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Application of Steam Turbine Driven Chillers in CHP/DES System

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Agenda

- Introductions and Opening Remarks
- York University Keele Campus & Energy Management Overview
- YorkW!$E Energy Management Project Overview
- Steam Chiller Cogeneration/Trigeneration Project
- Equipment Overview

Keele Campus Overview

- Founded in March 1959, and is now Canada's third-largest university
- Canada's leading interdisciplinary research and teaching university
- Over 53,000 students with the expansion of undergraduate engineering program.
- Over 7,000 employees
- Single largest contiguous campus in Canada
- > 8,000,000 sq. ft.
- 21 MW electrical peak load
- Over 14,000 tons of centralized chillers for air conditioning
- Prime opportunity for peak shaving
- Similar to scope of City of North Bay

- **Motto –** redefine THE POSSIBLE,
- Tentanda Via: The Way must be tried

Energy Management Overview

- **Energy Management Department's primary function is to provide;**
  - Heating,
  - Cooling,
  - Power, and
  - Water to all academic, administrative, retail, and residences on campus
  - Administer large energy retrofit project.

- **Central Utilities:**
  - Generates high pressure steam, 1,724kPa (250psi) for heating and 5^{o}C (41^{o}F) chilled water for cooling,
  - Delivers these by way of 3.6 km (2.24 Miles) underground service tunnels to mechanical rooms of each building for distribution to the various heating, ventilating, and air conditioning (HVAC) units within the building
  - Generate and distribute power through our 10 megawatt co-generation plant and associated 13,800 volt electrical distribution system.

The Energy Management unit is a 24-hour per day, 365 days per year operation that is staffed by highly skilled technicians and management whose sole responsibility is to provide the utilities requirements of our community in a safe and efficient manner and in accordance with all regulatory requirements.

Energy Management Overview

- **Historical Operating Budget - $25 million CDN (almost $70,000/day, $0.80/sec)**
  - Natural Gas 20%
  - Electricity 40%
  - Water 20%
  - Oil – backup <1%
  - Maintenance and Operations 20%

- **Previous energy management projects:**
  - $17,000,000 CDN natural gas fired Solar Taurus 60 turbine co-generation facilities
  - 5 MW in1997, and
  - additional 5 MW in 2003

<u>YorkW!$E Energy Management Project</u>

In September 2005, the concept of an Energy Performance Contracting Program was finalized, which aimed to invest $41,500,000 CDN in plant and building system renewal and retrofit projects so that annual energy costs and greenhouse gases could be reduced by <u>25%.</u>

In November 2005, MCW Custom Energy Solutions Ltd. was selected as the successful contractor.

In February 2006, the pilot project for the YorkW!$E Energy Management Program was brought forward for Board approval.

Since that time, numerous energy conservation measures were approved and implemented in campus buildings and in the central plant and utility distribution systems with >$4,400,000 CDN in utility company incentives to date being reinvested.

What next on the journey to reducing consumption?

- Completed review of possible next steps in early 2012 as natural gas prices had fallen drastically making some of the remaining HVAC heating measures financially unattractive, were there now better unforeseen options?

- ANSWER: YES

New Tri-generation Steam Turbine Chiller Project

(nicknamed “King Kong” by plant operators)

As part of the Energy Management Program the Board of Governors approved a $5,000,000 CDN budget to engineer, procure and install a 3,000 ton tri-generation steam turbine driven chiller in the Keele Campus Central Utilities Building

This project had several attributes which independently substantiated the concept;

- Reduced energy consumption and associated environmental stewardship (reducing annual electrical consumption by 5,231,000 kWh and peak consumption by 2 MW, over 4,000 tons of CO_2 avoided, twice the capacity and efficiency, part load efficiency almost 4 x better during start up testing)
- Met the requirement for Incremental Peak Cooling Capacity – various new buildings
- Maximizing York Electrical Power Generation – unloads back end cogen boiler steam constraint (2.8 MW gain in August 2014 commissioning and testing)
- Minimized imported power and reducing cost of purchased electricity
- Investment Business Case and Incentive Timeliness (<8 year payback as Class A or Class B electrical electricity rate structures, with an electricity saving of $523,101/year, incentive over $1,030,000 on electricity, $44,000 on natural gas)
- Modernization and reliability – replaced very inefficient obsolete 1964 unit
- Infrastructure investment deferral – electrical sub-stations, new chillers

Old 1964 Chiller on the way out!

Chiller Installation in the Central Utilities Building

Key Lessons Learned

- To achieve minimum flow (20%) on our primary distribution piping system, we added a Chilled Water recirculation line to keep minimum flow circulating through the chiller, during low nighttime loads. This minimum flow is needed to keep the chiller running.

- Turbine glad seals using line pressure steam not desirable (Implemented Manufacture recommendations).

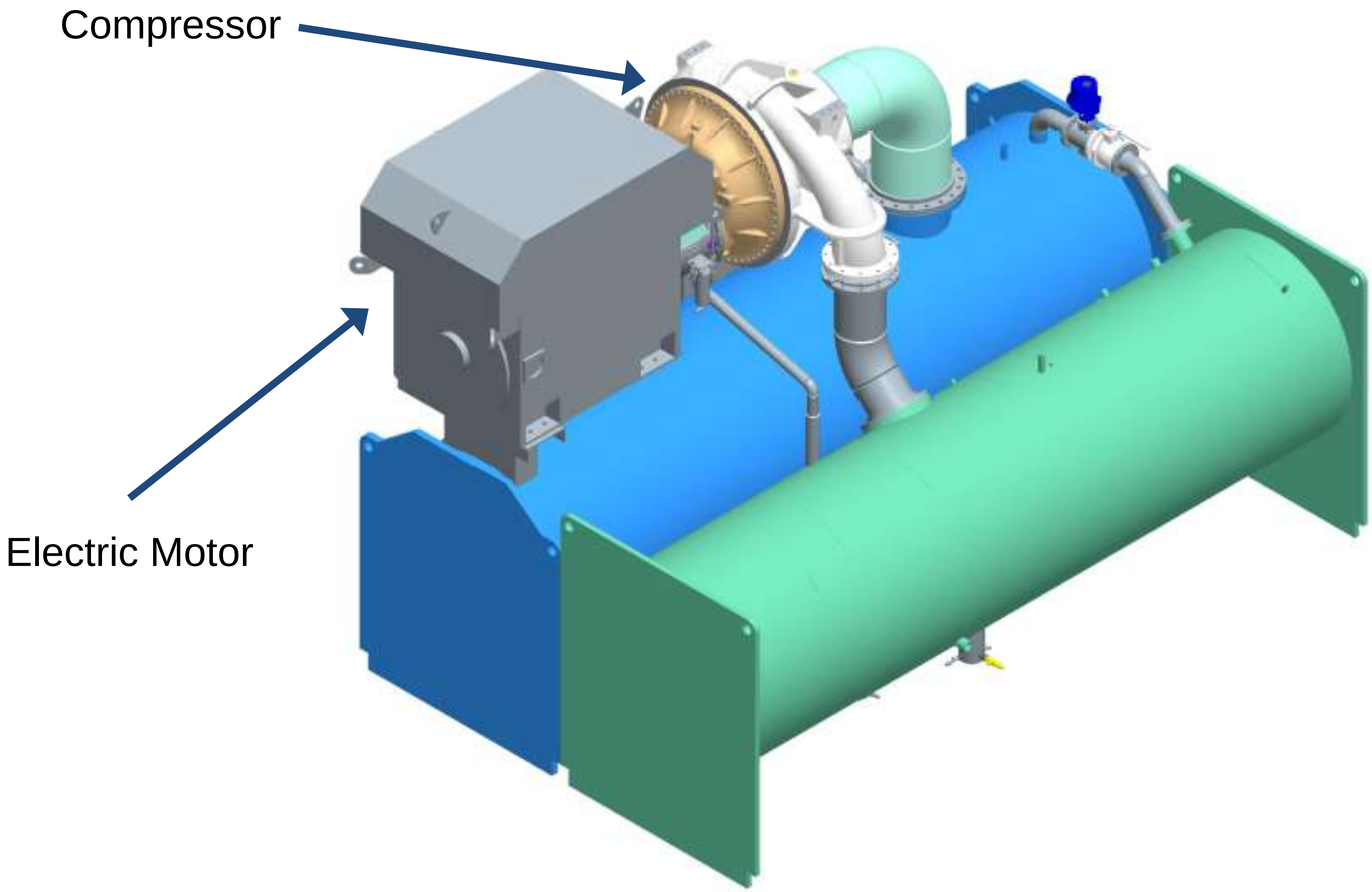
- If a fast opening steam relief line is to be used so you don’t trip boilers in the event of a turbine trip, then incorporate that for cleaning the steam piping and start up routine.

Keele Campus Load Profiles

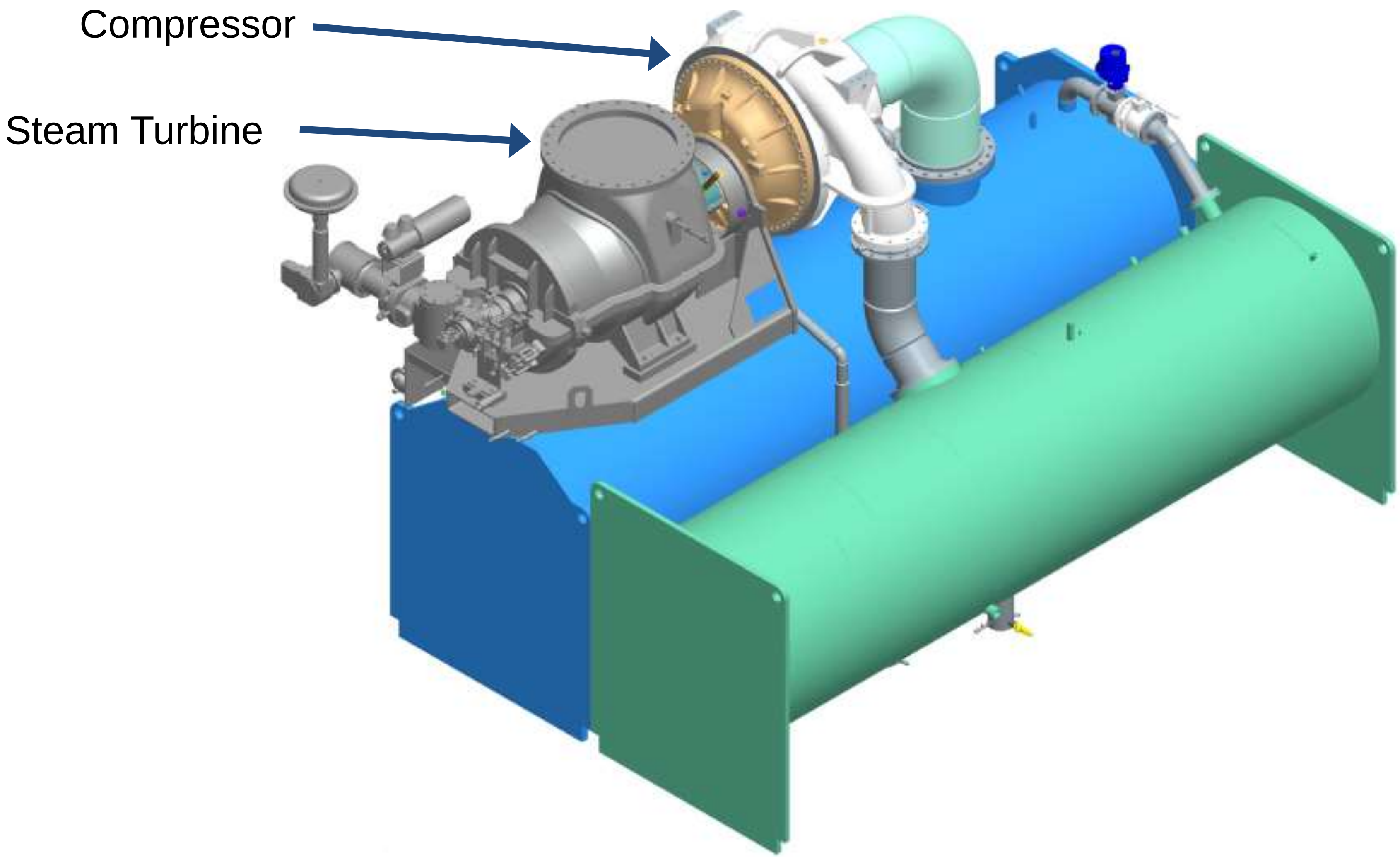
	Keele Campus
Electricity – summer	21,000 kW
(Solar Cogen 1 & 2)	- 9,500 kW (has air inlet cooling)
(York Tri-gen steam chillers)	- 5,000 kW (reduces electrical infrastructure)
	6,500 kW
Electricity – winter	15,000 kW
(Cogen 1 & 2)	- 11,500 kW
	3,500 kW (mostly on an independent circuit)

Equipment Overview

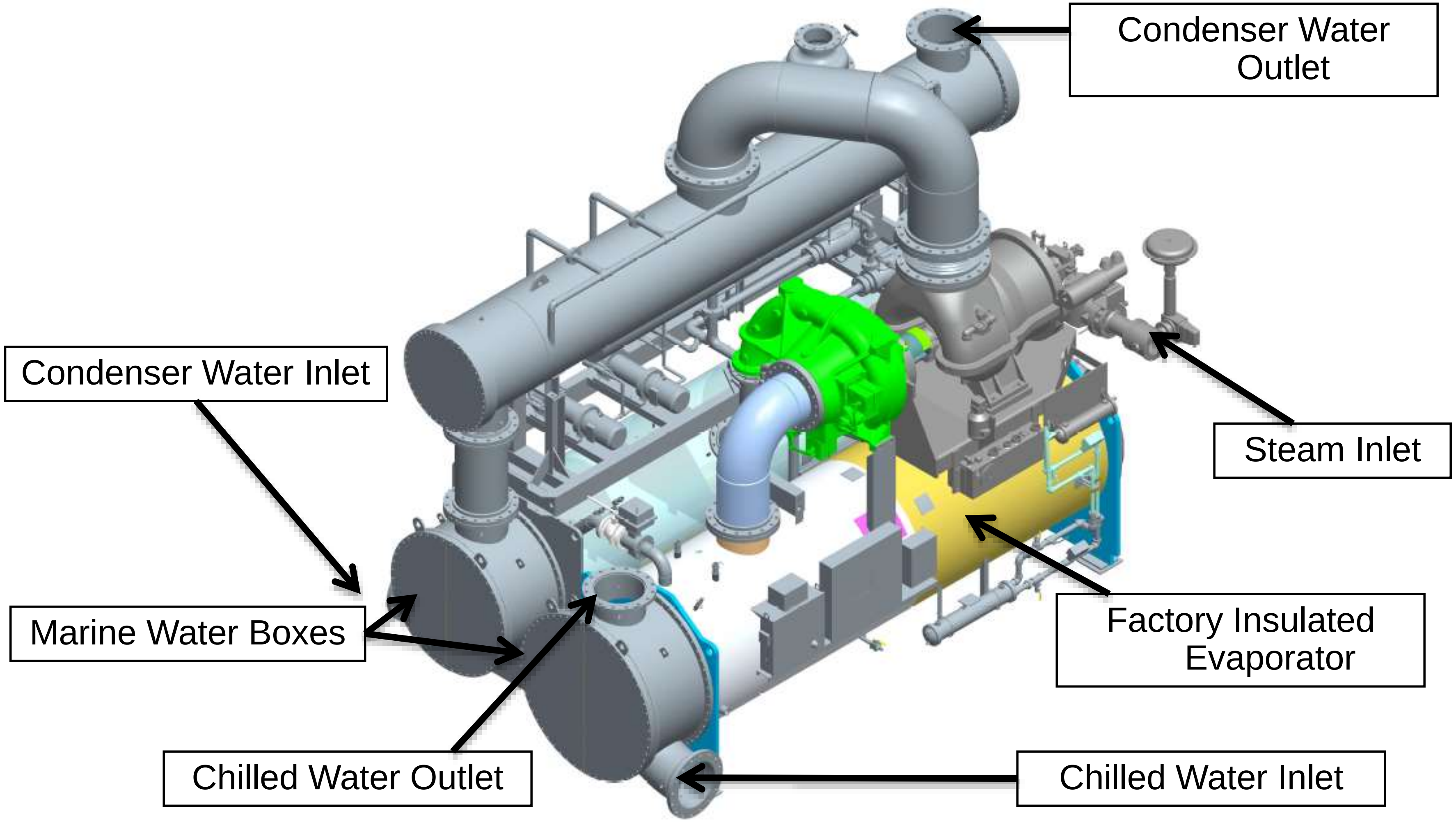
Electric Motor Driven Centrifugal Chiller



Electric Motor Driven Centrifugal Chiller



Key Components



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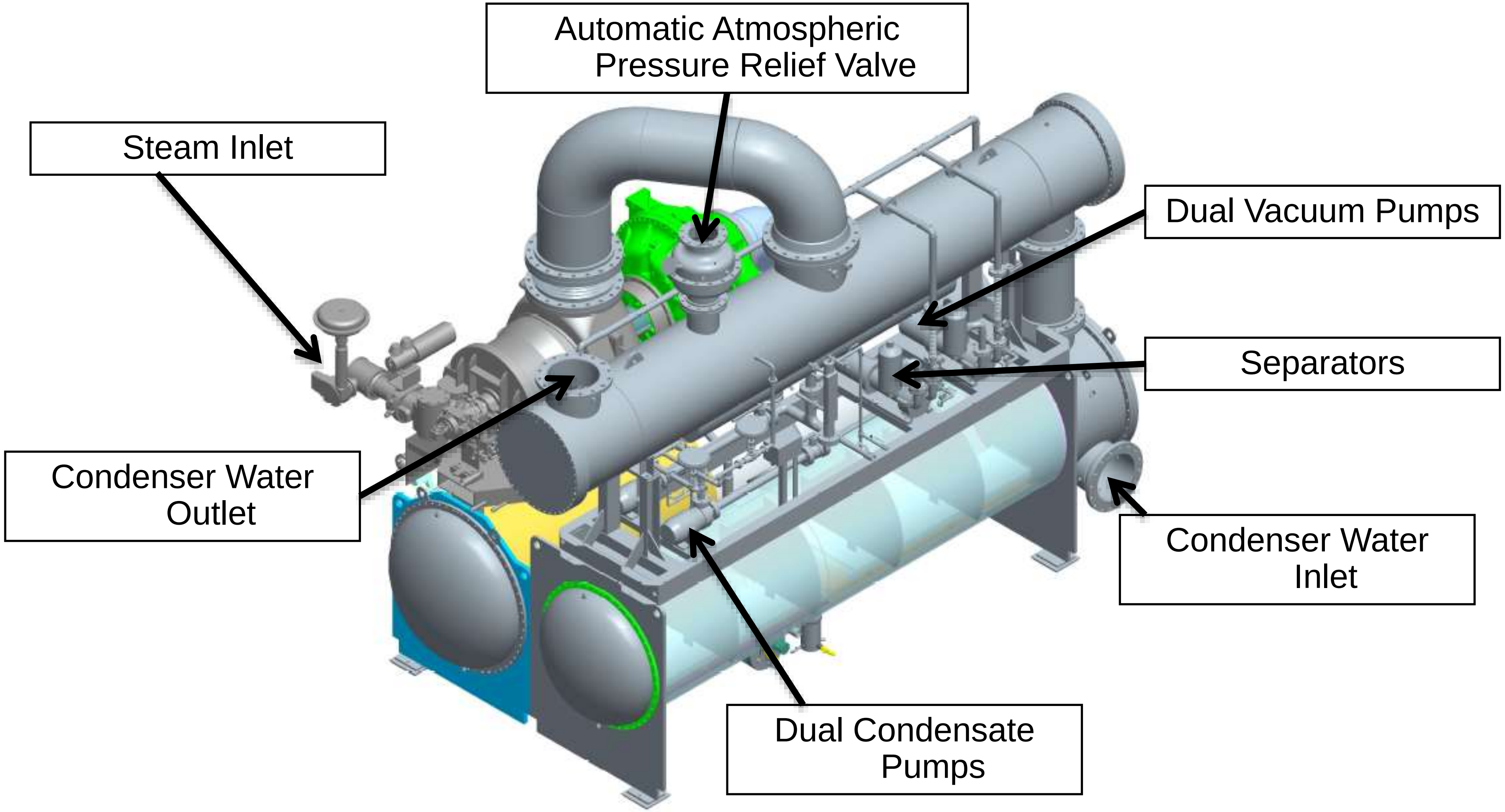
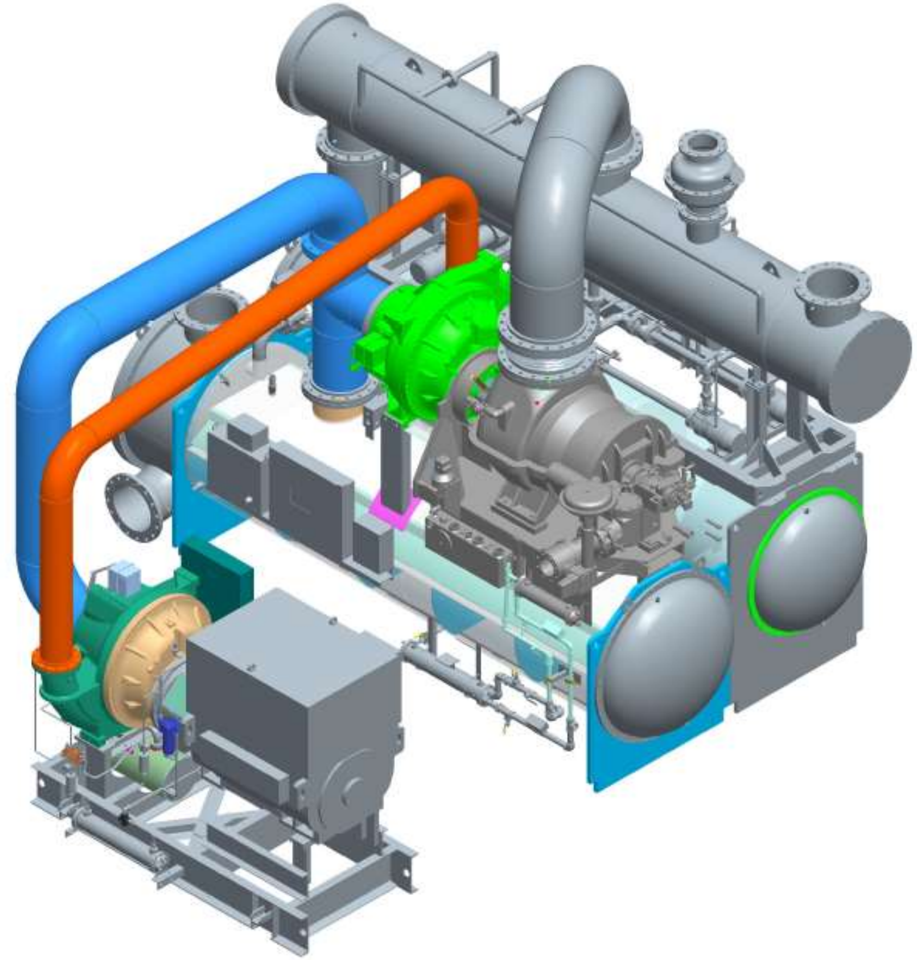
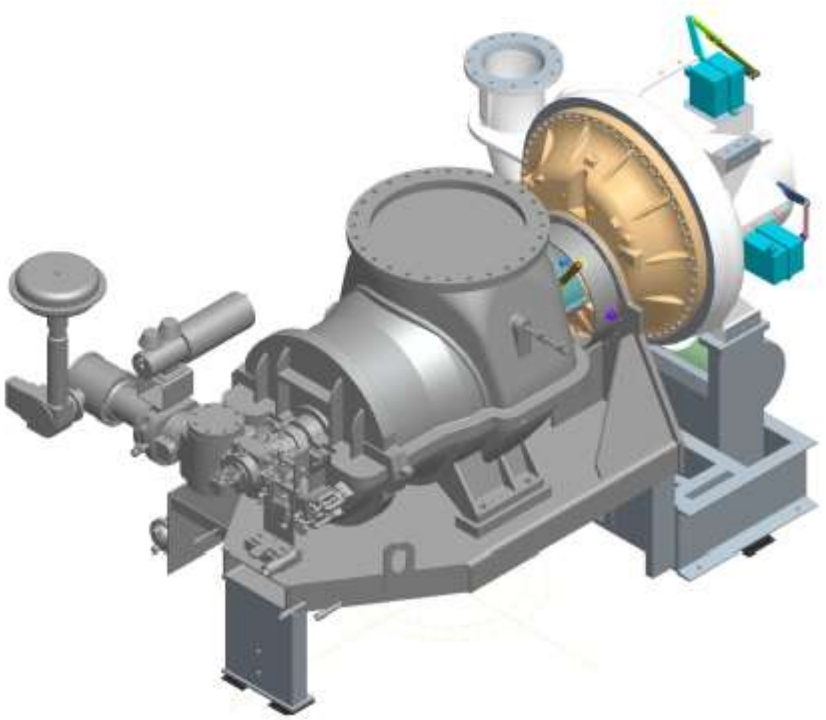


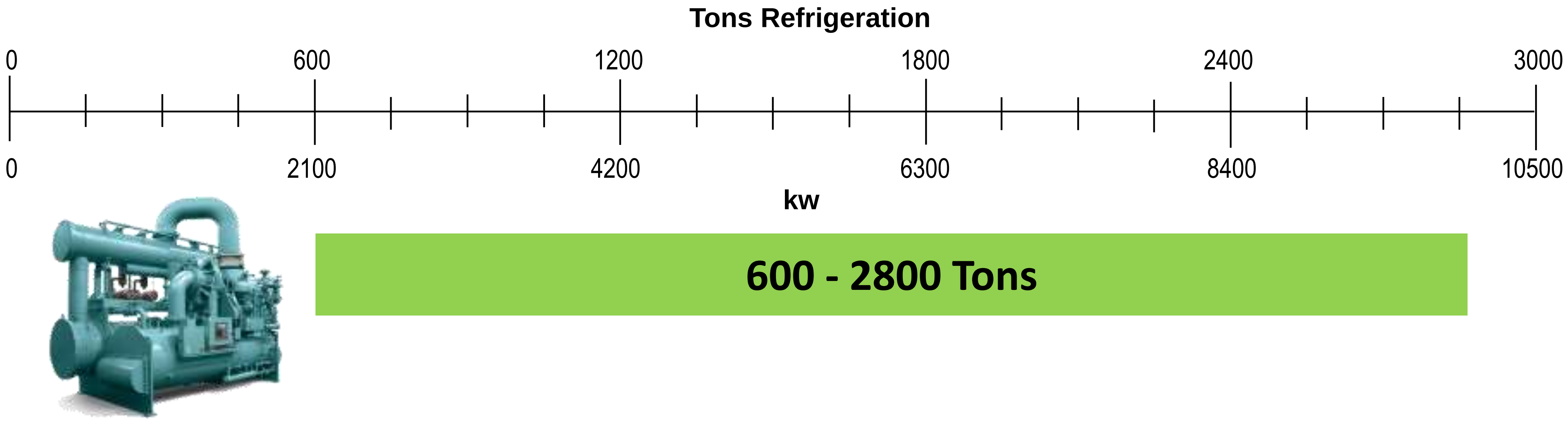
Steam Turbine with Parallel Electric Drive



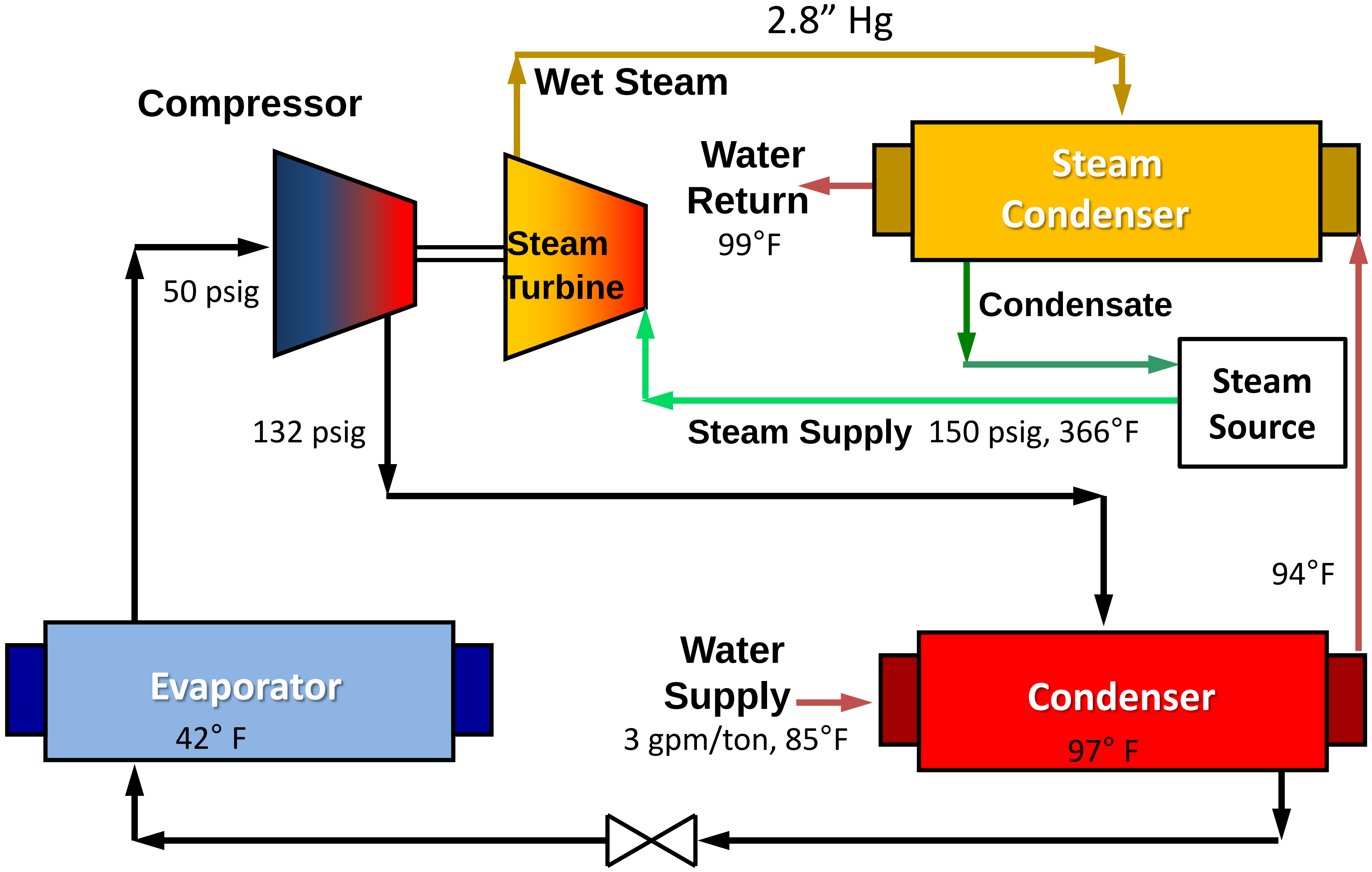
Floor Mounted Steam Turbine



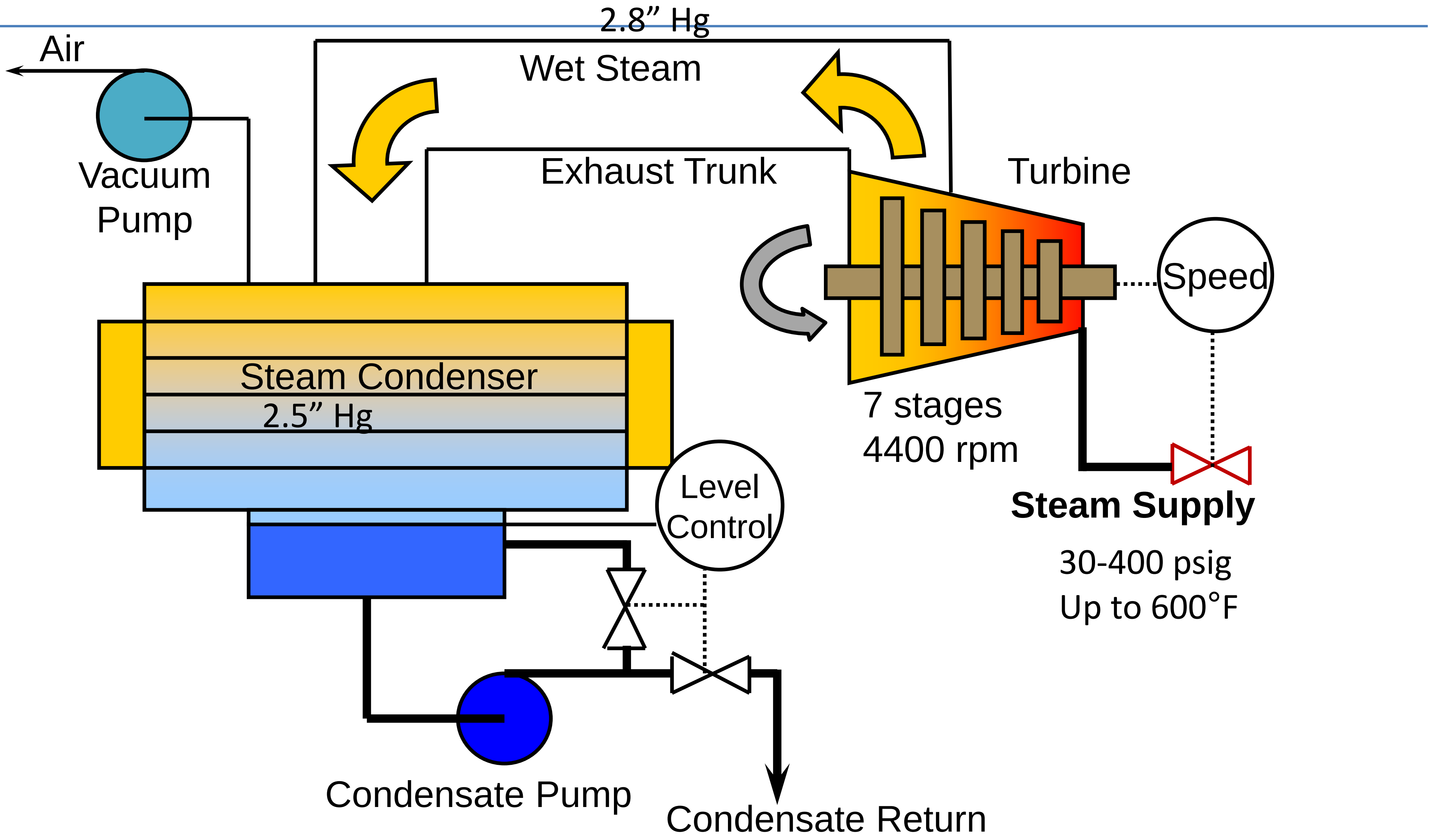
Product Range



Typical Schematic – 2000 Tons



Steam System

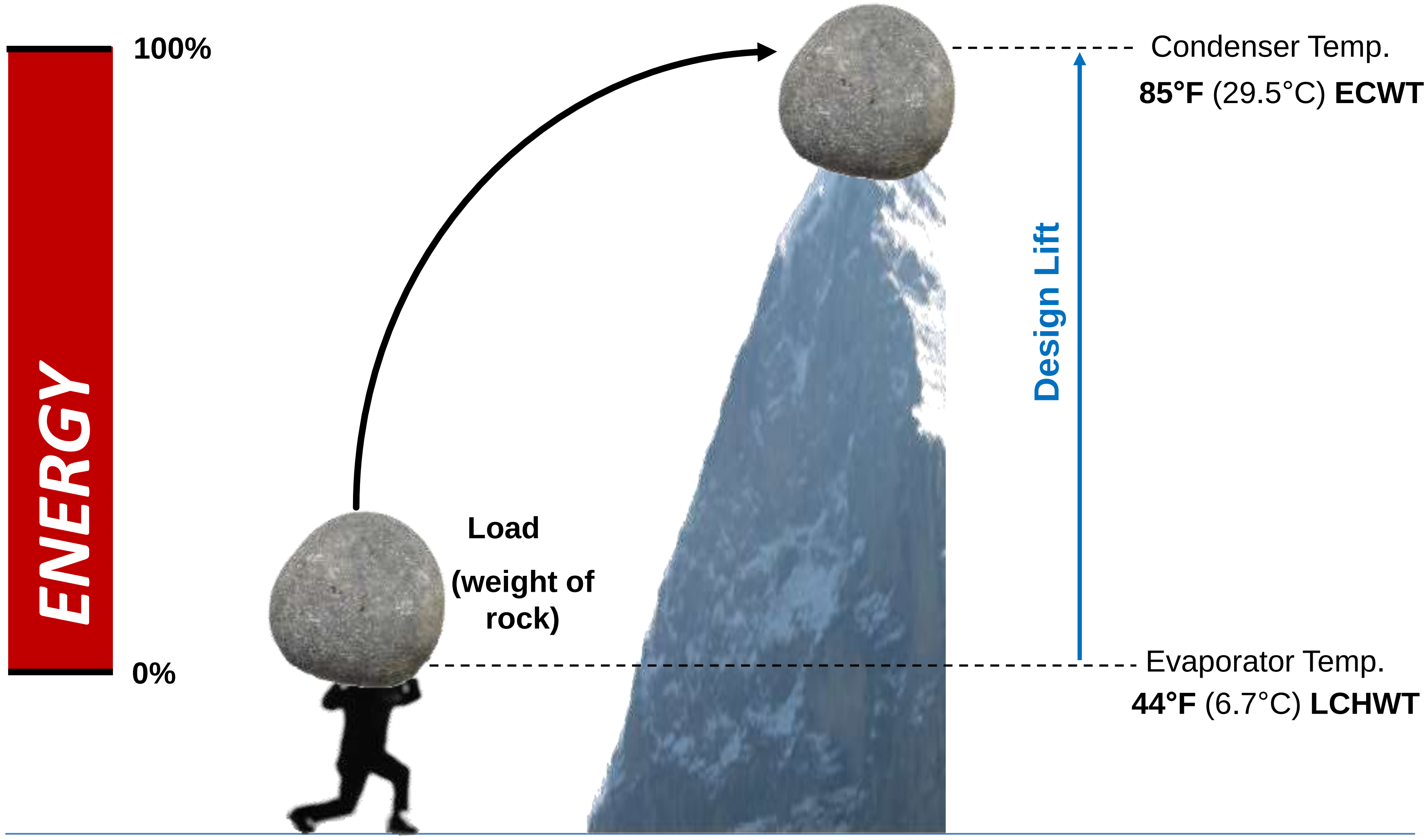


NPLV/IPLV Formula

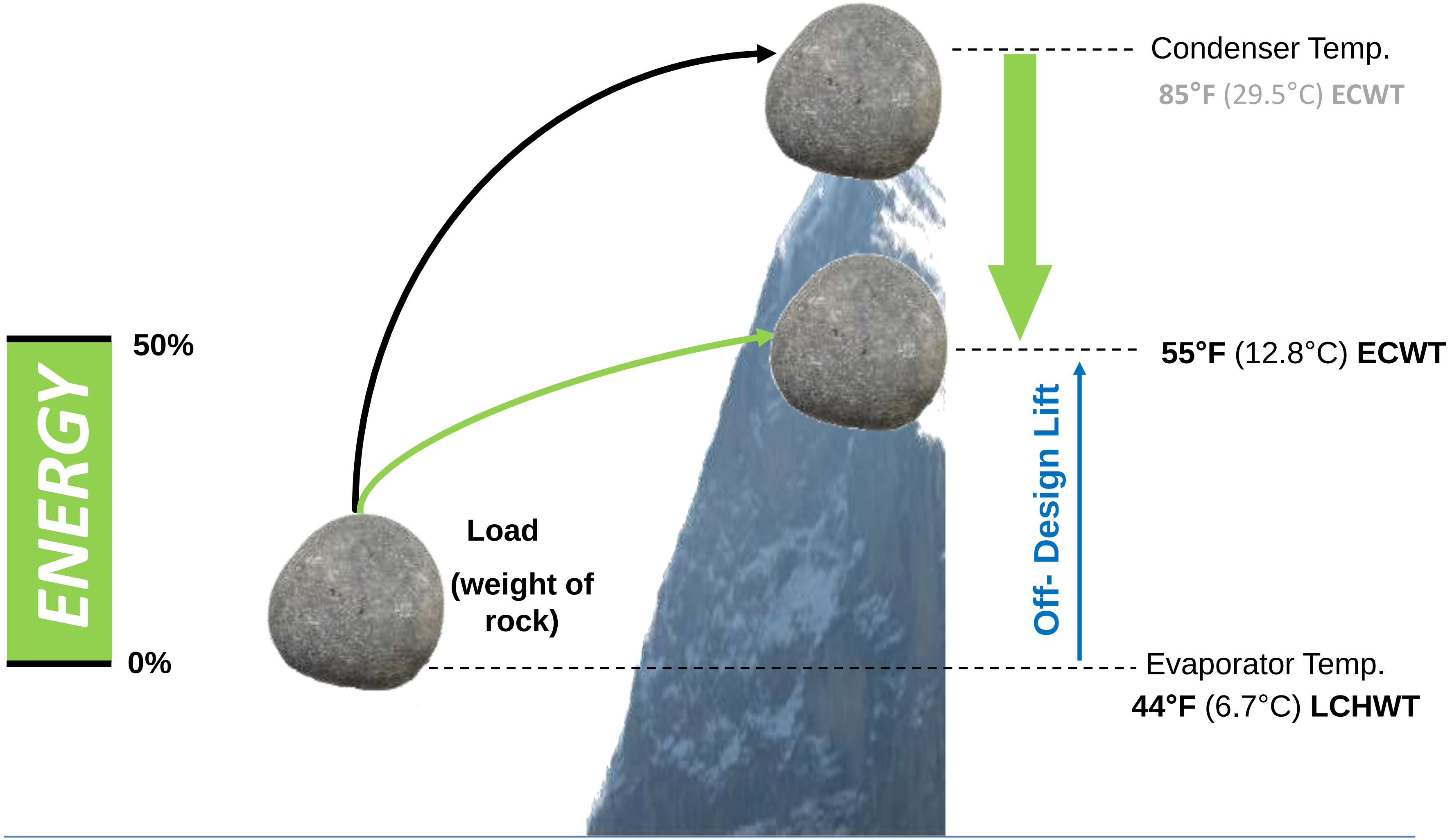
$$\text{IPLV/NPLV} = \frac{1}{(.01/A) + (.42/B) + (.45/C) + (.12/D)}$$

A = KW/Ton @ 100% Load @ 85.0 °F ECWT or 95.0 °F EDB
B = KW/Ton @ 75% Load @ 75.0 °F ECWT or 80.0 °F EDB
C = KW/Ton @ 50% Load @ 65.0 °F ECWT or 65.0 °F EDB
D = KW/Ton @ 25% Load @ 65.0 °F ECWT or 55.0 °F EDB

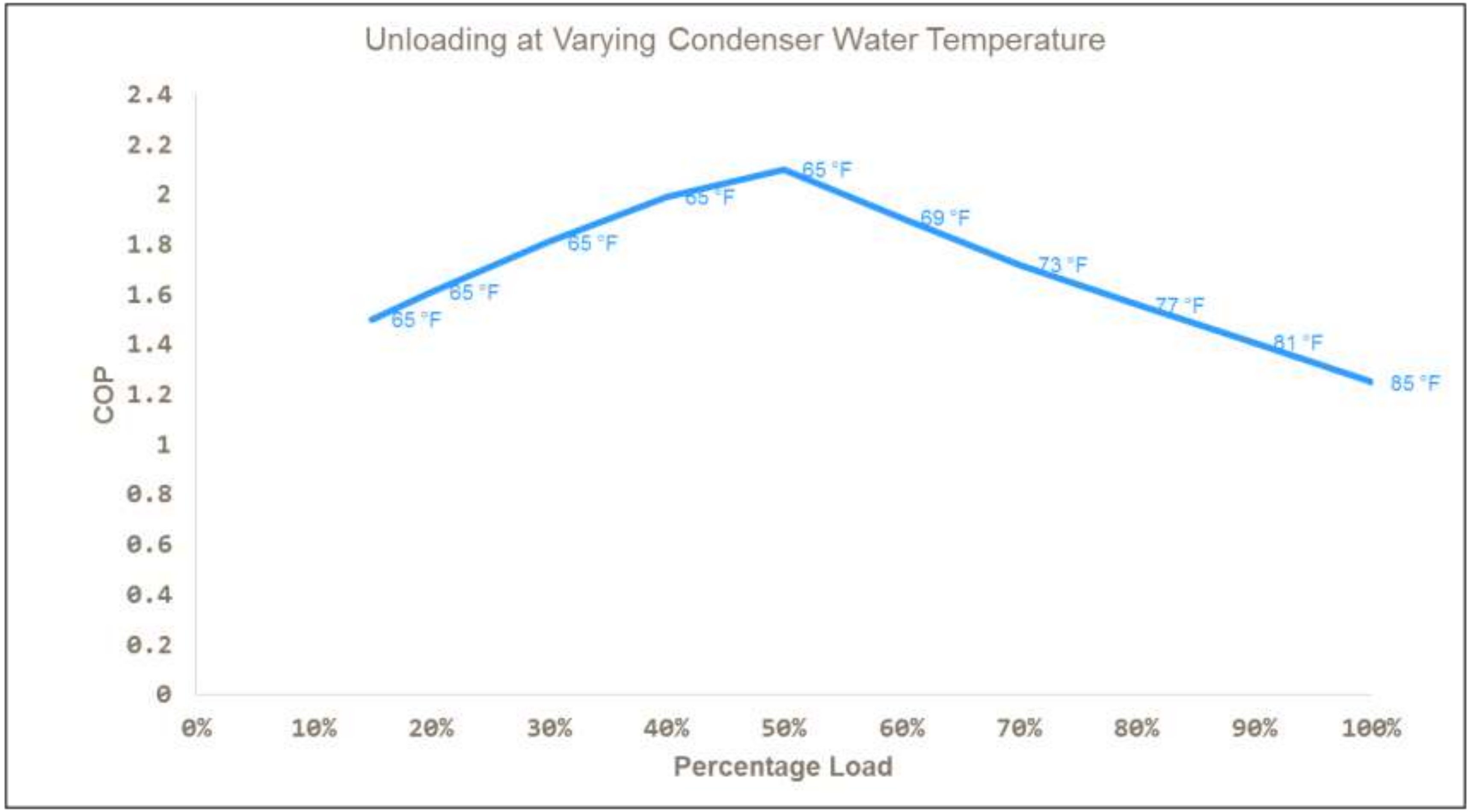
Chiller Energy Analogy – Design Point



Chiller Energy Analogy – Off-Design

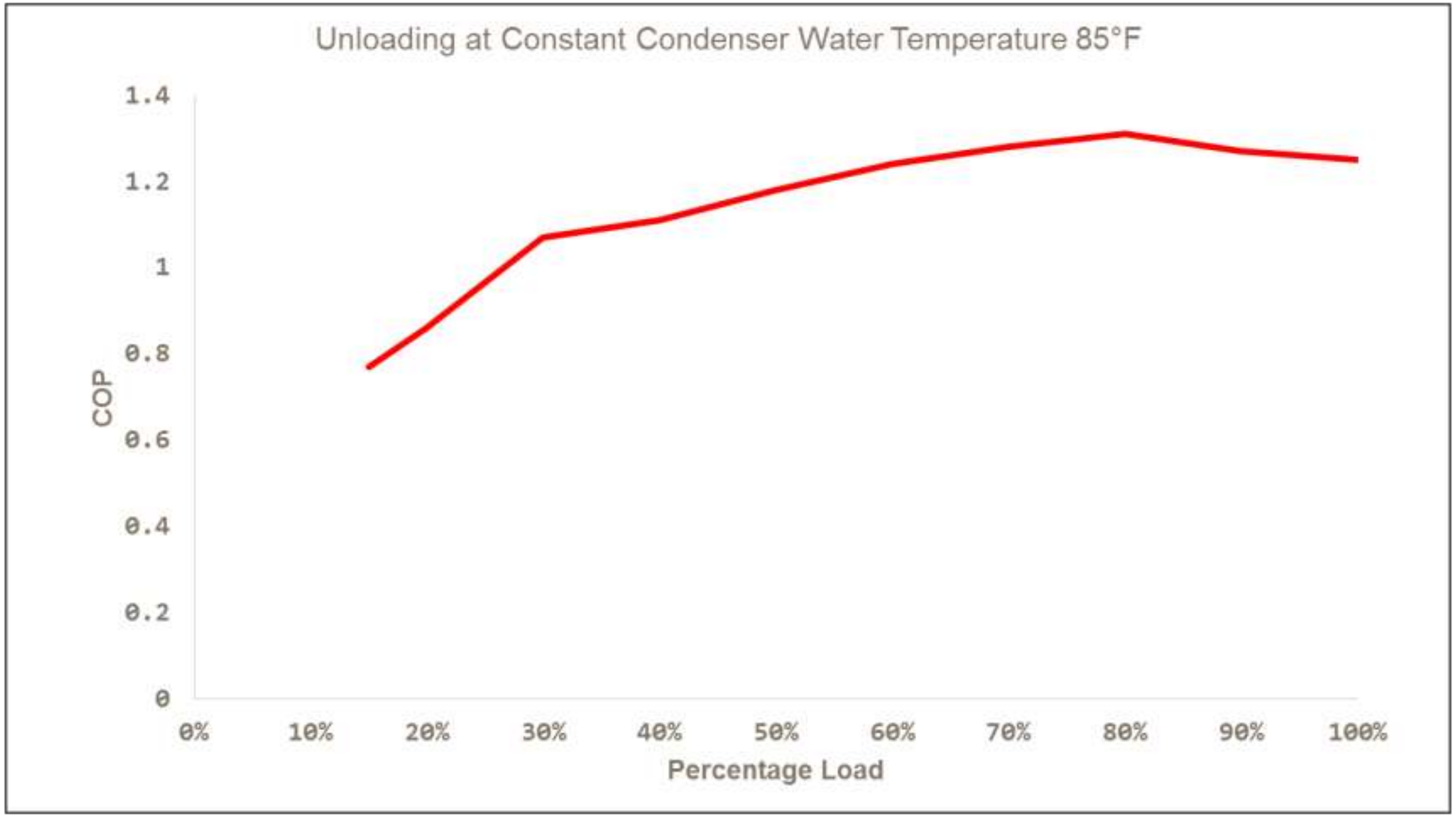


Unloading Per AHRI



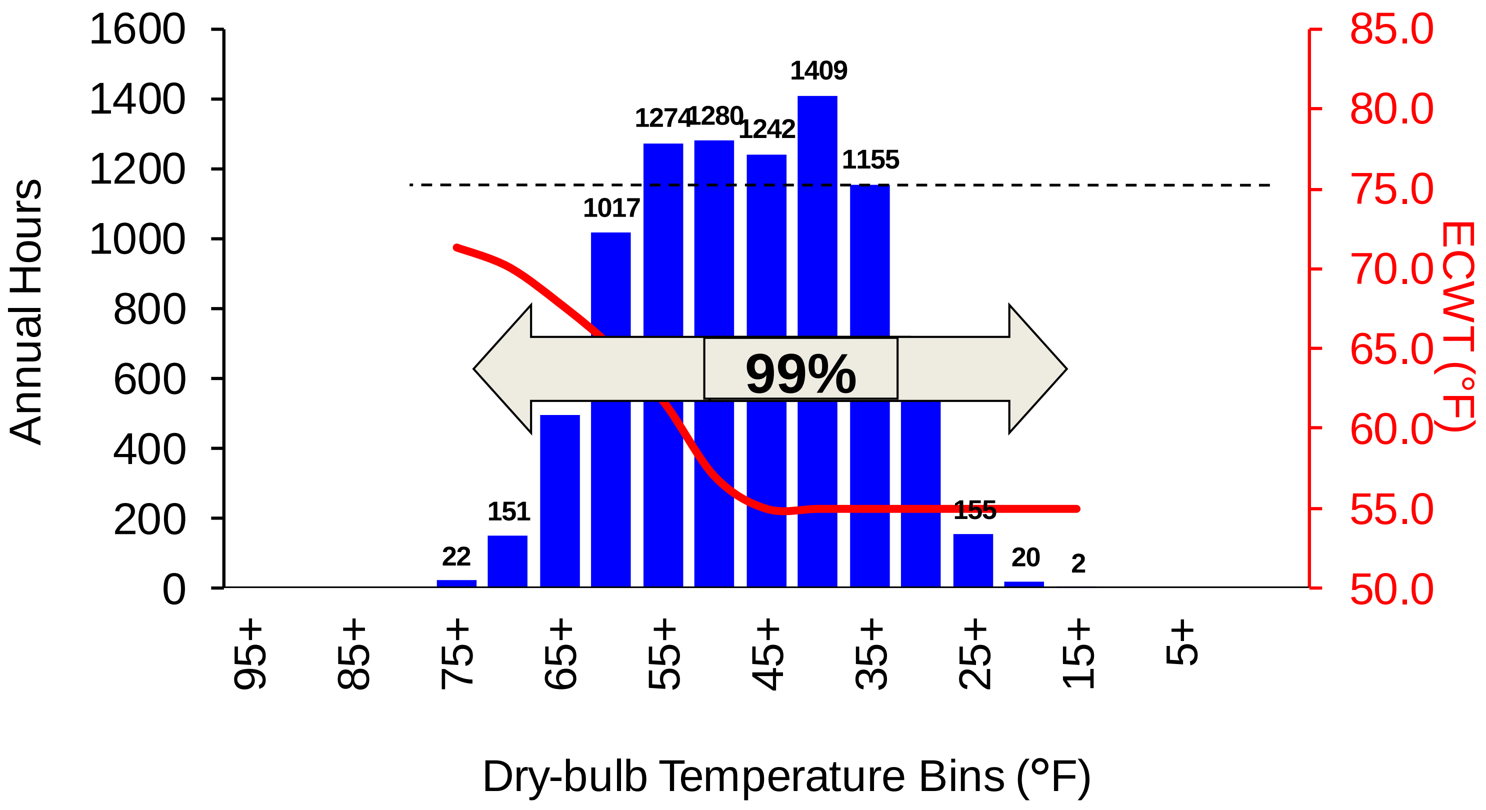
ECWT – entering condenser water temperature, COP – coefficient of performance

Unloading with Constant ECWT (85°F)



ECWT – entering condenser water temperature, COP – coefficient of performance

Vancouver Weather (ASHRAE CWEC Weather)



Note: ECWT = Avg WB + 8 approach

Typical Performance –
AHRI Conditions 120 psig, 350° F steam

Parameter	Unit of Measure-ment	I	II	III	IV	V	VI	VII
Cooling Capacity	Tons	600	900	1100	1300	1600	2000	2800
Design Steam Rate	lb/hr/ton	9.6	9.3	9	8.8	8.7	8.9	8.6
Off-Design Steam Rate	lb/hr/ton	6.5	6.4	6.1	5.9	5.8	6	5.7

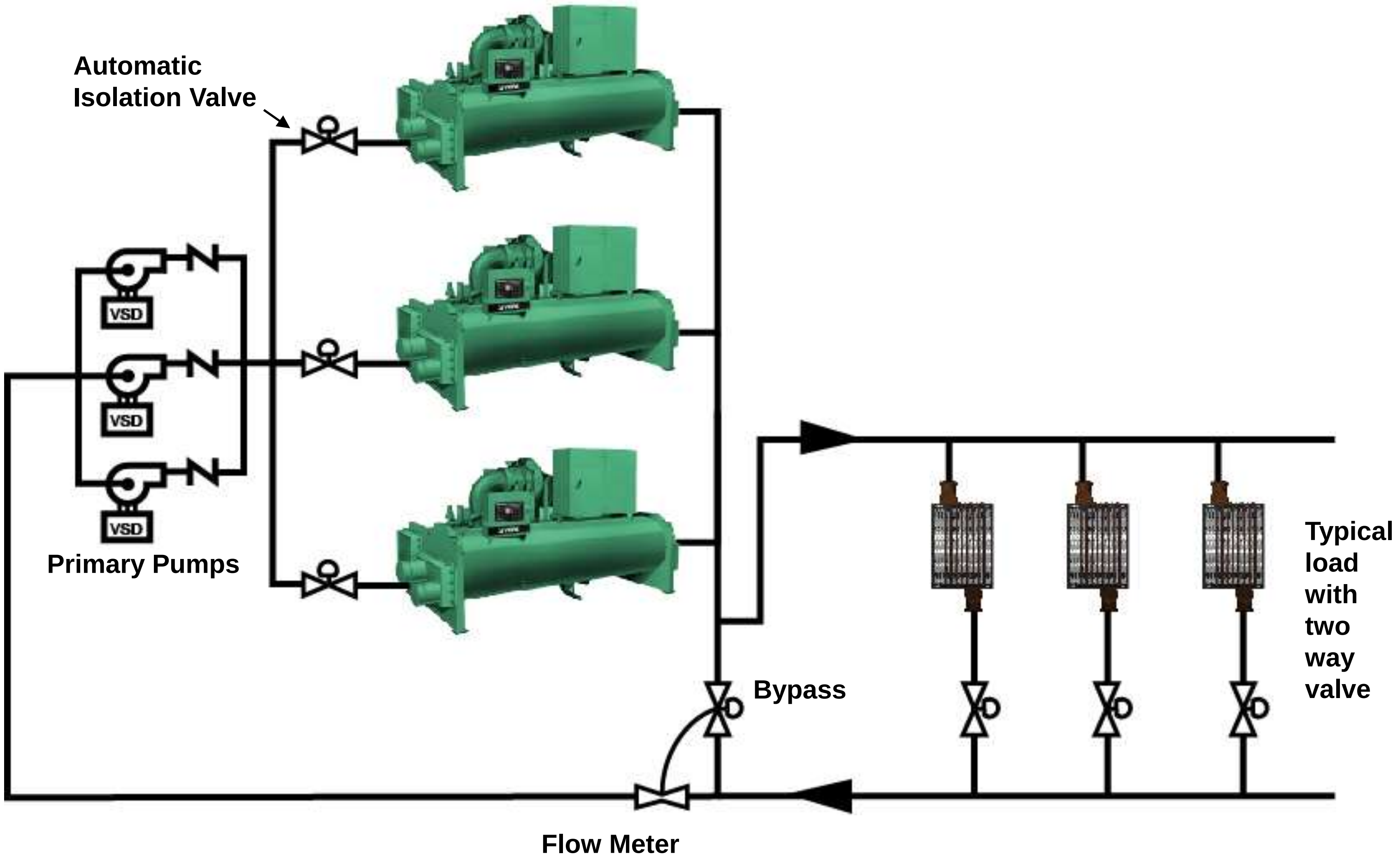
Achieving 20% Higher Capacity With Lower ECWT with a typical 3000 Ton Chiller

ECWT Deg F	% Design Load	% Steam Rate of Design
85	100	100
80	105%	97
75	110%	95
70	115%	94
65	118%	91.3
60	121%	91.6
55	123%	92.5

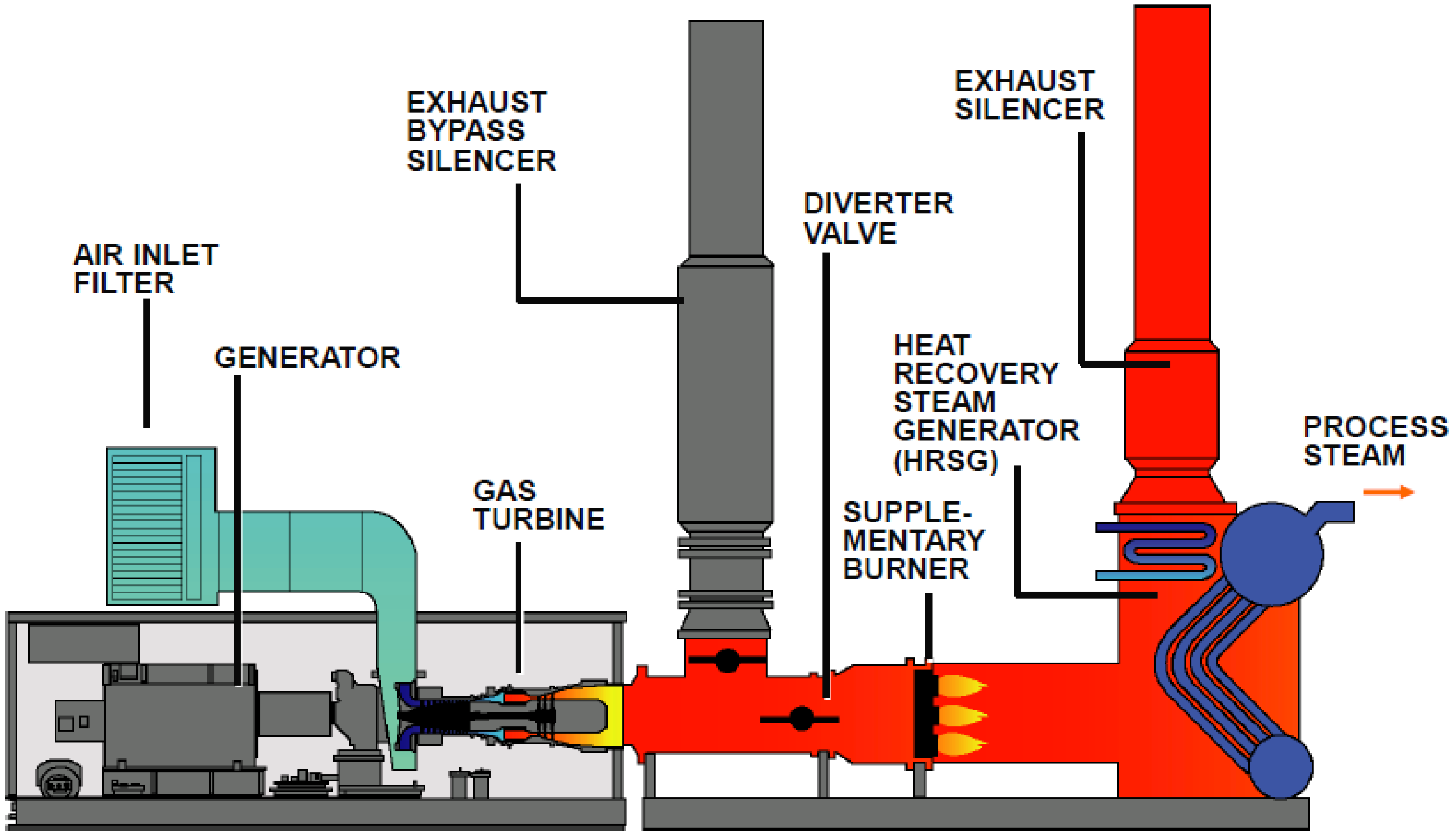
Perhaps shut off a chiller in the plant room

ECWT – entering condenser water temperature, COP – coefficient of performance

Variable Primary Flow



Typical Combustion Turbine CHP



Questions?