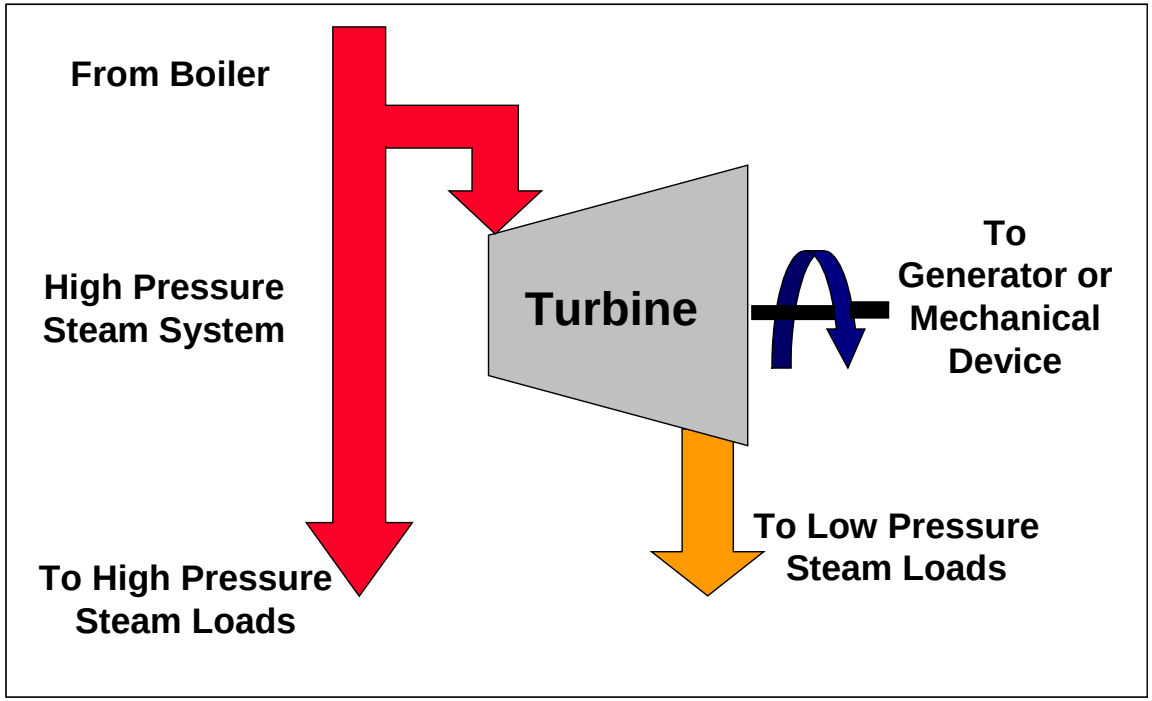
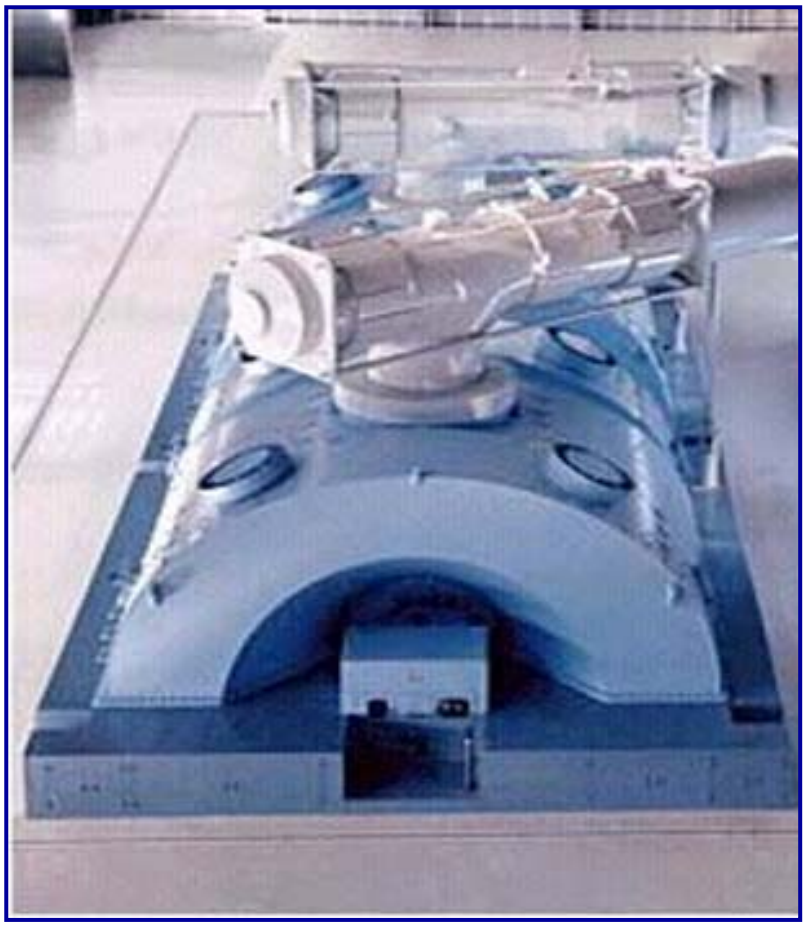
Industrial (Steam)

Steam Turbine

- Steam turbines are one of the oldest prime mover technologies still in use.
- Steam turbines extract heat from steam and transform it into mechanical work by expanding the steam from high pressure to low pressure.



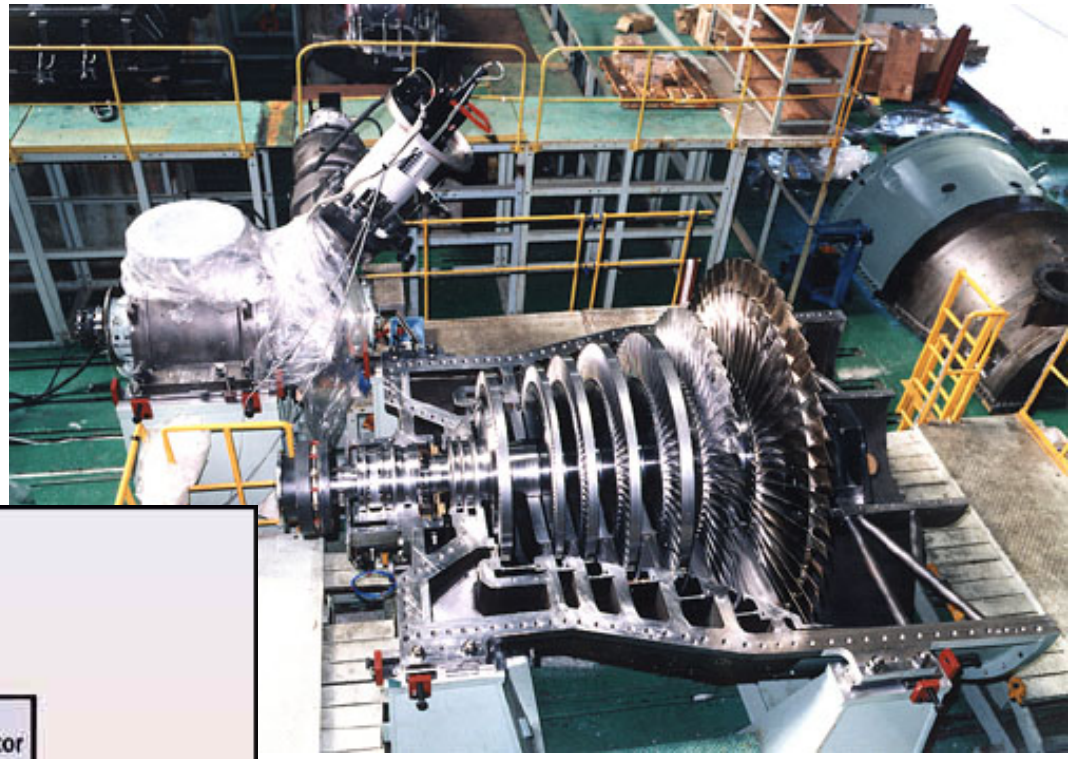
Steam Turbine Characteristics

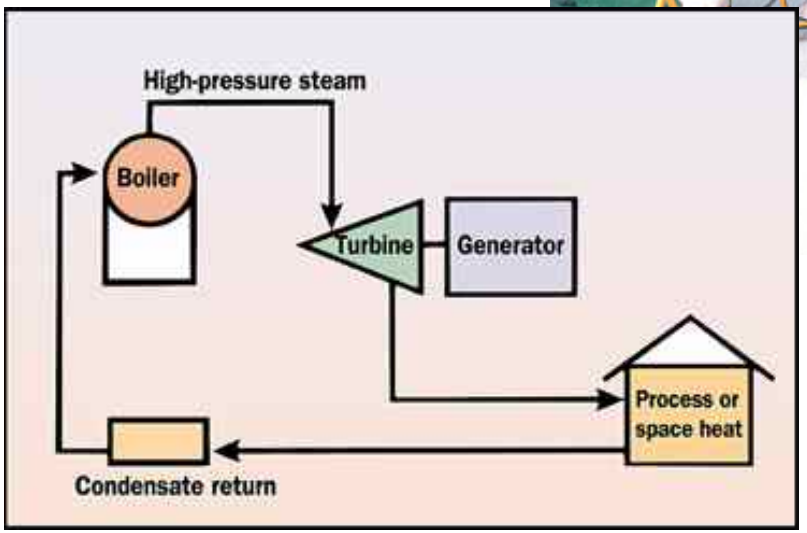


- Run from <1 MW to 500 MW
- High-pressure steam flows through the turbine blades and turns the turbine shaft
- Steam turbine shaft is connected to an electric generator for producing electricity
- Power output is proportional to the steam pressure drop in the turbine
  - the larger the pressure drop of the steam, the larger the output capacity of the turbine/generator
- No emissions from a steam turbine
  - emissions are from the boilers used to produce the steam

Two Classes of CHP Steam Turbines

- Condensing
  - Fully Condensing
  - Extraction
- Non-Condensing (Backpressure)





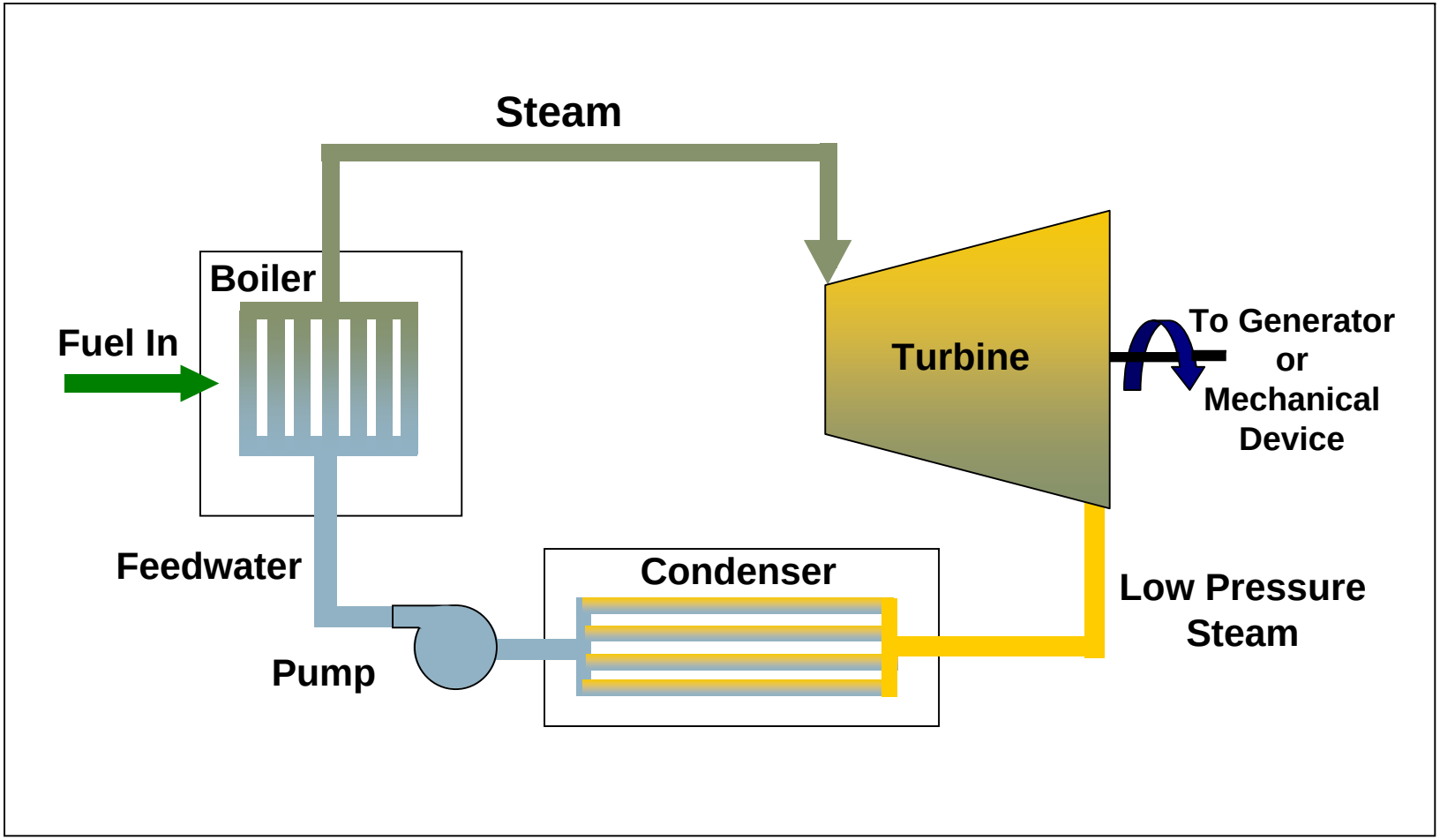
Condensing Turbine

- Operate with an exhaust pressure less than atmospheric (vacuum pressure)
- Experiences the maximum pressure drop through the turbine which results in greater energy extracted from each lbm of steam input
- Turbine efficiencies approx. 30-40%
- The condenser can be either air or water cooled – condenser cooling water can be utilized for process or space heating loads
- Usually more expensive than Non-Condensing Backpressure turbines

Non-Condensing Turbine (Backpressure)

- Operate with an exhaust equal to or in excess of atmospheric pressure
- Exhaust steam is used for lower pressure steam process loads
- Available in smaller sizes and pass large amounts of steam per MW of output (low efficiencies)
- Produce less useful work than a condensing turbine, but since the unused steam from the turbine is passed on to process loads, the lower turbine power generation efficiencies (15% to 35%) are not a concern
- Very cost effective when paralleled with pressure reduction valves (PRV), providing an efficient use of the pressure reduction requirements
- Usually less costly than condensing turbines

Simple Steam Cycle Turbine System



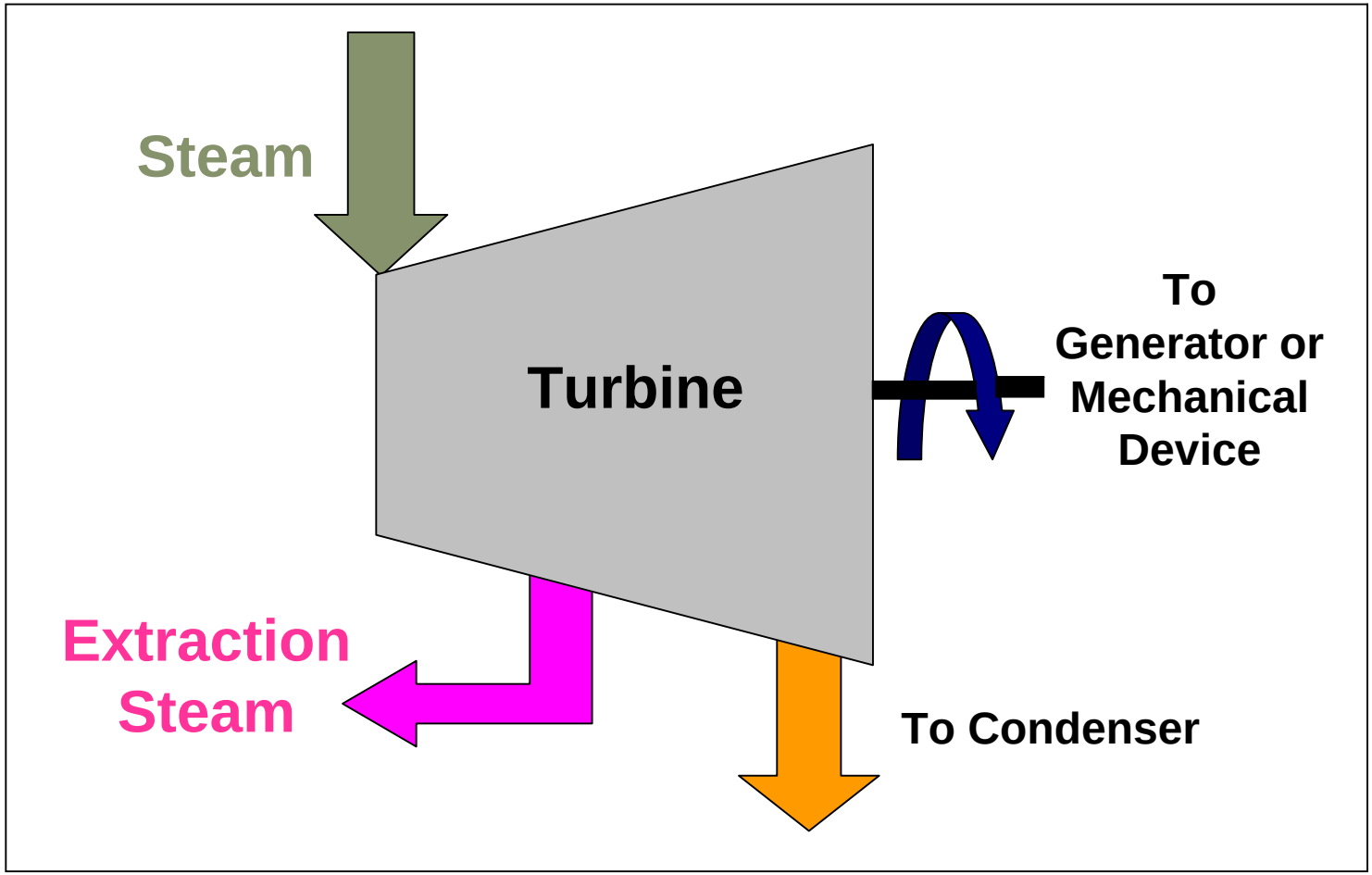
Steam Turbine Rules-of-Thumb

	Backpressure	Condensing
Power Generation Efficiency, %	15 - 35	30 - 40
Steam Exhaust Pressure	At or above atmospheric	Below atmospheric
Steam Required, lb/h per kW	20 - 100	7 - 10
Installed Cost, $/kW	300 - 400	500 - 700
O & M Cost, ¢/kWh	.15 – .35	.15 - .35

Extraction Steam Turbine

- Either condensing or backpressure
- Multi-stage turbines that are designed with one or more outlets to allow intermediate pressure steam (between inlet and exhaust pressures) to be withdrawn for process applications

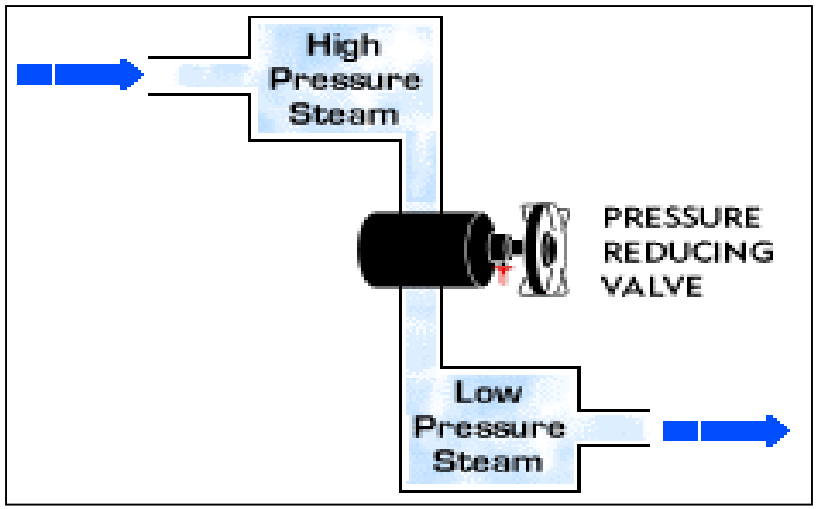
Extraction Steam Turbine



When are Steam Turbines Utilized in CHP System…

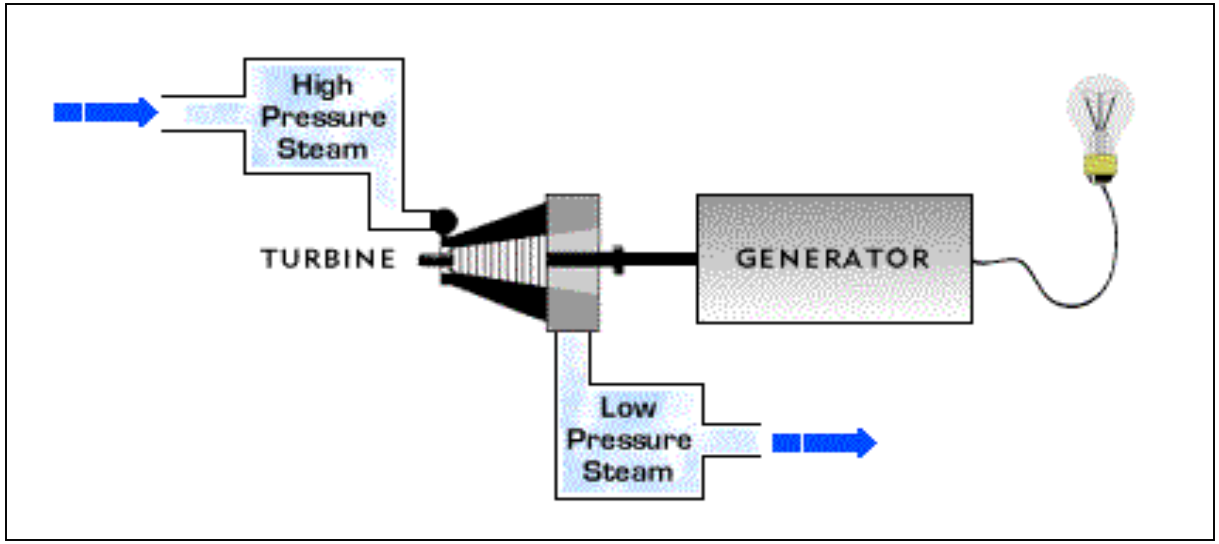
- Prime Mover – when operated directly by steam generated on-site in a boiler and used to generate electricity through an electric generator
- Thermally Activated Machine – when operated by steam generated by recycling waste thermal energy or by replacing steam pressure reduction valves (PRVs)

Reducing Steam Pressure Wisely

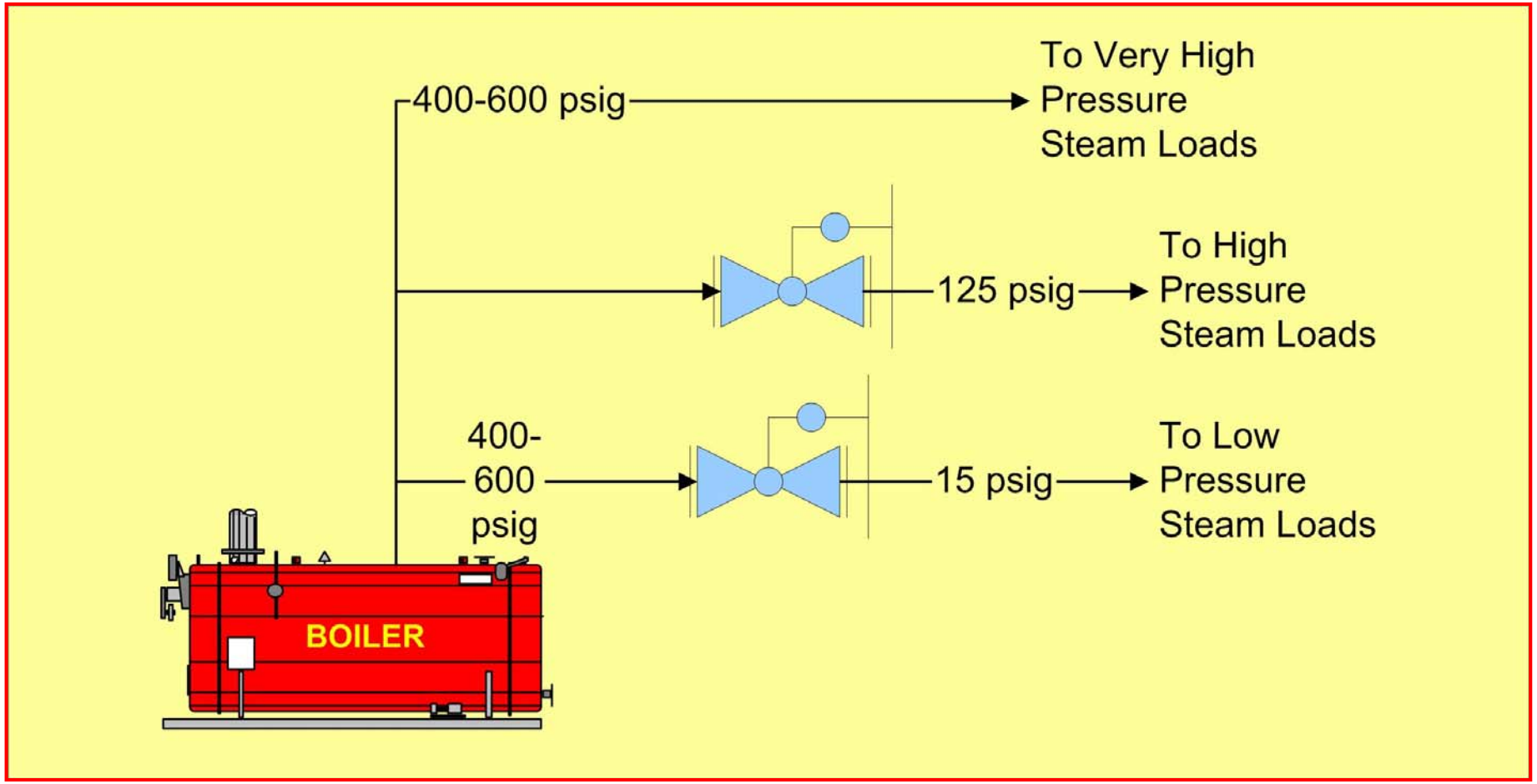


Before

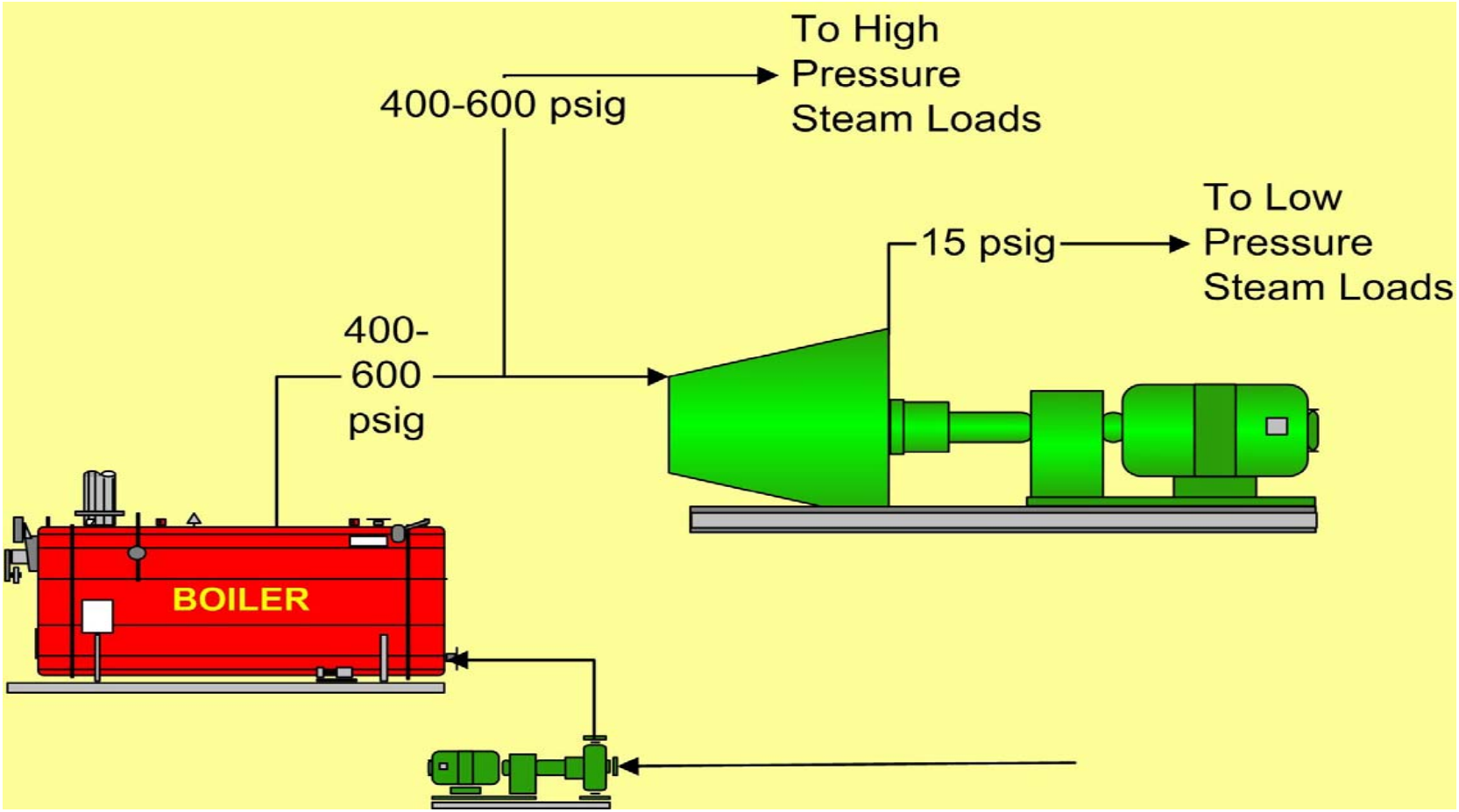
After



Typical Pressure Reduction Station



Applying Backpressure Steam Turbines

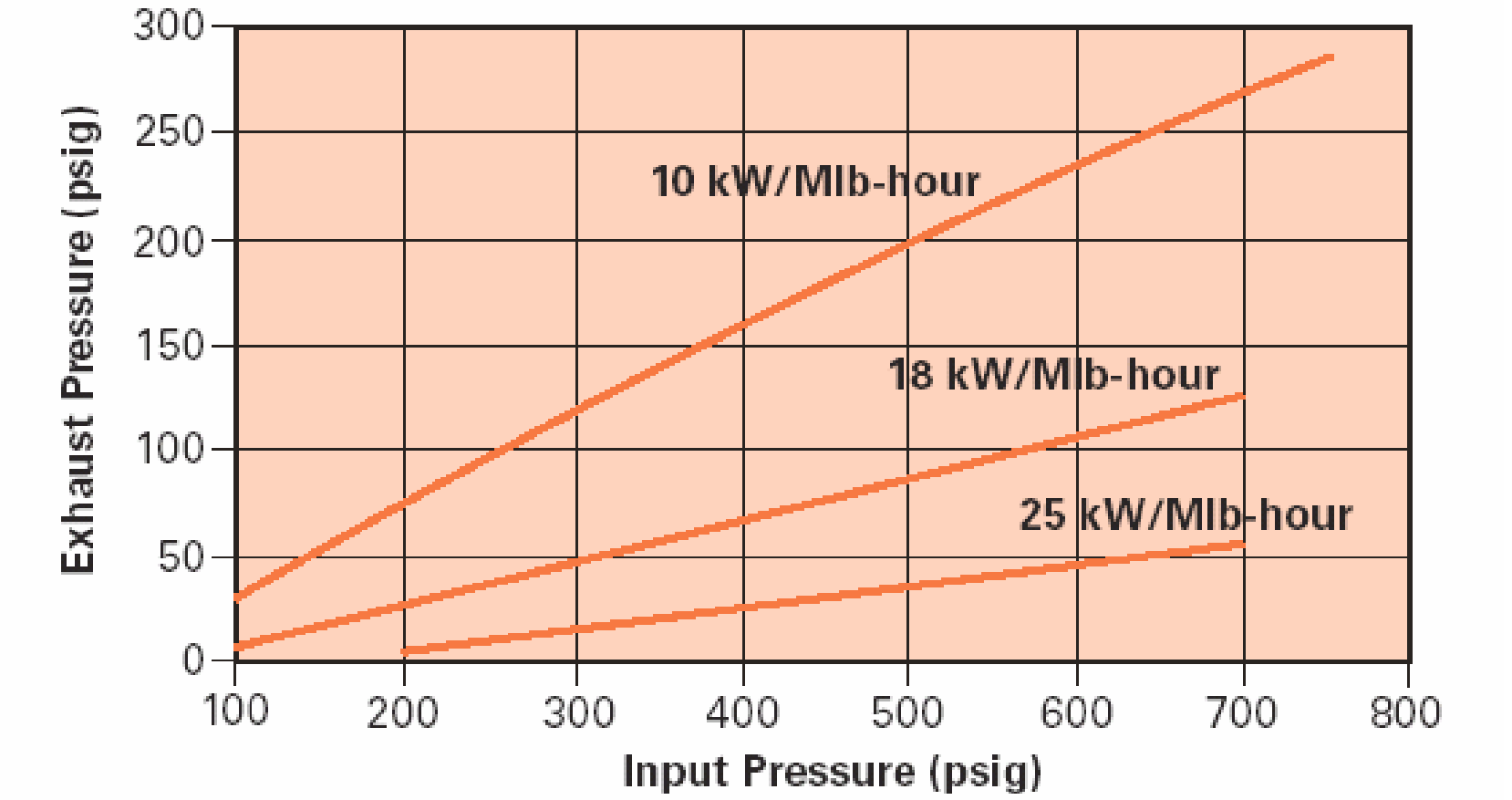


Backpressure Steam Turbine Instead of Pressure Reducing Valve

	Probably Not Attractive	Probably Attractive	Drop Dead Gorgeous
Steam Flow Rate	<4,000 lbm/h	>4,000 lbm/h	>10,000 lbm/h
Inlet Pressure	<125 psig	>125 psig	>150 psig
Pressure Drop	<100 psi	>100 psi	>150 psi
Cost of Electricity	<1.5 ¢/kWh	>1.5 ¢/kWh	>6.0 ¢/kWh
Capacity Factor	<25%	>25%	>50%

Source: TurboSteam

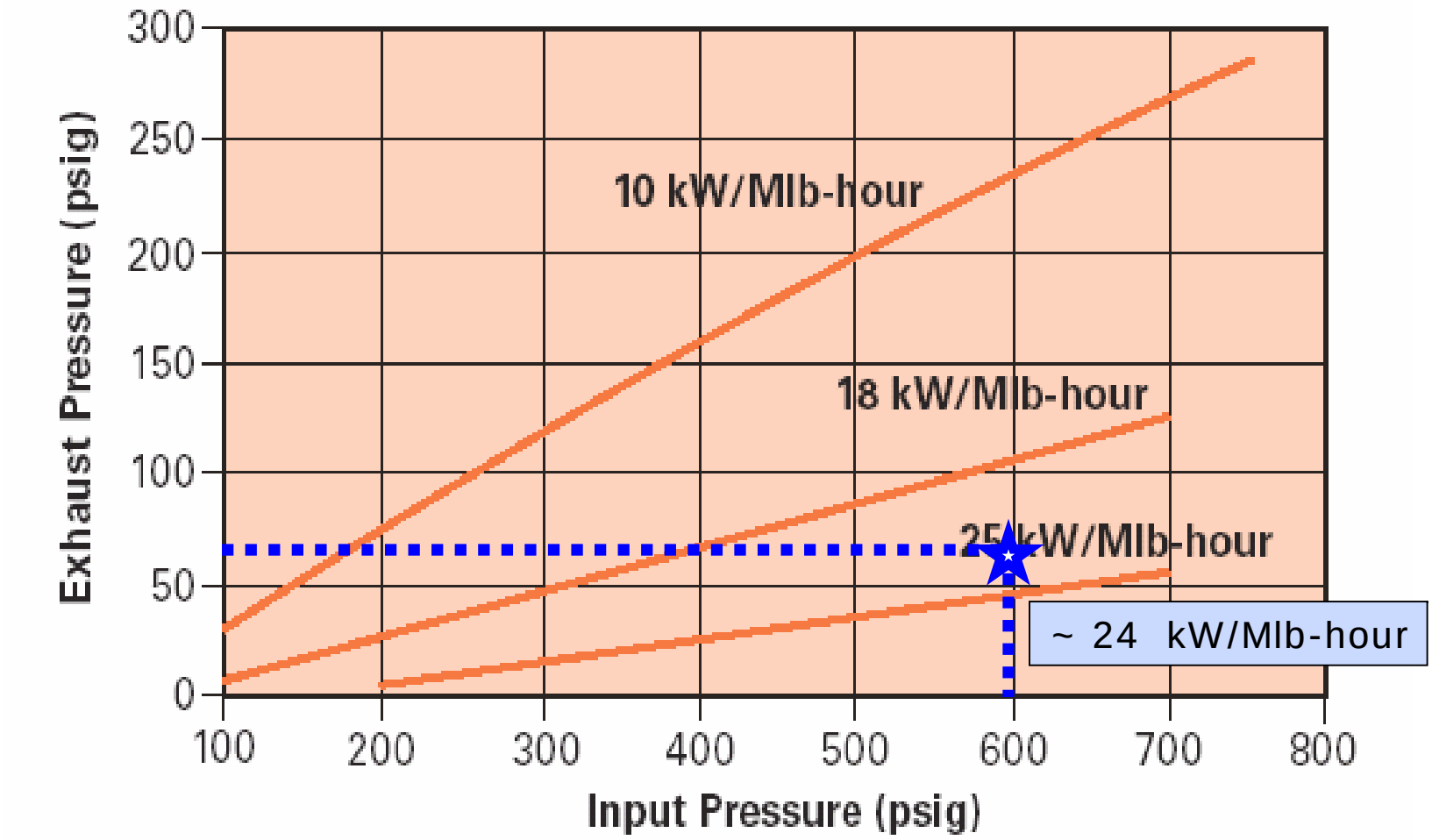
How Much Power Can Be Developed?



How Much Power Can Be Developed?

Power Available from Backpressure Turbine				
1	**Inlet Pressure**	From Owner	**600**	**psig**
2	**Outlet Pressure**	From Owner	**65**	**psig**
3	**Steam Usage**	From Owner	**40,000**	**pounds/hour**
4	**Steam Usage**	Divide Line 3 by 1,000	**40**	**Mlb per hour**
5	**Power Gen Heat Rate**	Get Value from Chart		**kW/Mlb-hour**
6	**Power Available**	Multiply Line 4 by Line 5		**kW**

How Much Power Can Be Developed?



How Much Power Can Be Developed?

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3	**Steam Usage**	From Owner	**40,000**	**pounds/hour**
4	**Steam Usage**	Divide Line 3 by 1,000	**40**	**Mlb per hour**
5	**Power Gen Heat Rate**	Get Value from Chart	**24**	**kW/Mlb-hour**
6	**Power Available**	Multiply Line 4 by Line 5	**960**	**kW**

What are the annual savings experienced by a backpressure steam turbine?

Assumptions

Gen Size:	960 kW
Hours of Operation:	3,000 hrs
Average Electricity Cost:	6.0 ¢/kWh
Backpressure Turbine Installed Cost:	$400 /kW
Backpressure Turbine O&M Cost:	2.5 ¢/kWh
Standby Charge:	$3 /kW

Calculations

Electricity Generated: (960 kW) X (3,000 hrs) = 2,880,000 kWh

Electricity Generated: (2,880,000 kWh) X (6.0 ¢/kWh) = $172,800

O&M Charges: (2,880,000 kWh) X (0.25 ¢/kWh) = $7,200

Standby Charges: (960 kW) X ($3/kW) X (12 months) = $34,560

Annual Savings: ($172,800) - ($7,200) - ($34,560) = $131,040

Installed Costs: (960 kW) X ($400/kW) = $384,000

Simple Payback: ($384,000) / ($100,800) = 2.9 years

Steam Turbine Summary

- If a facility is utilizing a Pressure Reducing Valve (PRV) to reduce steam pressure, a backpressure steam turbine can be substituted in using “free fuel” (steam) to reduce the steam pressure and generate electricity simultaneously
- One of the more easily applied CHP technologies
- Relatively short paybacks