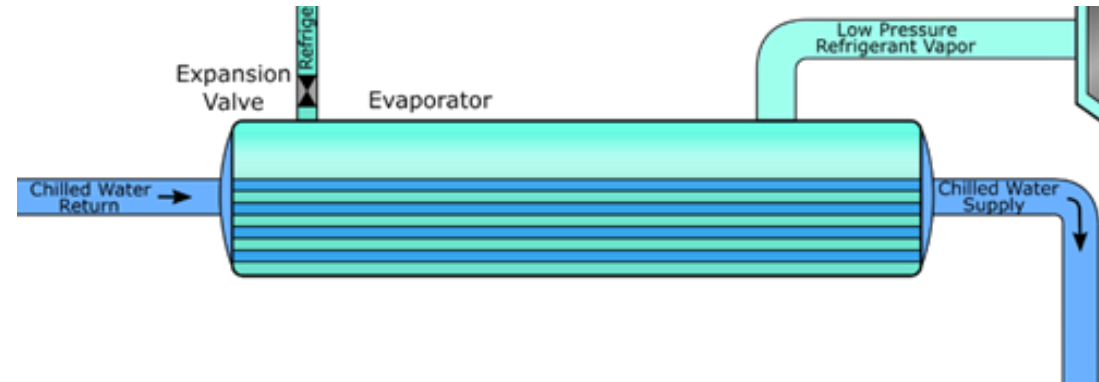
Air Locking on MultiCell Tower

Opportunities Summary Table

#	Description	Cost Savings	Power Reduction	Energy Savings	Estimated Cost*	SR (Yr)*
		\$/Yr	kW	kWh/Yr	\$	
1	Eliminate Air from Entering Tower Pumps	\$133,595	227.2	1,908,500	-	-
2	Shut Off and Repair Pump P- [REDACTED]	See #1	See #1	See #1	-	-
TOTALS		\$133,595	227.2	1,908,500	-	-

Additional Case Studies

Inefficiency from Low Refrigerant Level

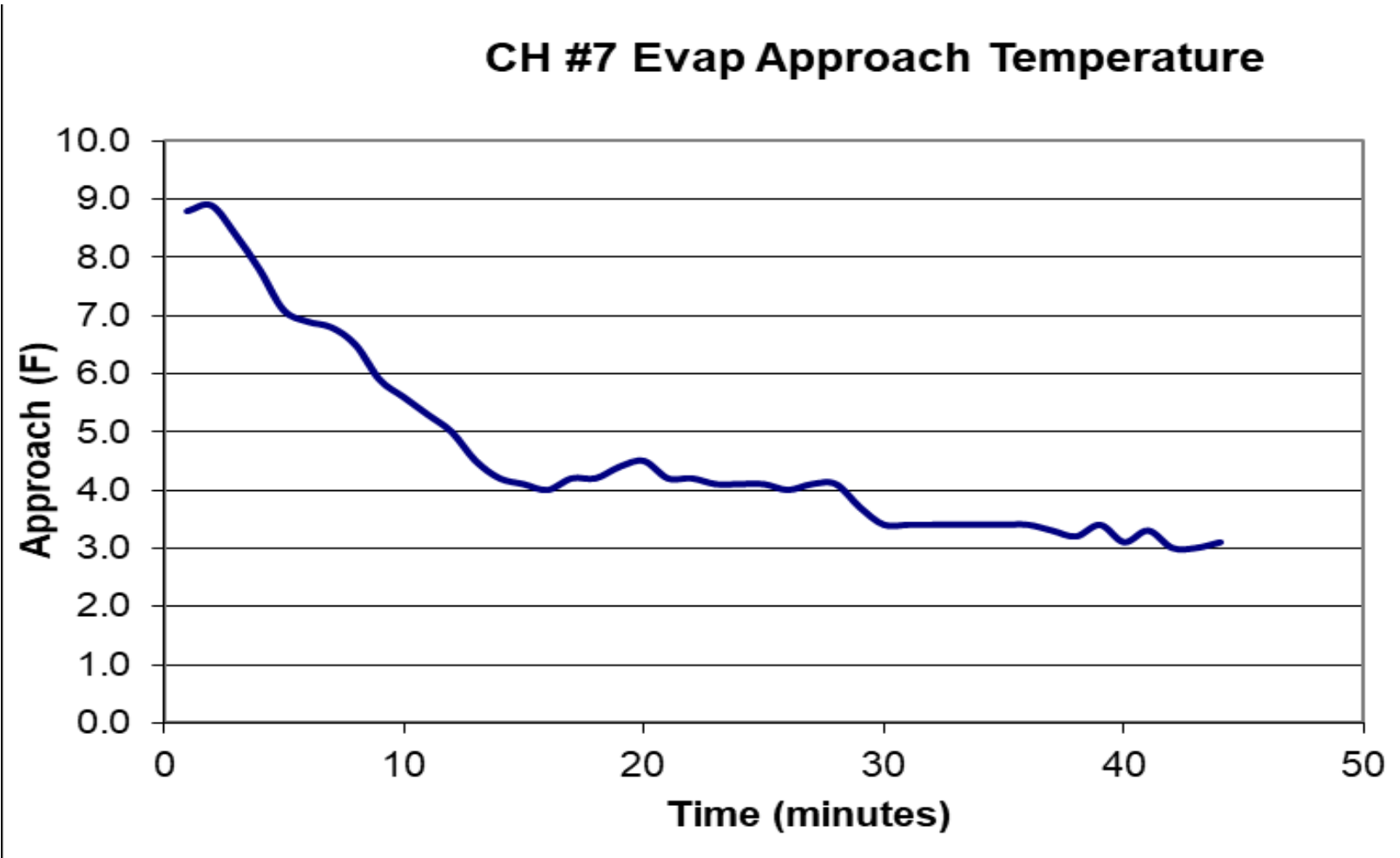


- Refrigerant level was kept low due to droplet carryover concerns: $\sim 10 - 15\%$ low by mass
- Evaporator had a design value of $dT_{min} \sim 3.2^{\circ}F$
 - Onsite it ranged from $6^{\circ}F$ to $12^{\circ}F$
- All 7 chillers onsite had the same issue

The Results

- An increase in chiller system efficiency equivalent to a demand reduction of 1,057 kW
- The gains all came from improved efficiency related to suction pressure.
- Sight tubes with level alarms were installed on each chiller to alleviate concerns

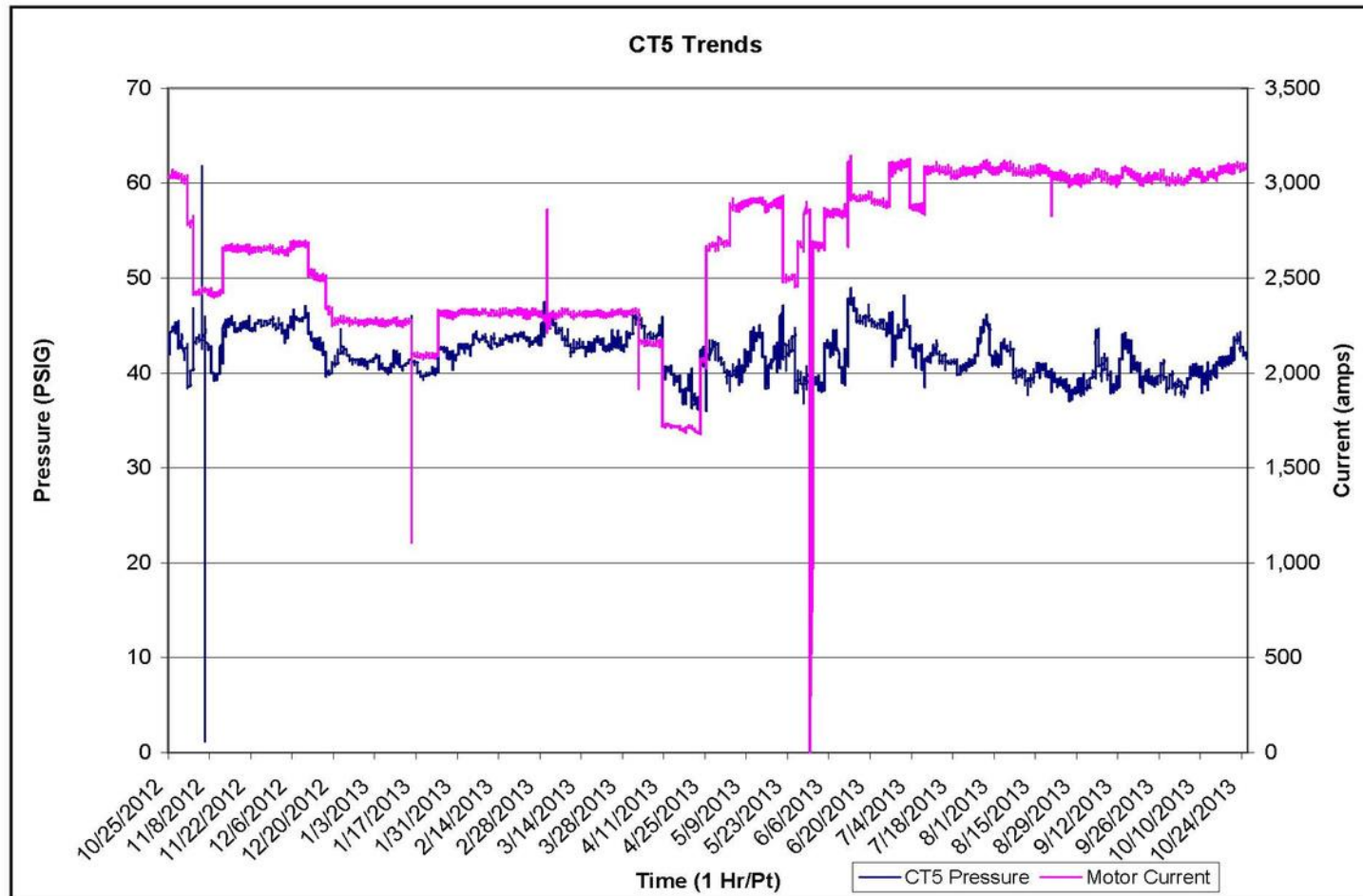
The Impact of Adding More Refrigerant



Parallel Pump Control for Cooling Towers

- During a cooling system investigation, two large cooling towers with on/off manual pump control were identified.
- Pump VFD's are a common way to increase pump efficiency and CAN be used for parallel pumping if design criteria are addressed.

Parallel Pump Control for Cooling Towers



Questions?

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www.kinergetics.net

Thank you!

Lambeau Field Energy Conservation Measures

Justin Dantzman
Assistant Director of
Facility Operations
Green Bay Packers



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