



**Save On Refrigeration –  
How to Optimize  
Commercial and  
Industrial Refrigeration**

Presented by  
Todd Toburen, Energy Smart Industrial Partner |  
Cascade Energy  
Theo Frey, Energy Management Analyst |  
Seattle City Light  
January 28, 2025



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## What Is This “Lighting Design Lab”?

- Seattle City Light's go-to resource for lighting and lighting controls since 1989 – 30+ years
- Formed by BPA and NW utilities to fill education needs for the transforming market
- Now expanded to include resources that support whole buildings
- Being rebranded!



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# Upcoming Events

Course	Day	Time
Lighting & Electrical Issues in 2021 WA & Seattle Commercial Energy Codes	Thu Feb 20	10:00-11:30 a.m.
Lessons Learned on Commercial Hot Water Heat Pump Installations	Thu Feb 27	10:00-11:00 a.m.
Our Friends: Smart Buildings Center, UW IDL, Comfort Ready Home	Thu Mar 11	10:00-11:30 a.m.
HVAC Issues in 2021 WA & Seattle Commercial Energy Codes	Thu Mar 20	10:00-11:30 a.m.
Water Heating Issues in 2021 WA & Seattle Commercial Energy Codes	Thu April 17	10:00-11:30 a.m.
Alternations Issues in 2021 WA & Seattle Commercial Energy Codes	Thu May 15	10:00-11:30 a.m.

Registration  
Open Soon

Event	Day	Time
Seattle City Light Trade Ally Office Hours	Fri Feb 21	9:00 a.m.

Stay up-to-date at [LightingDesignLab.com](http://LightingDesignLab.com) and by [subscribing to our newsletter](#).

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# Refrigeration System Optimization

For enhanced reliability and reduced costs



WE POWER SEATTLE

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## AGENDA

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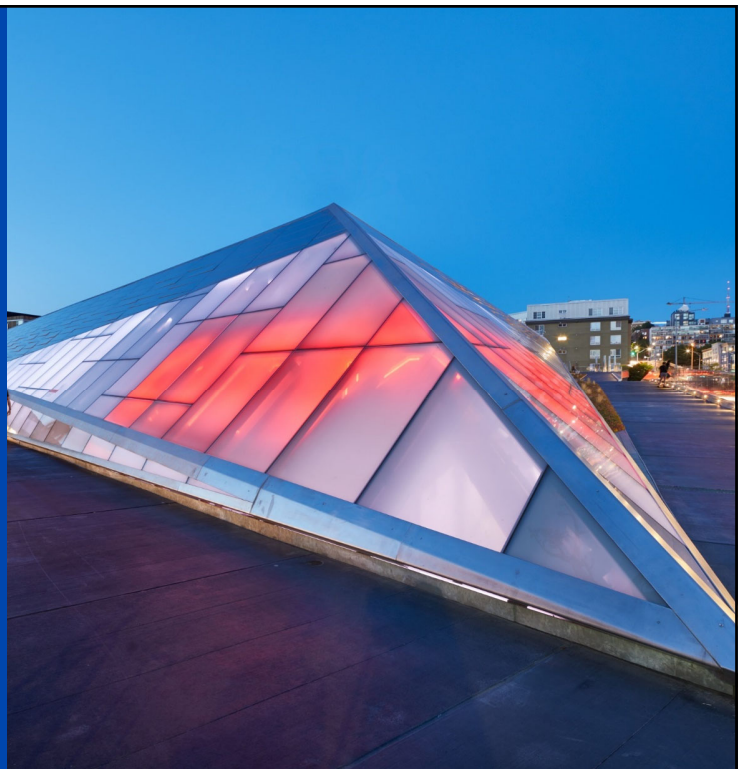
- Introductions
- City Light Incentive Overview
- Refrigeration System Optimization Opportunities
  - Compressors
  - Evaporative Condensers
  - Control Optimization
- Q&A
- Note:
  - *The session will break at approximately 9:30 for 10 minutes*

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Presented By

Theo Frey  
Energy Management Analyst




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# Incentive Offerings



## Capital Improvements

Fast Acting Door  
New Compressor



## New Controls

Floating Head & Suction  
On Demand Defrost



## Durable Operation & Maintenance

Adjust set points  
Clean Equipment


**\$0.33 per kWh**

# Even More Incentive Offerings

**Seattle City Light**

**SEATTLE CITY LIGHT 2025 ENERGY CONSERVATION INCENTIVES Effective January 1, 2025 COMMERCIAL, INDUSTRIAL, AND MULTIFAMILY RETROFIT PROJECTS**


CONSERVATION ACTION	INCENTIVE (\$/kW)	MEASURE NOTES
<b>RETROFIT LIGHTING**</b>		
LED fixtures (outdoor, indoor, high-bay, display cases, integrated retrofit kits, "smartlights"**)	\$0.25	Rebate is limited to DCL-eligible categories. All fixtures and retrofit kits must be certified by DesignLights Consortium (DLC) or meet design requirements which must be DLR/DOE/ENERGY STAR.
Other retrofit kits	\$0.17	For any DCL retrofit kit category other than integrated style.
Standard controls (including non-OPF, combined lighting controls)	\$0.25	Standard controls include daylighting and occupancy sensors.
OPF, enhanced lighting controls (LLC and non-LLC)	LLC: \$75 per fixture Non-LLC: \$50 per fixture	In addition to \$/kWh incentive for fixture efficiency and controls. See DCL's <a href="#">Selected Lighting Controls Qualified Product List (QPL)</a> for eligible fixtures.
<b>MECHANICAL WEATHERIZATION AND CONTROLS IMPROVEMENTS</b>		
*For multifamily projects, only common areas are eligible for incentives. ** Smartlights must be hardwired (e.g., no plug-in or wireless) and can be any lamp output.		
<b>Looking for LED lamps? Get instant discounts on qualified LED lamps at participating distributors. Visit <a href="#">Lighting to Go</a> for more information.</b>		
Child-Proof Upgrades	\$0.33	1 for 1 replacements of children not eligible.
Variable speed drives on ABB Fans	\$300 per HP	For constant speed fans serving VAV systems, reducing the function of inlet guide vanes or other throttling devices.
Economizer controls	\$0.33	For economizer VAVC System Improvements.
Multi-Resonance HVAC Equipment Projects	\$0.33	Includes Multi-Resonance control system upgrades.
Building automation system upgrades	\$0.33	Includes Multi-Resonance control system upgrades.
Heat recovery improvements	\$0.33	Must generate kWh savings.
Dedicated outdoor air systems (DOAS) or very high efficiency (VHE) DOAS	\$0.27	Must meet <a href="#">IEEE/ASHRAE DOAS requirements</a> .
Package terminal heat pumps (PTHPs) for building envelope and residential care	\$600 per unit	Existing equipment must be electric resistance; proposed equipment must be fully compliant with ASHRAE 90.1-2019.
<b>Looking for heat pumps, hybrid heat pump water heaters, variable refrigerant flow, chillers, pumps, fans, and more? Get high-efficiency equipment at participating distributors. Visit <a href="#">Electronics HVAC</a> for more information.</b>		
<b>DATA CENTER AND IT EQUIPMENT</b>		
Computer room air conditioning (CRAC)	\$0.27	For new equipment or variable speed drives/ECM retrofits.
Efficient server/rack power supplies (SPS) systems, > 20kW	\$0.33	Server data centers, Commercial only.
Efficient server/rack power supplies (SPS) systems, > 20kW	\$0.33	Server data centers, Commercial only.
Server virtualization	\$100	For each server removed. Max. 200 Commercial only.
Plug load reductions	\$0.33	Data Center or IT Plug load, Commercial only.
Data center air flow management	\$0.07	Commercial only.
<b>OTHER RETROFIT MEASURES</b>		
Compressor replacement	\$0.33	
Process loads	\$0.27	Primarily for industrial customers.
Generator block heaters	\$200 each < 2kW \$1,500 each if >= 2 kW	
Efficient engine heater controls	\$200 each	
Disable Operators & Maintenance Improvements	\$0.33	
Variable speed drives	\$0.33	For constant speed equipment with remaining service life.

CONSERVATION ACTION	INCENTIVE (\$/kW)	MEASURE NOTES
<b>WATER HEATING MEASURES</b>		
Heat pump water heater systems	\$0.33	Must meet IECC's Advanced Water Heating Specifications B.3. Commercial only. Systems <= 120 gallons not eligible.
Electrically controlled boilers	\$0.27-\$0.33	Clear water circulation pumps < 3 1/2 HP not eligible.
<b>REFRIGERATION MEASURES</b>		
New refrigeration equipment/ new doors	\$0.18	Must be above federal code.
Refrigeration system improvements	\$0.33	Includes a variety of measures including insulation, fast acting doors, heat recovery compressors, and condenser efficiency.
Refrigeration controls	\$0.33	
<b>MULTIFAMILY WEATHERIZATION</b>		
<b>3-3 FLOORS</b>		
Replace single-pane, or metal double-pane window with a window between > 22 and <= 30 ft factor	\$12 per square foot	U-value calculation is an average value. Also available for patio doors.
Replace single-pane, or metal double-pane window with <= 22 ft factor	\$16 per square foot	
Upgrade existing attic, floor, or wall insulation	\$0.30-\$2 per square foot	Contact City Light for details on qualifying existing insulation conditions.
Exterior door ENERGY STAR certified	\$40 per door	Replacing nonstandard exterior door, contact City Light for details on qualifying existing conditions.
<b>4+ FLOORS</b>		
Replace single-pane, or metal double-pane window with a window between > 22 and <= 30 ft factor	\$0 per square foot	U-value calculation is an average value. Also available for patio doors.
Replace single-pane, or metal double-pane window with <= 22 ft factor	\$0 per square foot	
Upgrade existing attic, floor, or wall insulation	\$0.75-\$1.80 per square foot	Contact City Light for details on qualifying existing insulation conditions.
To receive funding for the above weatherization elements, the building must be an approved building, condominium, retirement community, and/or cooperative with 5 or more units and have permanently installed electric heat (distribution, wall unit, furnace, heat pump) as its primary heat source.		
If 50% or more of your building benefits are income-qualified, your project may be eligible to participate in City or Seattle Office of <a href="#">Housing Affordability Programs</a> which offers incentives up to 100% of project cost.		
Incentives may not exceed 70% of project costs. Incentives are subject to availability of funds and eligibility. This list is not comprehensive; work directly with an Energy Management Analyst to understand all available measures and provide the necessary project details. Funding levels are finalized only when a Participation Agreement is signed between Seattle City Light and the customer. In order to receive an incentive, equipment installation cannot begin and products/equipment shall not be purchased until the project has been reviewed and approved by City Light.		
The Commercial Retrofit and Multifamily Weatherization Applications are available online. Once your application is received, all project applicants will work directly with an Energy Management Analyst to provide the necessary project details.		
<b>Questions or want to initiate an application?</b>		
 Contact Seattle City Light Energy Advisors at <a href="mailto:SCLEnergyAdvisor@seattle.gov">SCLEnergyAdvisor@seattle.gov</a> or (206) 684-3800. More information, including full program requirements, and application form online at <a href="http://seattle.gov/city-light/business-solutions">seattle.gov/city-light/business-solutions</a>		

## But Wait There's More (Supplemental Incentives)

 **Project Development Incentive**     Must be completed by June 15<sup>th</sup>, 2025

\$0.025 per kWh

 **Energy Program Manager**     Multiple Projects  
One non-lighting  
Minimum estimate 200,000 kWh  
2-year contract  
Caps out at \$150,000

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## Cost Cap



**Base Incentive (\$0.33/kWh) capped at 70% of project cost**



**Supplemental Incentives capped at 100% of project cost**



**Durable O&M are the most likely to Cap**

Bundling with a capital measure can help

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## How to Participate

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- Contact a City Light Energy Management Analyst (EMA) or Energy Smart Industrial Partner (ESIP)
- Review opportunity with EMA or ESIP
  - Site visit / or baseline data collection may be needed
- Incentive and Energy saving estimate made by City Light EMA
- **Participation agreement** executed between City Light & customer
  - ***BEFORE Completion of project !!***
- Project completed & verified
- Incentive paid



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## Energy Smart Industrial Program

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- Funded by the Bonneville Power Administration
- Todd is an active participant in our projects
  - Site Visits
  - Identify opportunities
  - Measurement & Verification
- Energy Studies for large projects
  - Identify savings estimates
  - Estimate project costs

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Thank you!


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Seattle City Light



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# Efficiencies in Refrigeration

**Todd Toburen**  
*Energy Smart Industrial*

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# Overview

## Refrigeration Basics

## Compressors

## Condensers

## Evaporators

## Control Systems

## Opportunity Tool Belt

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# Facts and Figures Sheet



**1) Top 10 Categories of Refrigeration O&M Energy Savings**

- Optimize Suction Pressure (2% compressor savings per °F)
- Optimize Condensing Pressure (1.8% compressor savings per °F)
- Use your Best Part Load Option
- Condenser Water Delivery: Nozzles, Pumps and Treatment
- Re-Commission Evaporator Valves & Regulators
- Reduce Loads
- Keep Frost Out
- Optimize Defrost
- Calibrate
- Document, Standardize

**2) Compressor "Lift": Suction Pressure and Discharge Pressure**  
 Increasing suction pressure **decreases** capacity. 2% compressor savings per °F  
 Decreasing condensing pressure **decreases** capacity. 1.5% compressor savings per °F  
 The single largest factor driving energy use in a refrigeration system!

**3) Slide Valve Position & Capacity**

% Valve	% Capacity
100%	100%
90%	85%
80%	70%
70%	55%
60%	40%
50%	25%
40%	10%
30%	5%
20%	2%
10%	1%

**4) Compressor Part Load**

% Valve	% Capacity	% Power
100%	100%	100%
90%	85%	75%
80%	70%	55%
70%	55%	40%
60%	40%	25%
50%	25%	15%
40%	10%	8%
30%	5%	4%
20%	2%	2%
10%	1%	1%

**5) Condenser Performance**

Wet Bulk Approach:  $\Delta T = \frac{Q}{m \cdot C_p}$   
 Wet Bulk Approach:  $\Delta T = \frac{Q}{m \cdot C_p}$   
 Wet Bulk Approach:  $\Delta T = \frac{Q}{m \cdot C_p}$

**6) Centrifugal Fan and Pump VFD Power Relationship**

Speed	Capacity	Power
100%	100%	100%
90%	81%	73%
80%	64%	51%
70%	49%	34%
60%	36%	22%
50%	27%	13%
40%	16%	7%
30%	9%	3%
20%	4%	1%
10%	1%	0.1%

**7) Evaporator Definitions**

Evaporator temperature difference (TD) = Entering Air °F - Refrigerant °F  
 Refrigerant-to-liquid evaporators are typically rated for 1.0 to 1.2 TD  
 Factor suction pressure to provide rated evaporator TD  
 Evaporator air delta temperature (ΔT) = Entering Air °F - Leaving Air °F  
 A good air ΔT = 1/2 (normal half) of the evaporator TD  
 If ΔT or ΔT could indicate the evaporator is underperforming

**8) Calculations**

Motor Efficiency =  $\frac{\text{Brake Horsepower} \times 0.746}{\text{Power} \times \text{Hours}} = \text{kWh}$   
 Amps x Volts x 1.73 x Power Factor = 1000 x hours = kWh

**9) Motor Efficiency and Power Factor**

Motor	Efficiency	Power Factor
1/2 HP	85%	0.85
3/4 HP	86%	0.86
1 HP	87%	0.87
1.5 HP	88%	0.88
2 HP	89%	0.89
3 HP	90%	0.90
5 HP	91%	0.91
7.5 HP	92%	0.92
10 HP	93%	0.93
15 HP	94%	0.94
20 HP	95%	0.95
25 HP	96%	0.96
30 HP	97%	0.97
35 HP	98%	0.98
40 HP	99%	0.99

**10) Definitions**

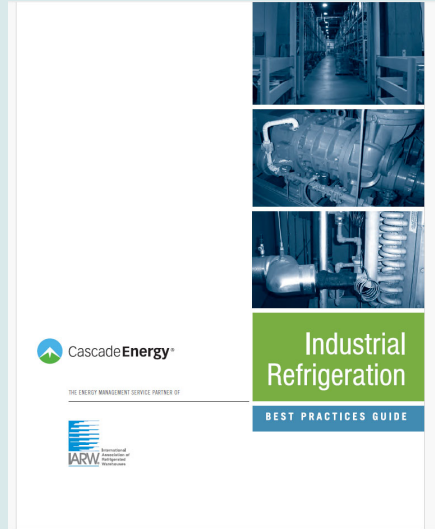
Brake Horsepower (BHP): "What you want" divided by "what it costs"  
 Motor Horsepower (MHP): Net available horsepower  
 TD: Total Differential  
 TD: Total Differential  
 TD: Total Differential

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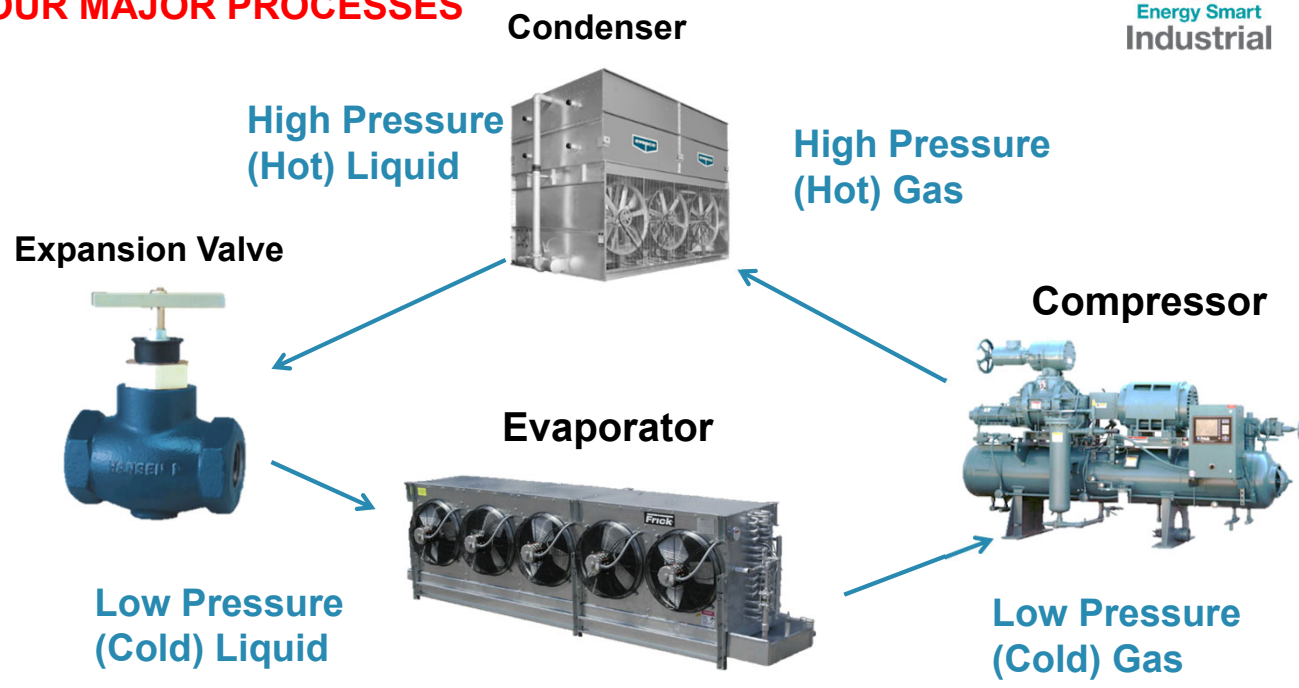
# Industrial Refrigeration Best Practices



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## FOUR MAJOR PROCESSES



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### Compressors

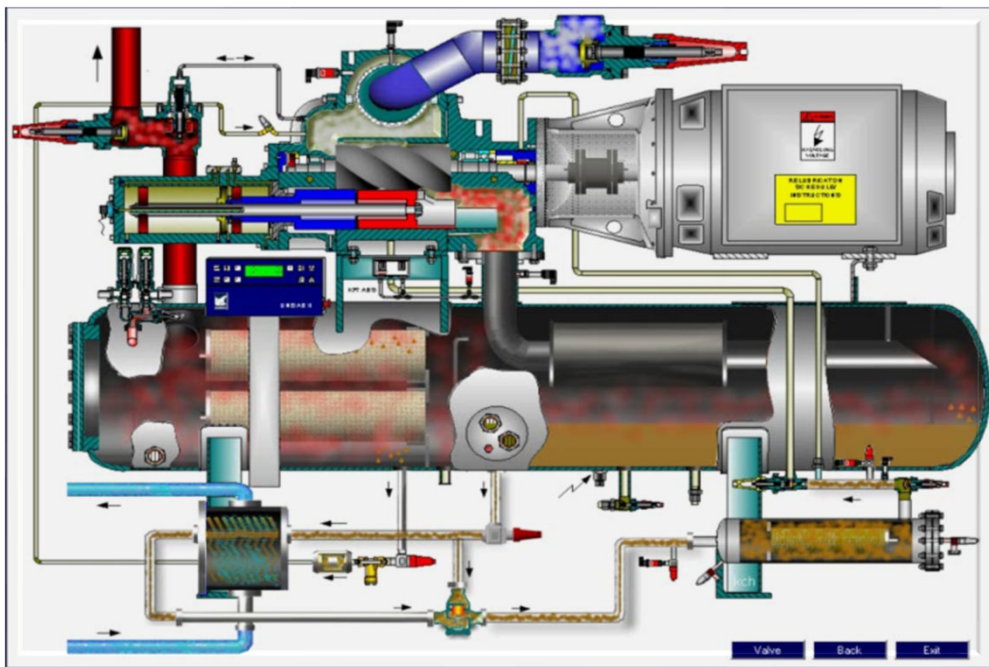


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### Twin Screw Compressor



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# Compressor Energy Opportunities

- 1. Discharge Pressure Reduction
- 2. Suction Pressure Optimization
- 3. Part Load Control
- 4. Oil Cooling
- 5. Coalescent Filters

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## Reduce "Lift" Gain Higher Performance

**Raise Suction:** More Capacity (TR)

**Lower Discharge:** Less Power (BHP)

**Compressor performance = BHP/TR**

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### Rules of Thumb

**2%** compressor savings per °F of increase in **suction** temperature

**1.5%** compressor savings per °F of decrease in **condensing** temperature

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## Compressor Part Load

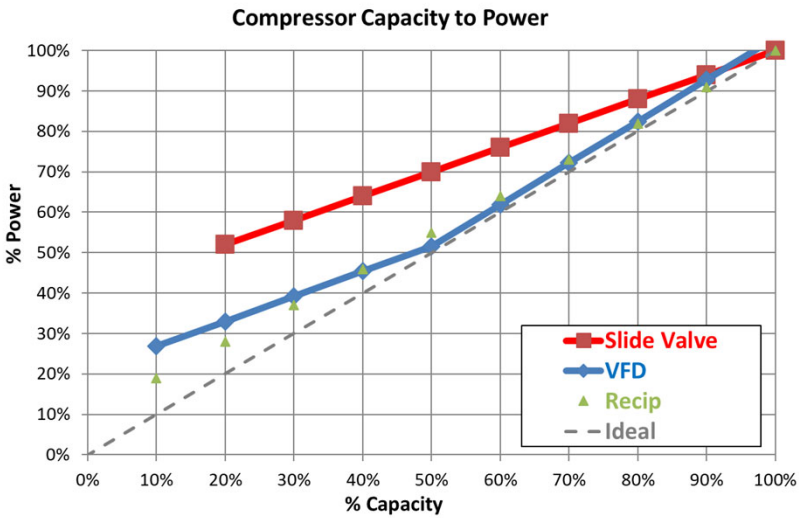
Two absolute rules:

- 1. Compressor efficiency is worse as compressors unload
- 2. Speed control is the most efficient part-load control for screw compressors

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### Compressor Part-Load Performance



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### VFD's vs. Slide Valves

**Given:** Two same-model, screw compressors, but one has a VFD. What is the power at **60% capacity**?



Slide Valve

**76%**



VFD

**62%**

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### VFD's vs. Slide Valves

Given: Two **same-model, screw** compressors, but one has a VFD. Which **one is more efficient at full load**?



Slide Valve

100%



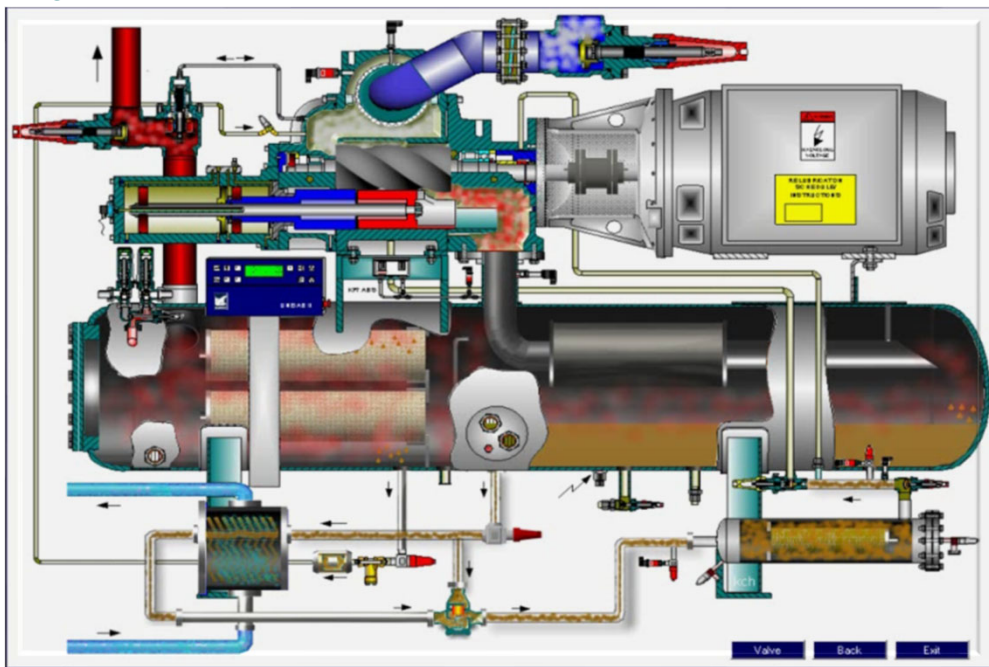
VFD

103%

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### Oil Cooling / Filters

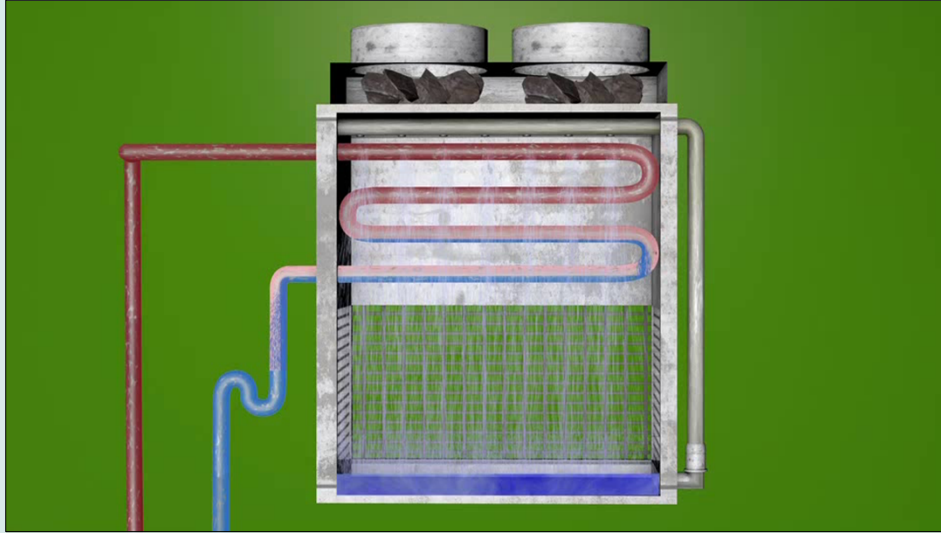


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## Condensers

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Energy Smart  
Industrial

## Evaporative Condensers

1. Evaporative condensers drive towards wet bulb temperature  
Wet bulb temperature is lower (or occasionally the same) as dry bulb
2. Lower lift = lower compressor power
3. Condenser Fan VFD's
4. On Packaged condensing systems, VFD's or ECM's
5. Condenser water pumps are usually NOT a good energy project, but worth looking at on remote sump systems
6. Look at sump heater settings

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### Throttled Pumps



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### Nozzle Types



Older design 180° nozzle



Newer "clog free" nozzles

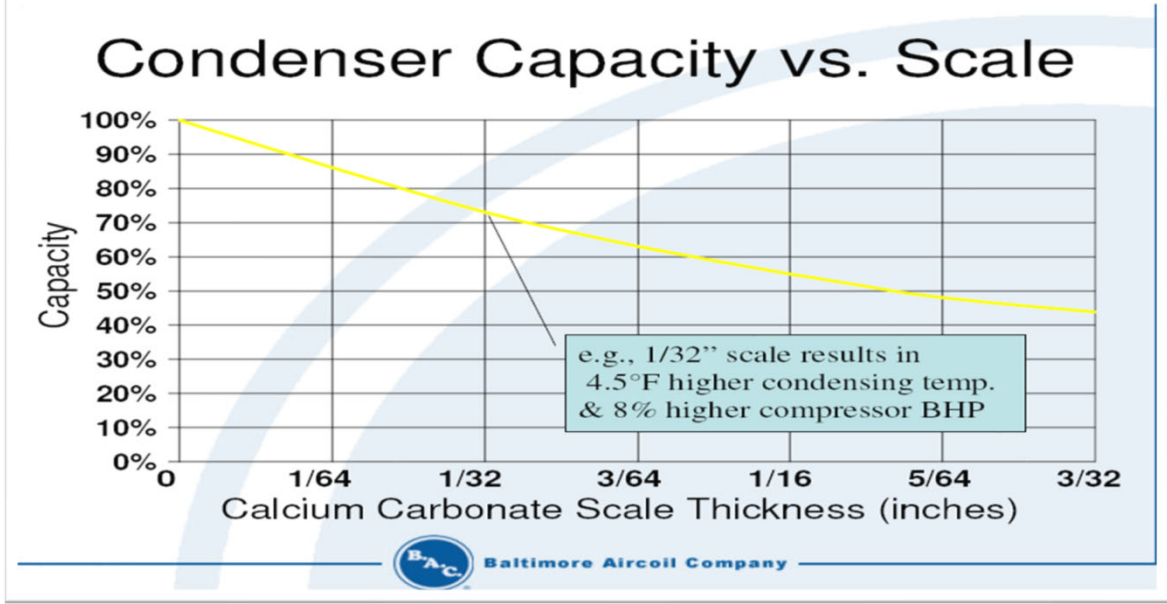


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Impact on Performance



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Purgers—What Can Go Wrong?



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# Evaporators



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# Evaporator Capacity Control

## Capacity Control

- Fan cycling
- Constant fan operation (cycle liquid solenoid)
- Variable speed - VFDs



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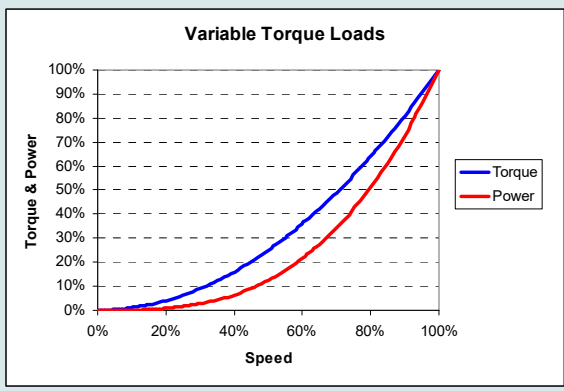
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### Fans—Variable Torque Loads

## Fans follow “affinity” or “cubic” law

- Capacity ~ speed, power ~ speed<sup>3</sup> !!!!!
- Example at 50% speed: capacity is 50%, power is 12.5%



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# SYSTEMATIC DEFROST OPTIMIZATION

## Defrost Types

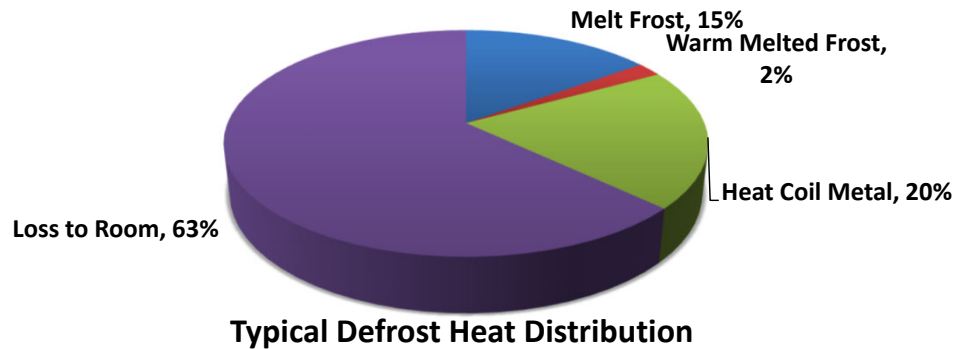
1. Hot gas defrost
2. Electric defrost
3. Air defrost
4. Water defrost

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## The Reality of Defrost

- **What % of heat is actually used to melt frost?**



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## Implementing Defrost Changes

- **Approach a defrost management plan systematically**
- **Start with clean coils; address problem evaporators**
- **Address the source of infiltration; keep frost out**
- **Make changes gradually and check evaporators and pans daily for signs of frost build-up**

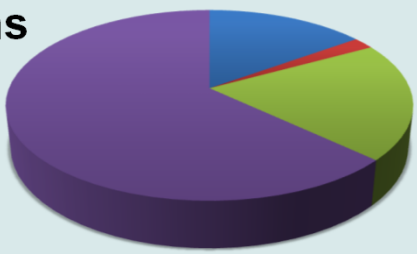
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### Where Does Your Frost Come From?

- **Dock Doors**
- **Freezer Doors**
- **Product**
- **Wall or Ceiling Penetrations**
- **Water Defrost**
- **People**
- **Other**



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## Control Systems

- Central Control Systems
- Individual Unit Control

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# Controls

## Compressors

- Sequencing
- Floating Setpoints
- Proper VI Settings

## Evaporators

- Group fan control
- Fan cycling
- Floating temp setpoints
- Runtime defrost
- Cap maximum speed on VFD's

## Condensers

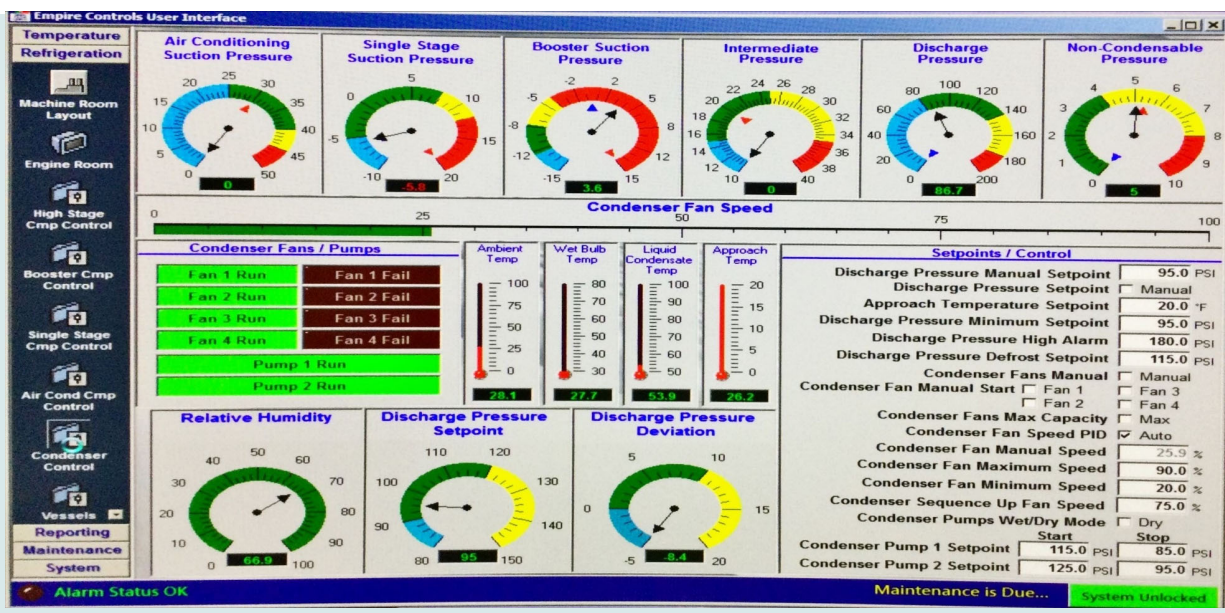
- Floating Head pressure
- Group fan control
- Defrost bumps

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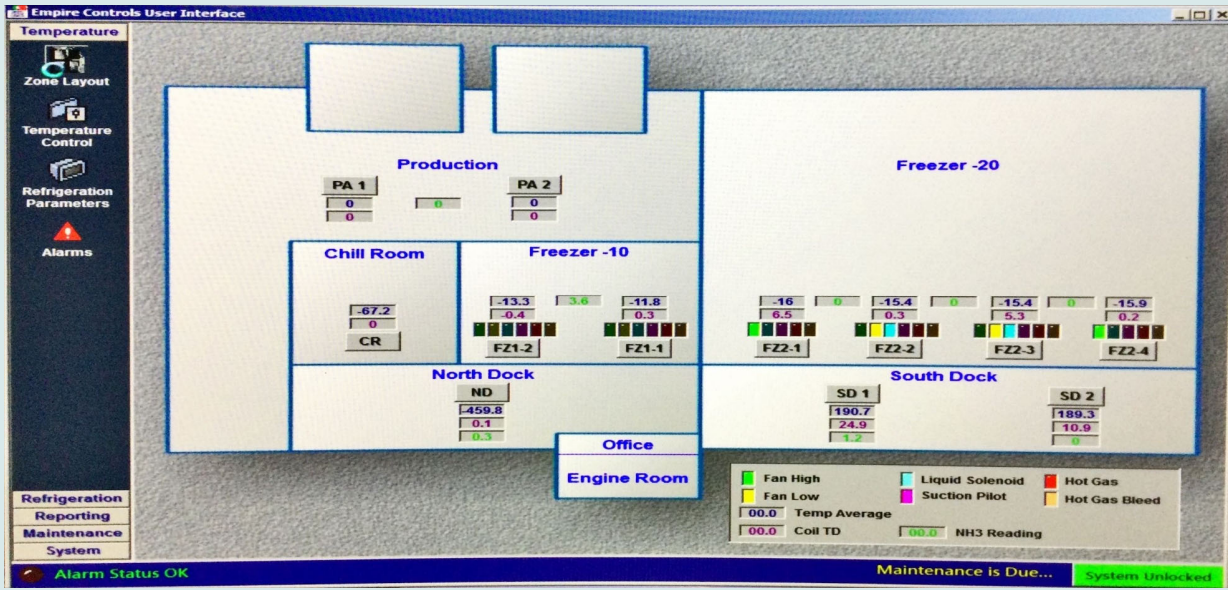
# Controls



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# Controls



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# Controls



Refrig Enable	Temp SetPt (°F)	CoilTD Limit (°F)	Evaporator Fan Low/High Speed		Manual Alarm Inhibit	Low Temp Alarm (°F)	High Temp Alarm (°F)	Refrig Enable	Temp SetPt (°F)	Alarm Inhibit	Low Temp Alarm (°F)	High Temp Alarm (°F)	Zone	Alarm Inhibit	Low Temp Alarm (°F)	High Temp Alarm (°F)
			Min/Max	Setpt												
FZ1-1	-20.0	12.0	Low	High	<input checked="" type="checkbox"/>	-99.0	100.0	Fin Coil 1	-15.0	<input checked="" type="checkbox"/>	25.0	45.0	Chill Rm	<input checked="" type="checkbox"/>	25.0	40.0
FZ1-2	-20.0	12.0	Low	High	<input checked="" type="checkbox"/>	-99.0	100.0	Fin Coil 2	-15.0	<input checked="" type="checkbox"/>	25.0	45.0	North Dock	<input checked="" type="checkbox"/>	25.0	40.0
FZ2-1	-15.0	12.0	40.0	100.0	<input checked="" type="checkbox"/>	-99.0	10.0	Fin Coil 3	-15.0	<input checked="" type="checkbox"/>	25.0	45.0	South Dock 1	<input checked="" type="checkbox"/>	25.0	40.0
FZ2-2	-15.0	12.0	Low	High	<input checked="" type="checkbox"/>	-99.0	10.0	Fin Coil 4	-15.0	<input checked="" type="checkbox"/>	25.0	45.0	South Dock 2	<input checked="" type="checkbox"/>	25.0	40.0
FZ2-3	-15.0	12.0	Low	High	<input checked="" type="checkbox"/>	-99.0	10.0	Fin Coil 5	-15.0	<input checked="" type="checkbox"/>	25.0	45.0	Processing Area 1	<input checked="" type="checkbox"/>	25.0	40.0
FZ2-4	-15.0	12.0	40.0	100.0	<input checked="" type="checkbox"/>	-99.0	10.0						Processing Area 2	<input checked="" type="checkbox"/>	25.0	40.0
FZ3-1	-20.0	6.0			<input checked="" type="checkbox"/>	25.0	99.0									
FZ3-2	-20.0	6.0			<input checked="" type="checkbox"/>	25.0	99.0									
FZ3-3	-20.0	6.0			<input checked="" type="checkbox"/>	25.0	99.0									
Zone (Manual Defrost)	Defrost Interval (Hrs)	Coil Pump Down (Min)	Defrost Time (Min)	Drip Time (Min)	Demand Defrost Enable	Demand Defrost CoilTD (°F)	Demand Defrost Delay (Min)	Termination Temp (°F)	Termination Delay Time (Min)							
FZ1-1	6.0	14.0	30.0	5.0	<input type="checkbox"/>	1.0	10.0	99.0	5.0							
FZ1-2	5.0	12.0	30.0	5.0	<input type="checkbox"/>	1.0	10.0	99.0	5.0							
FZ2-1	10.0	20.0	45.0	5.0	<input type="checkbox"/>	1.0	5.0	99.0	5.0							
FZ2-2	10.0	22.0	45.0	5.0	<input type="checkbox"/>	1.0	10.0	99.0	5.0							
FZ2-3	10.0	22.0	45.0	5.0	<input type="checkbox"/>	1.0	5.0	99.0	5.0							
FZ2-4	10.0	24.0	40.0	5.0	<input type="checkbox"/>	1.0	10.0	99.0	5.0							
FZ3-1	10.0	18.0	30.0	5.0	<input type="checkbox"/>	1.0	10.0	99.0	5.0							
FZ3-2	10.0	18.0	30.0	5.0	<input type="checkbox"/>	1.0	10.0	99.0	5.0							
FZ3-3	10.0	22.0	30.0	5.0	<input type="checkbox"/>	1.0	10.0	99.0	5.0							
Fin Coil 1	1.0	10000	600.0	45.0				57.0	5.0							
Fin Coil 2	1.0	5.0	10000	45.0				57.0	5.0							
Fin Coil 3	1.0	5.0	10000	45.0				57.0	5.0							
Fin Coil 4	1.0	5.0	10000	45.0				57.0	5.0							
Fin Coil 5	1.0	5.0	10000	45.0				57.0	5.0							

Alarm Status OK | Maintenance is Due... | System Unlocked

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## Tool Belt Compressors

- **Suction Pressure**
  - What are the temp requirements?
  - What is the coil TD
- **Discharge Pressure**
  - Can they use wet bulb control
  - Minimum condensing pressure (NW 100 psi is standard)
  - Is there a defrost bump

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## Tool Belt Condensers

- **Do the fans have VFD's (Max speed 90%)**
- **Good water distribution**
- **Clean coils**
- **Throttled valves on pumps**

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## Tool Belt Evaporators

- **Fan Cycling**
- **Group Control**
- **Clean Coils**
- **Standardize Temps**

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## Tool Belt Controls

- **SCREEN SHOTS!!!!**
- **Control system is where you can find many of the opportunities.**

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### How To Get Started

- **Contact a City Light EMA or ESI Representative**
- **Call a City Light Energy Advisor : 206-684-3800**
- **Email: [SCLEnergyAdvisor@seattle.gov](mailto:SCLEnergyAdvisor@seattle.gov)**



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# QUESTIONS

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