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CAMPUS ENERGY 2017

A Sustainable Future
Miami, FL

Economics of Overrunning Clutches to Automatically Connect and Disconnect Steam Turbines in CHP Systems

James Berry and Randall Attix

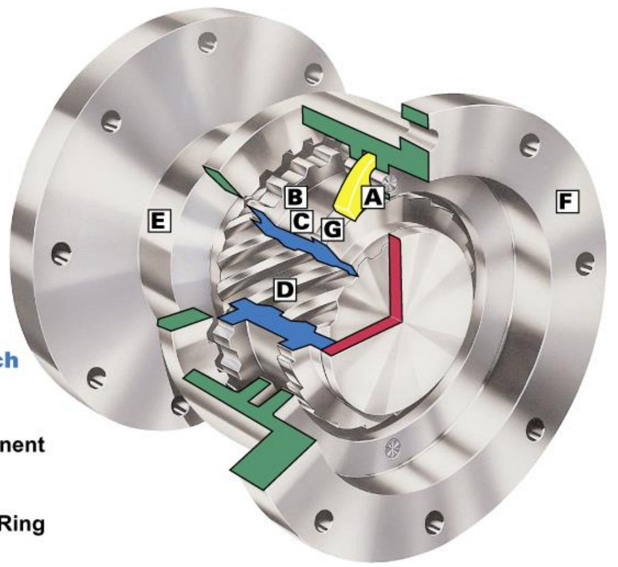
Presented at IDEA Conference on February 22, 2017

Clutch Company, Inc.

SSS Clutch Company, Inc.
New Castle, DE, USA
Application Engineering Sales
and Aftermarket Service
North and South America

SSS Gears Limited-Factory
Sunbury-on-Thames, UK
All Clutches are Built and
Tested in the UK factory

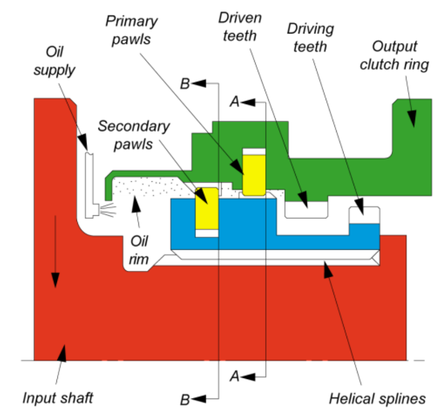
SSS High Power Automatic Overrunning Clutches

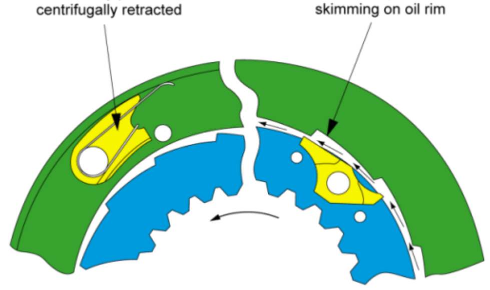


Elements of Basic SSS Clutch

- A Pawl
- B Clutch Teeth
- C Sliding Component
- D Helical Splines
- E Input Shaft
- F Output Clutch Ring
- G Ratchet Teeth

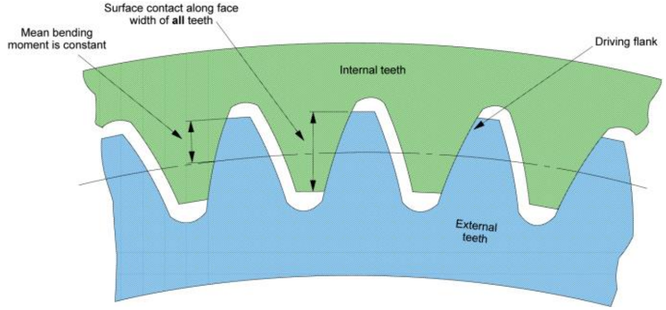
SSS Overrunning Clutch Details



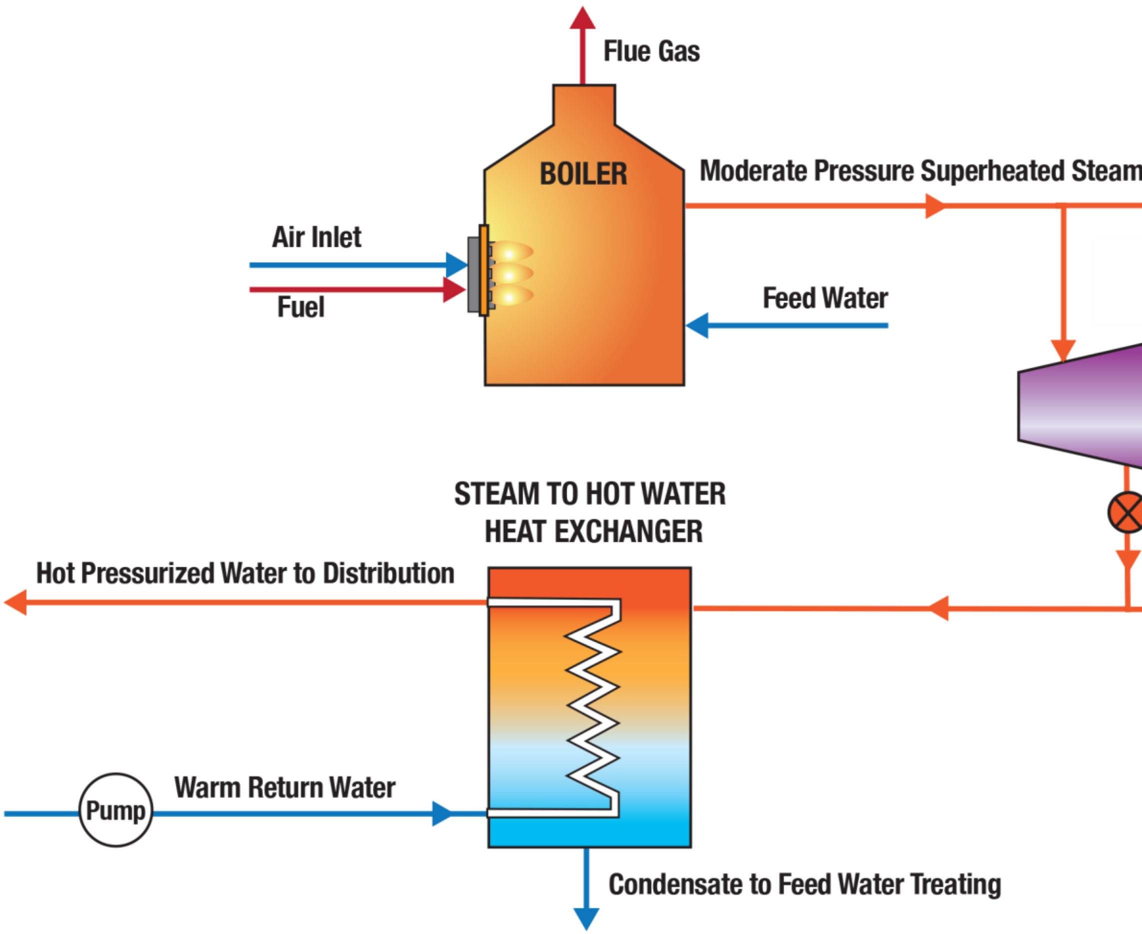


Condition with output at high speed and input stopped

SSS Overrunning Clutch & Diagram
Showing Surface Area Contact of Involute Shaped Teeth When Engaged



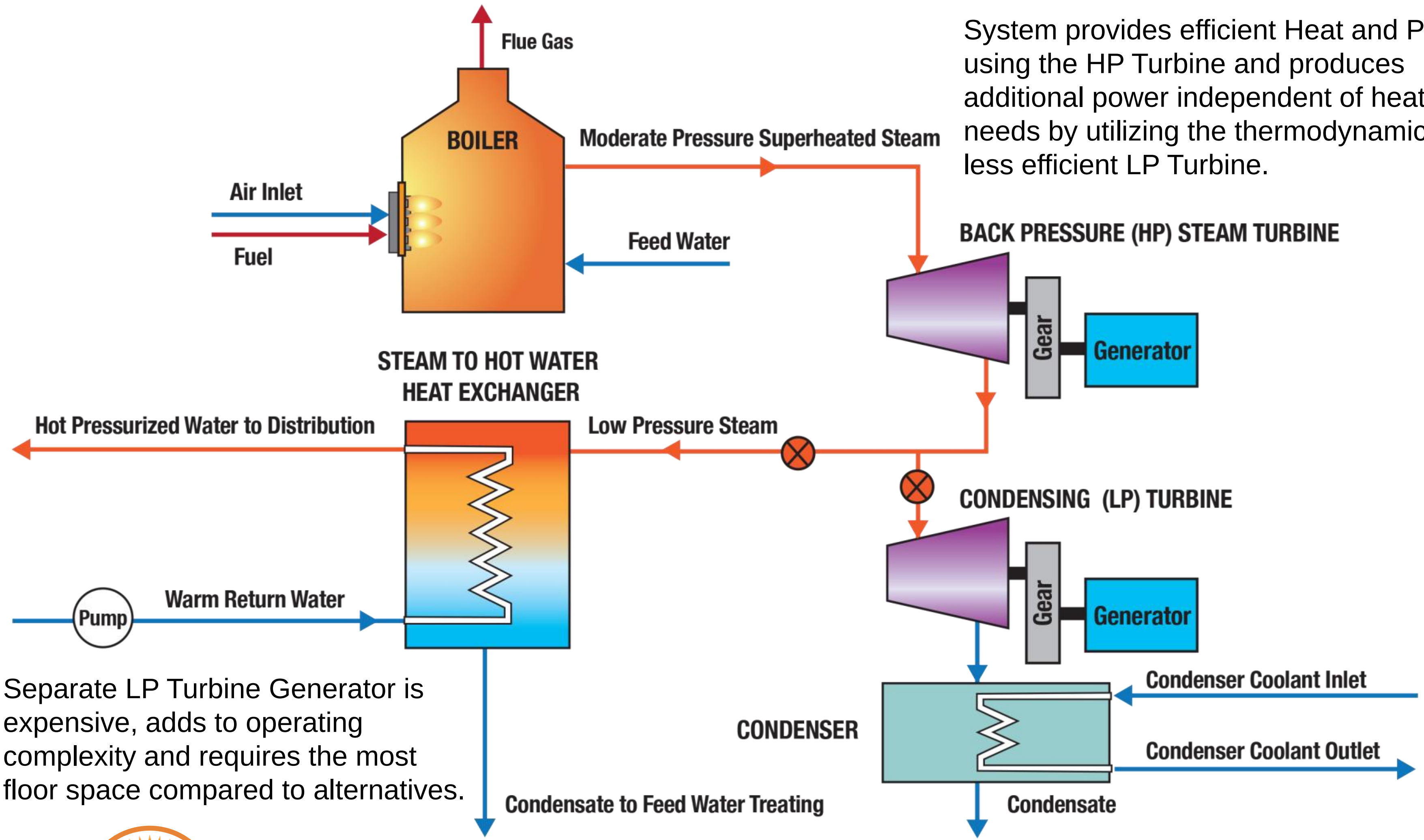
Typical CHP District Heating System
Continuous Power Generation from Back Pressure Steam Turbine



System provides thermodynamically and economically efficient Heat and Power, but lacks flexibility to provide power independent of heating needs.

Using two different size turbines with overrunning clutches improves operating economics for systems with large swings in heating loads.

Typical CHP District Heating System With Continuous Power Generation from Back Pressure Steam Turbine and Peaking Power from Condensing Turbine

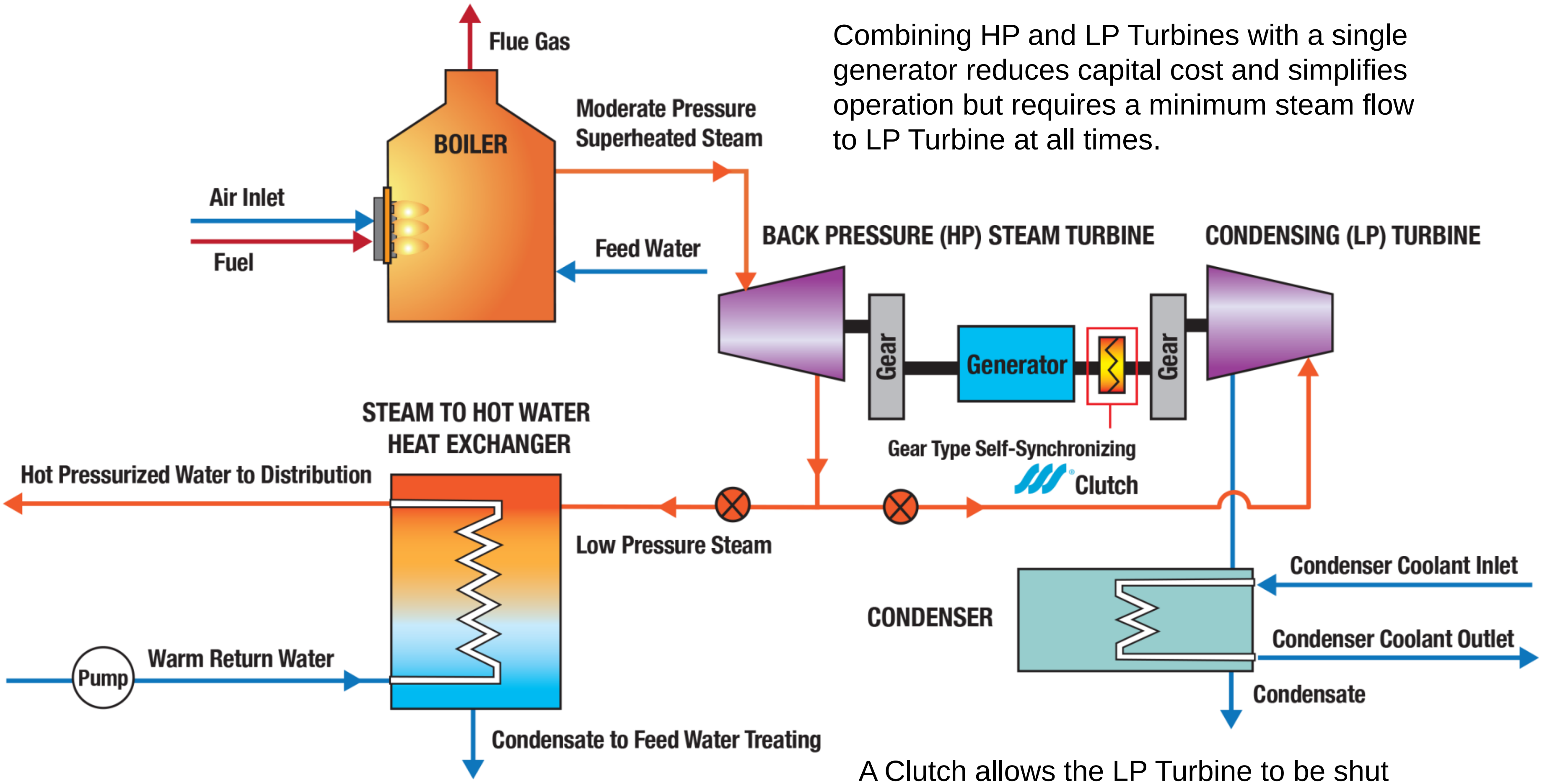


System provides efficient Heat and Power, using the HP Turbine and produces additional power independent of heating needs by utilizing the thermodynamically less efficient LP Turbine.

Separate LP Turbine Generator is expensive, adds to operating complexity and requires the most floor space compared to alternatives.

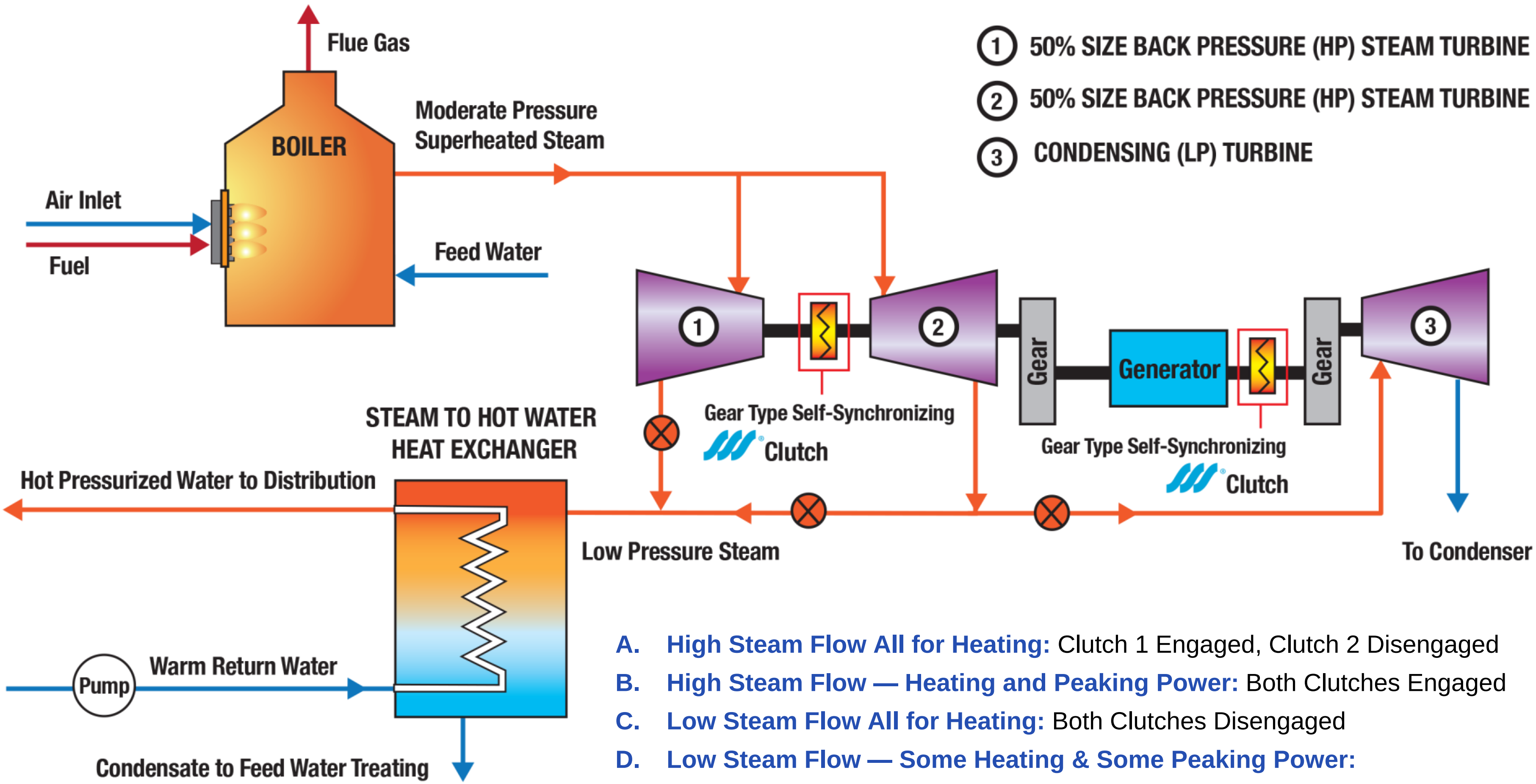
Typical CHP District Heating System With Continuous Power Generation from Back Pressure Steam Turbine and Peaking Power from Condensing Turbine

Combining HP and LP Turbines with a single generator reduces capital cost and simplifies operation but requires a minimum steam flow to LP Turbine at all times.



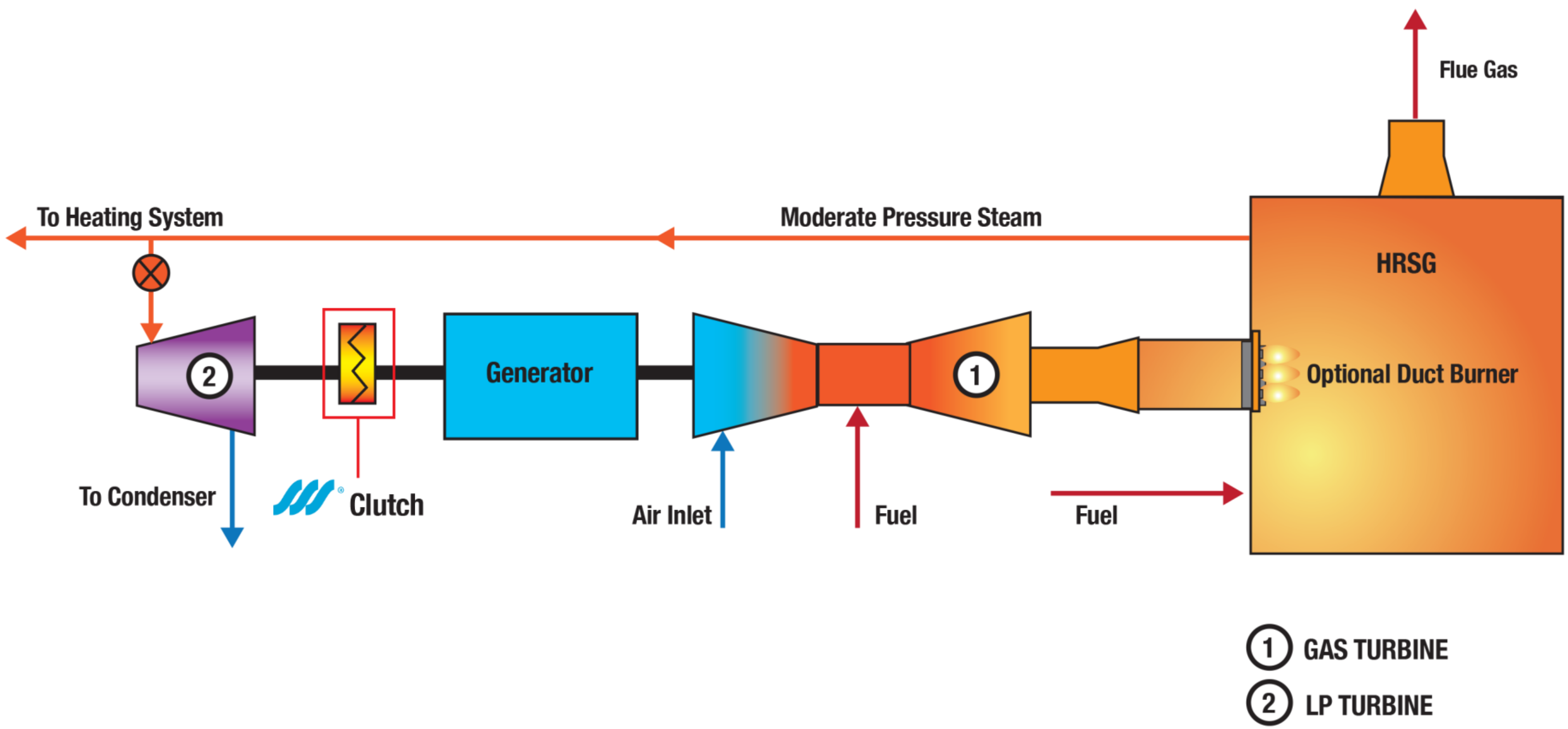
A Clutch allows the LP Turbine to be shut down when not needed, avoiding minimum steam flow waste.

Typical CHP District Heating System With Continuous Power Generation from Back Pressure Steam Turbine and Peaking Power from Condensing Turbine For Maximum Flexibiliy

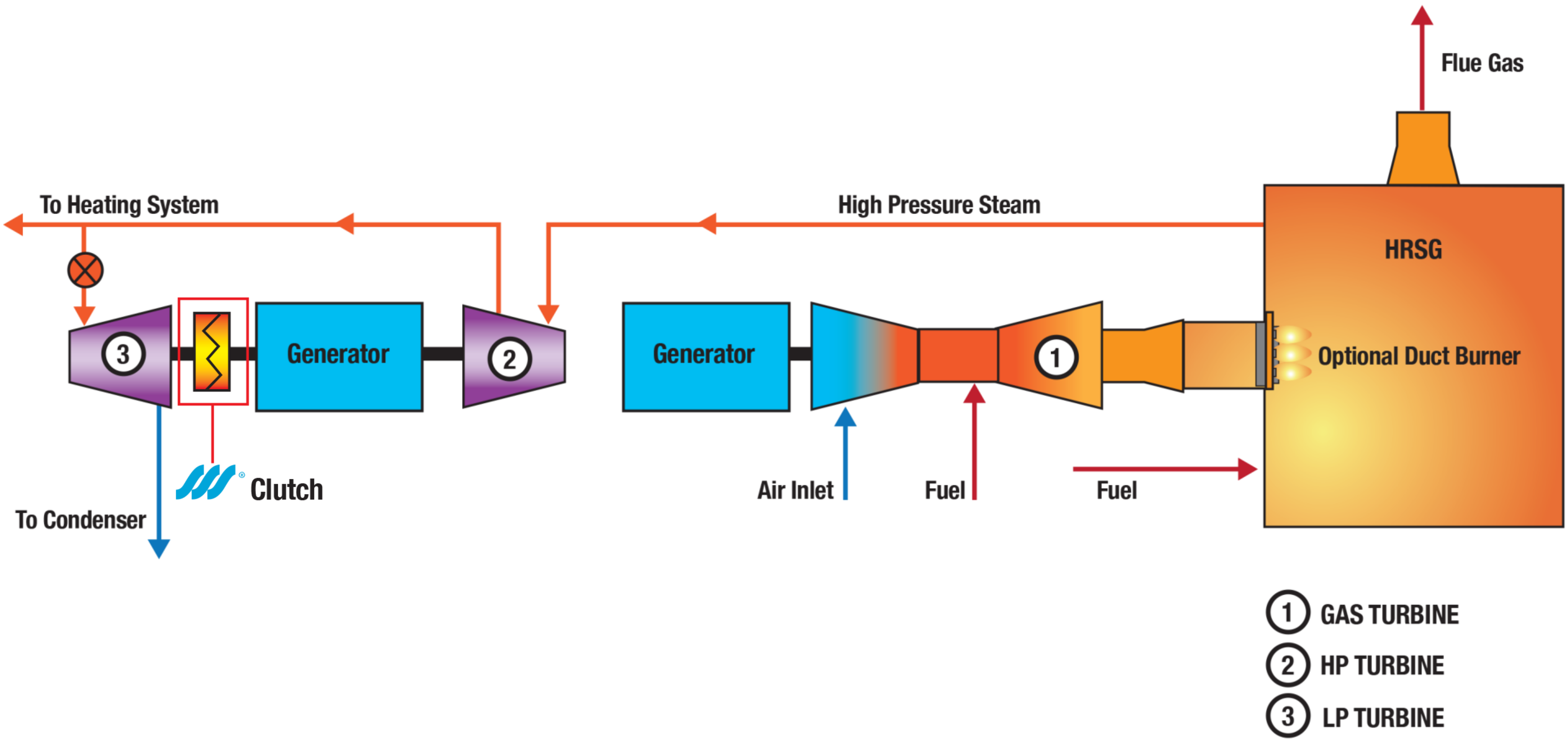


A. **High Steam Flow All for Heating:** Clutch 1 Engaged, Clutch 2 Disengaged
B. **High Steam Flow — Heating and Peaking Power:** Both Clutches Engaged
C. **Low Steam Flow All for Heating:** Both Clutches Disengaged
D. **Low Steam Flow — Some Heating & Some Peaking Power:** Clutch 1 Disengaged, Clutch two Engaged

Combined Cycle CHP District Heating Systems



Combined Cycle CHP District Heating Systems



Economics of Overrunning Clutch to Engage and Disengage Condensing Turbine

Factors to Consider

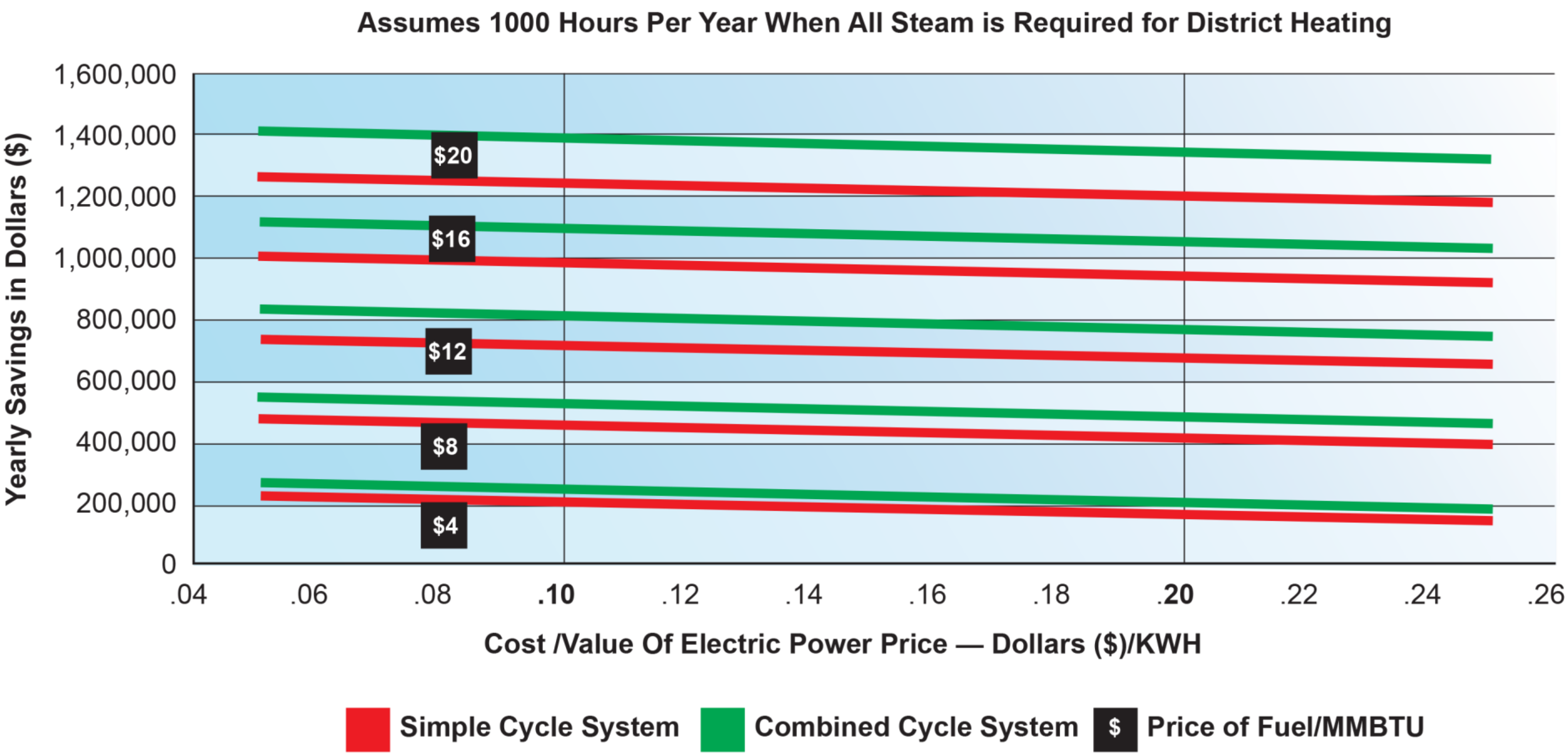
- **Cost of Fuel**
- **Cost of Electric Power**
- **Boiler Efficiency (or HRSG Efficiency if Operating with Duct Burner)**
- **Minimum Allowable Turbine Steam Flow**
- **Turbine Power Produced at Minimum Flow**
- **Auxiliary Loads to Support Turbine**

  Condenser Fans and/or Coolant Circulating Pump Power

  Condensate Pump and Boiler Feed Pump Power Associated with Condensing Turbine
- **Profiles of Heating and Electric Requirements**

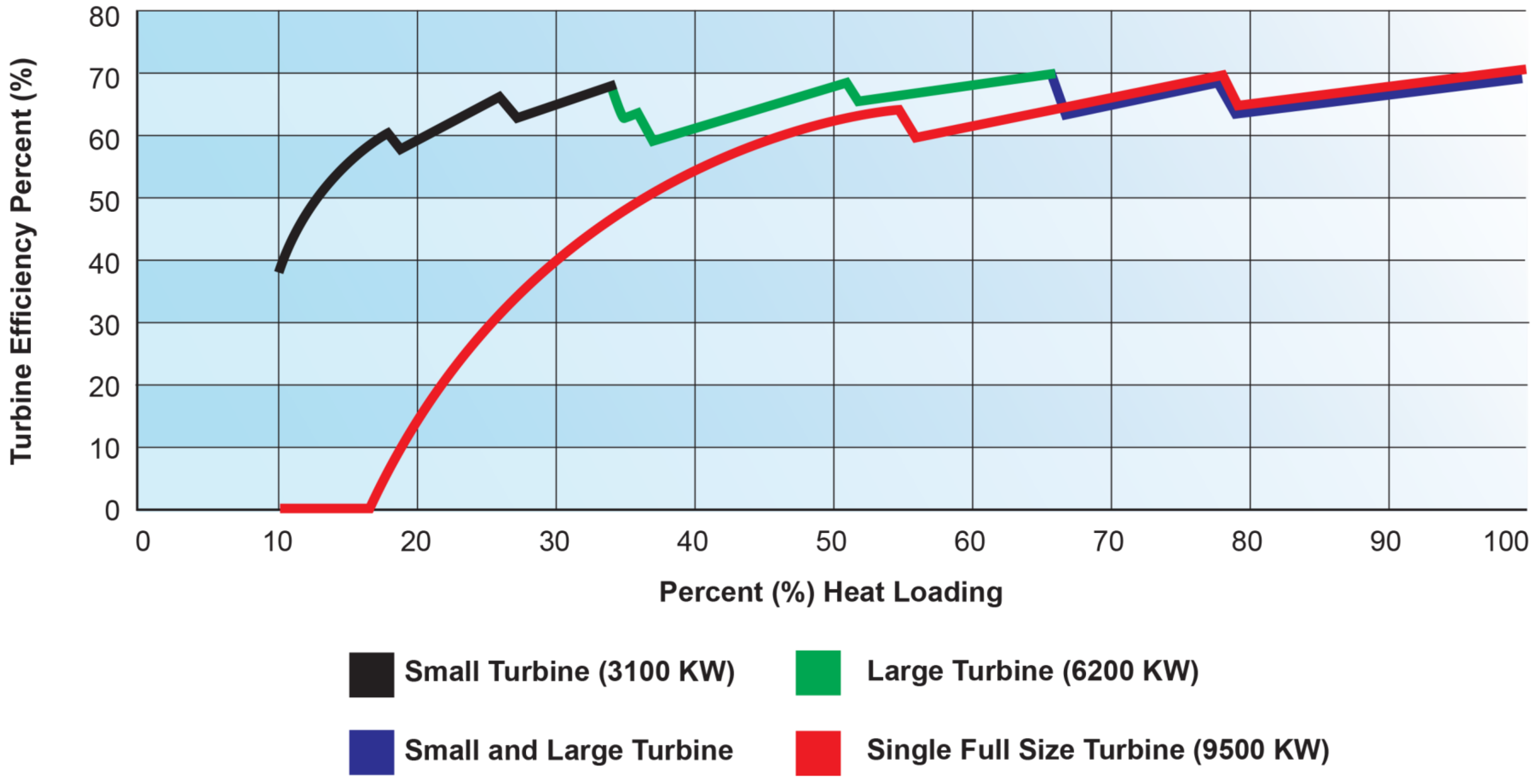
Savings from Disconnecting LP Turbine from HP–LP Steam Turbine Train When All Steam is Required for District Heating

Based on a 15 MW Rated Power for LP Turbine, 60 psia Inlet Pressure

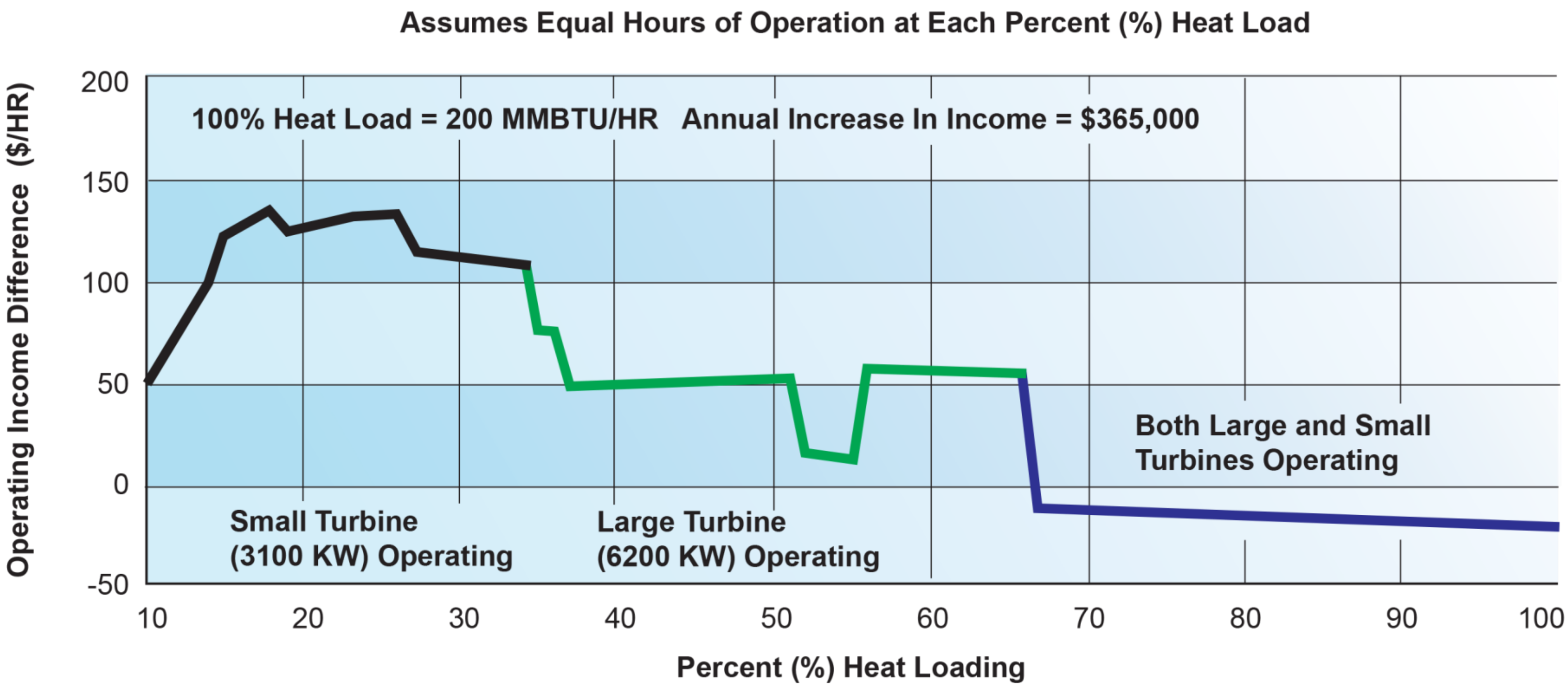


Turbine Efficiency:
Comparing One Large to Two Smaller Back Pressure Turbines

Based on a Design Heating System Load of 200 MMBTU/HR

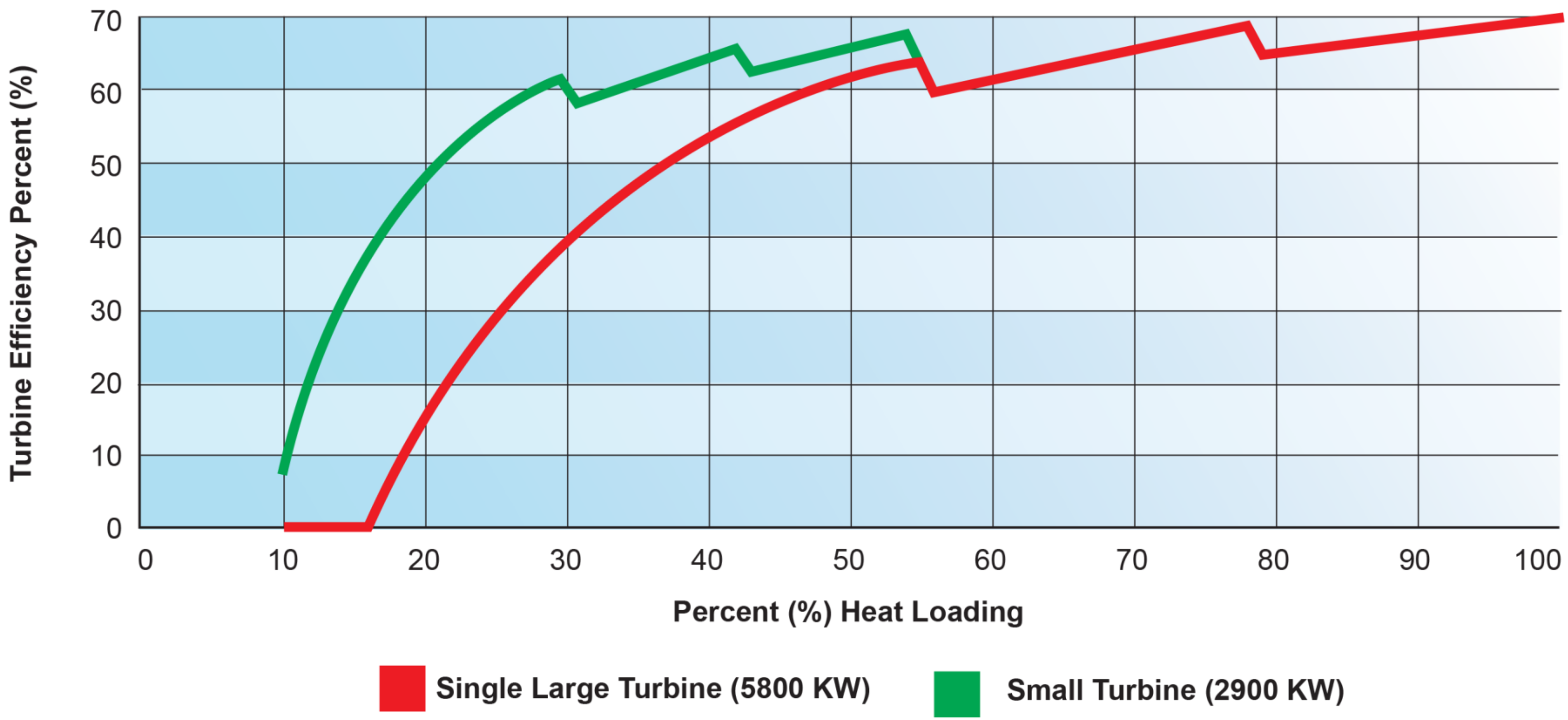


Improvement in Hourly Operating Income Versus Percent Heat Load: Comparing One Large Turbine to Two Smaller Turbines

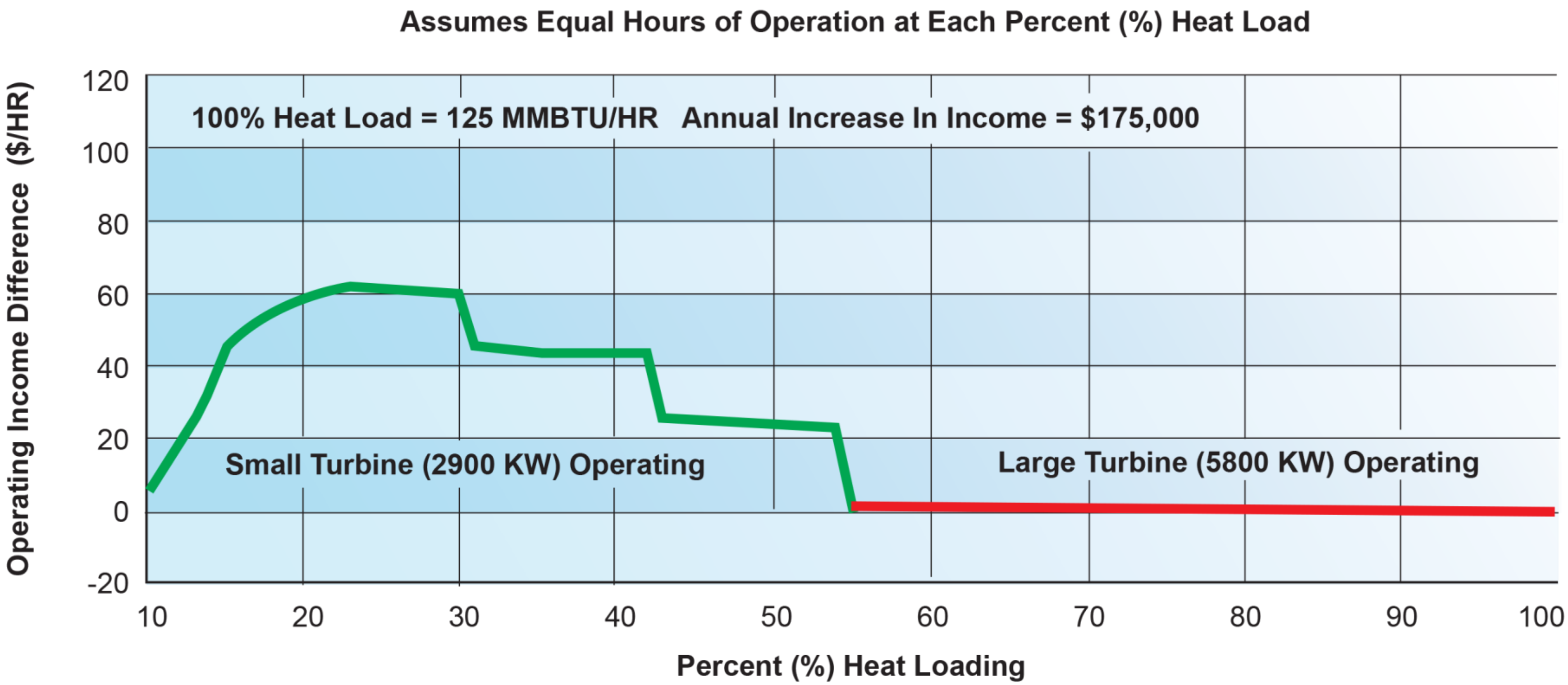


Turbine Efficiency:
Comparing Large Turbine Only to Large and Small Back Pressure Turbines

Based on a Design Heating System Load of 125 MMBTU/HR

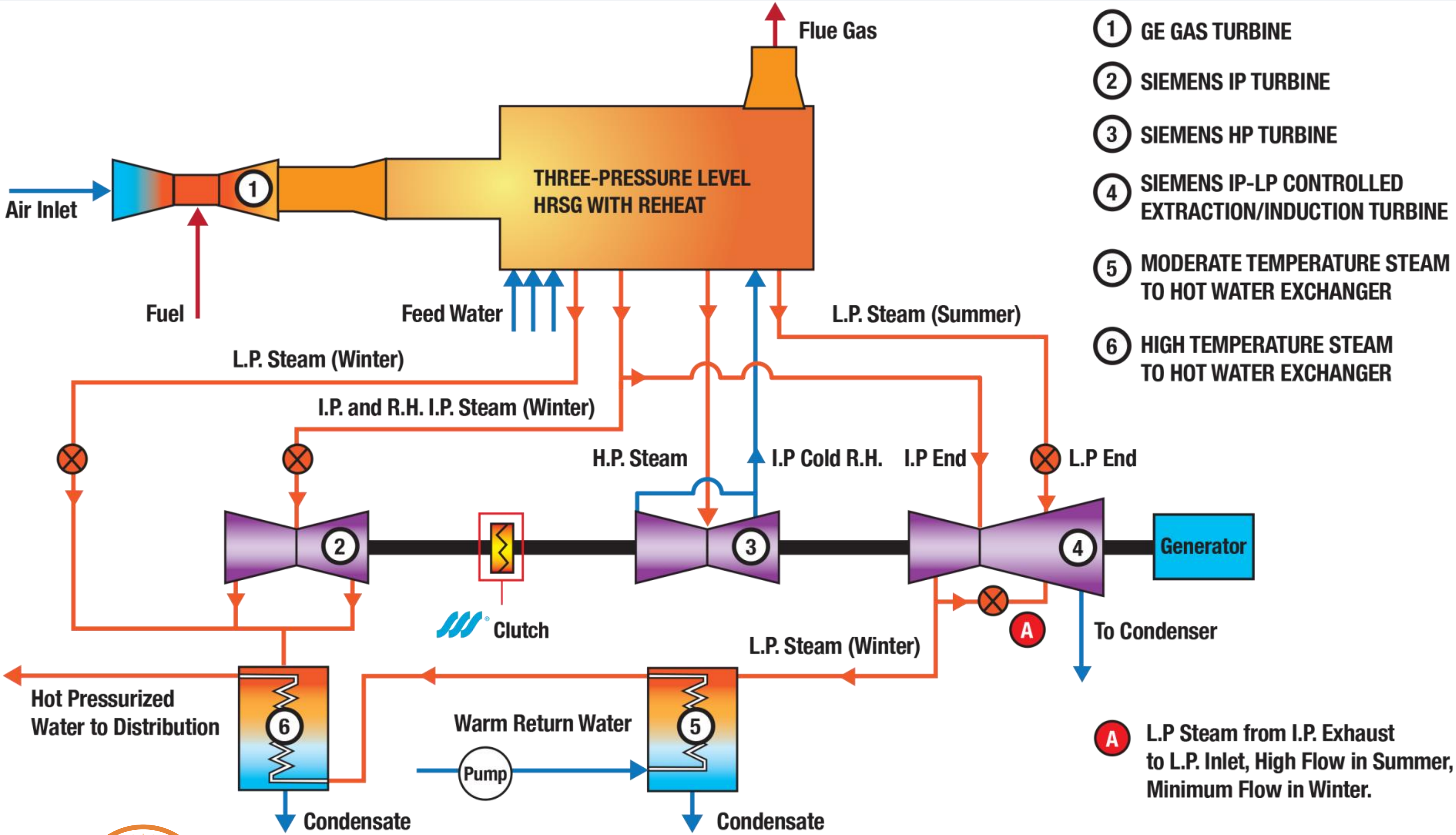


Improvement in Hourly Operating Income Versus Percent Heat Load: Comparing a Smaller Turbine at Reduced Heat Load Conditions



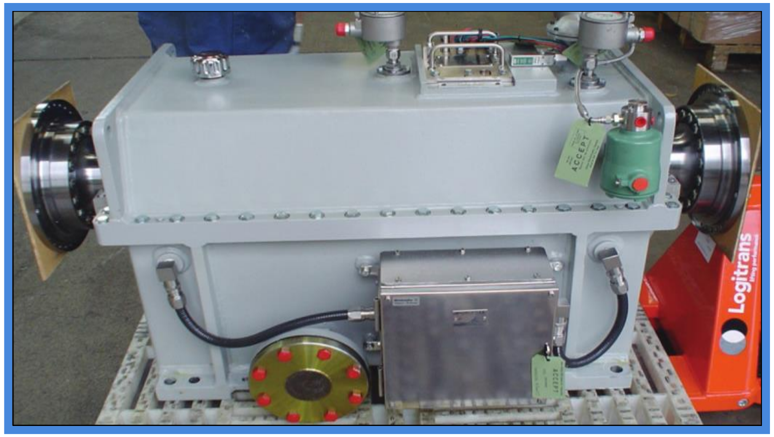
TPP2 CHP Plant — Riga, Latvia

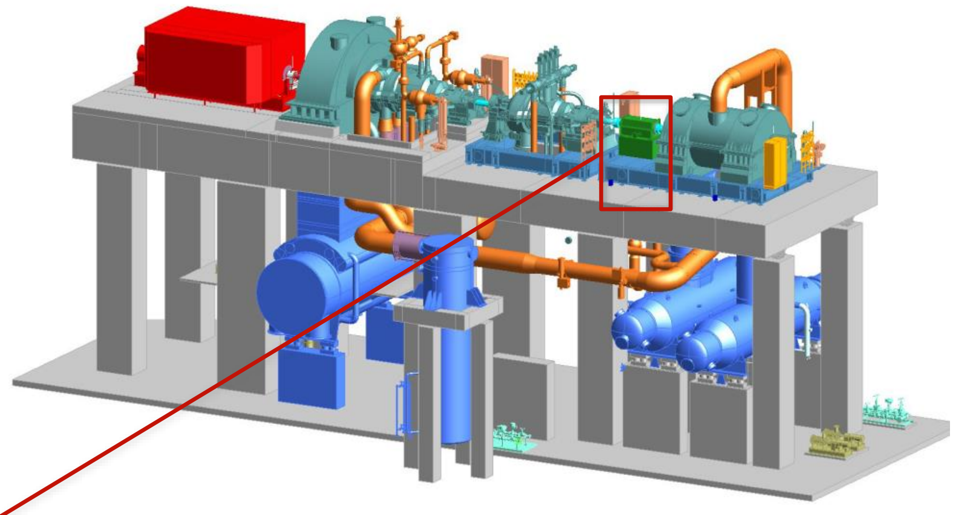
Riga TPP2 CHP System

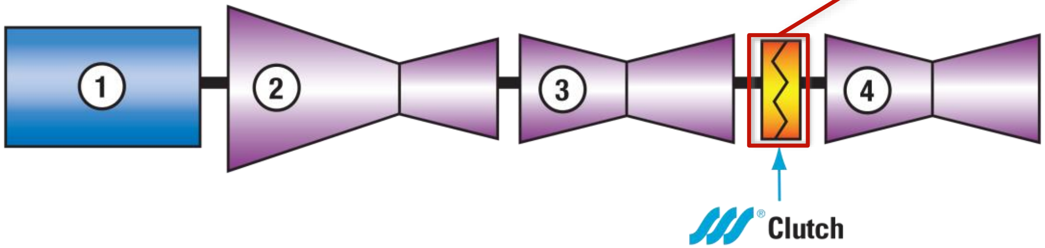


TPP2 CHP Plant — Riga, Latvia

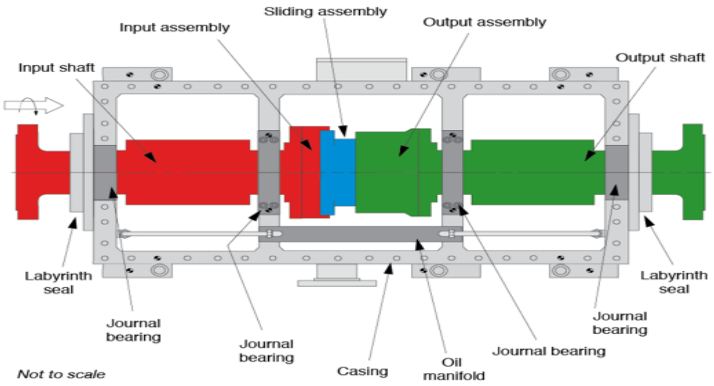
SIEMENS Steam Turbines Using an Encased Clutch







1. 3000 RPM SIEMENS Generator
2. SIEMENS SST-800 IP – LP Condensing Steam Turbine
3. SIEMENS SST-800 HP Turbine
4. SIEMENS SST-500 LP Heating Steam Turbine



Riga Case Study

Plant supplies the majority of the heat for the city of Riga and a substantial amount of the total power for the country of Latvia:

- **Original plant built in the 1970's, Plant Modernization completed in 2013**
- **Plant now includes two 400 MW combined cycle CHP systems**
- **Case study is about the 2nd of the two 400 MW systems known as Riga TPP-2**

System Output:

- **Summer 410 MWe**
- **Winter 390+ MWe plus 920 million BTU/HR**

Plant consists of:

- **GE Frame 9 Gas Turbine Generator**
- **Three Pressure Level HRSG with IP Reheat**
- **Steam Turbine Train with SSS® Overrunning Clutch:**
  - Siemens double flow IP turbine
  - SSS® Clutch to engage/disengage IP turbine
  - Siemens center admission HP turbine
  - Siemens IP-LP Extraction/Induction/Condensing turbine

Riga Case Study

Steam Conditions:

- **HP:** up to 125 bara/545 ° C (1800psia/1000 ° F)
- **IP and IP reheat:** up to 37 bara/545 ° C (537psia/1000 ° F)
- **LP:** up to 3.5 bara/275 ° C (51psia/525 ° F)
- **Condensing pressure:** as low as .02bara (0.3psia)

Rationale for the Clutch:

- **The system maintains almost the same power in the winter heating mode as in the summer full condensing mode**
- **Almost all of the low temperature heat lost in the condenser in the summer is recovered as high temperature condensing heat in the winter**

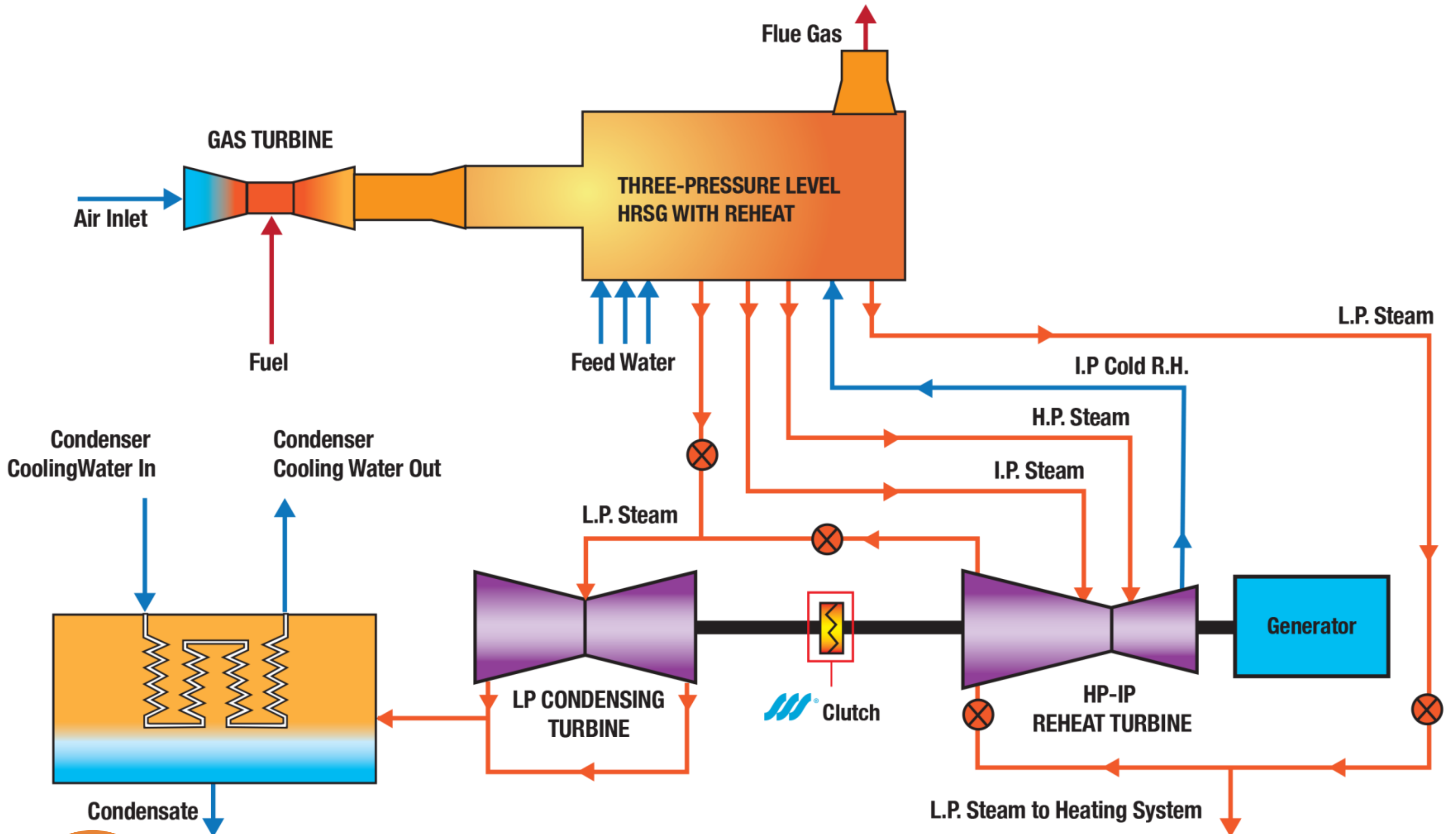
Rationale for the Clutch — This requires:

- **Different steam temperatures, pressures, and flows for the 3 levels of steam in the winter compared to summer**
- **Optimization of the double flow IP turbine for the winter steam conditions**
- **Optimization of the IP-LP Extraction/Induction/Condensing turbine for summer steam conditions**
- **A clutch allows the IP turbine to be shutdown in summer and engaged to the train in winter**

Seoul Combined Cycle Thermal Power Plants No. 1 and 2
Worlds First Underground Utility Size Thermoelectric Plant

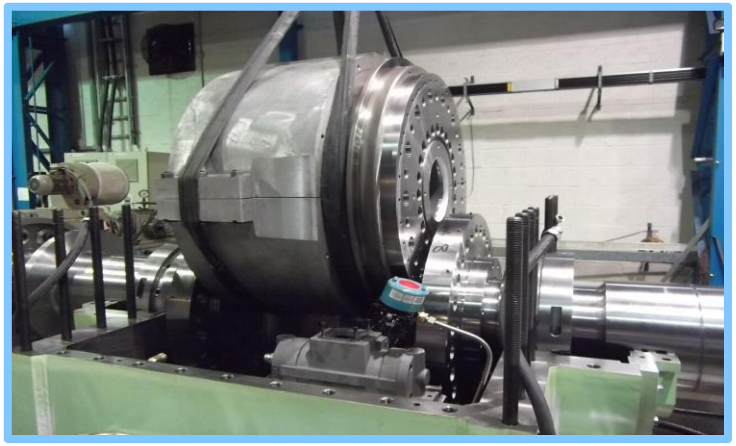
Seoul Combined Cycle Thermal Power Plants

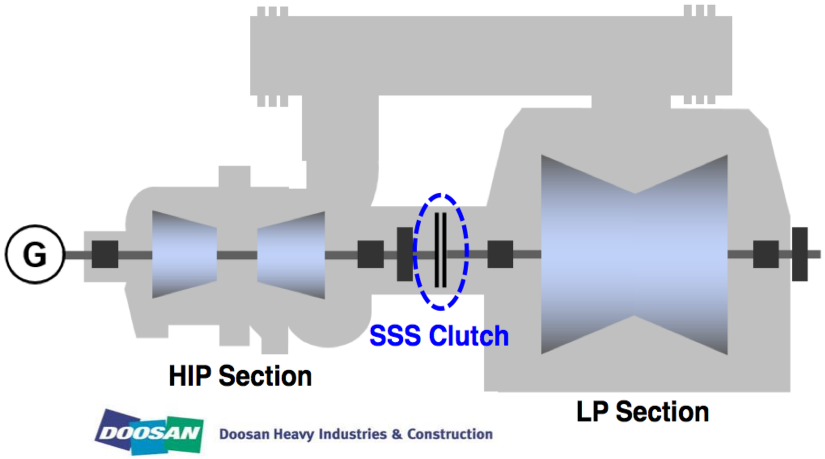
System Diagram (1 of 2 Units) — Korea Midland Power Co.Ltd.



Korea Midland Power Co. Ltd Case Study

- Seoul Combined Cycle Thermal Power Plants No. 1 and 2 Worlds First Underground Utility Size Thermoelectric Plant
- Located Mapo District, Western Part of Seoul, Korea
- Start-UP 2017
- 800 MW of Electric Power Generation: 10% of Seoul's Power Consumption
- 2,100 MMBTU/HR (616 MJ/s) Thermal Output to Heat Office Buildings, Public Facilities and 100,000 residences
- Fuel Primary: Gasified Imported LNG Fuel, Secondary: Coal
- Fuel Cost: approximately $10/MMBTU
- Value of Power Generated: Can Vary Between $150–$450/MW-HR





Technical Details and Rationale for Clutch

The Reason for the SSS® Clutch

- **The LP turbine has a minimum steam flow of approximately 500,000 LB/HR**

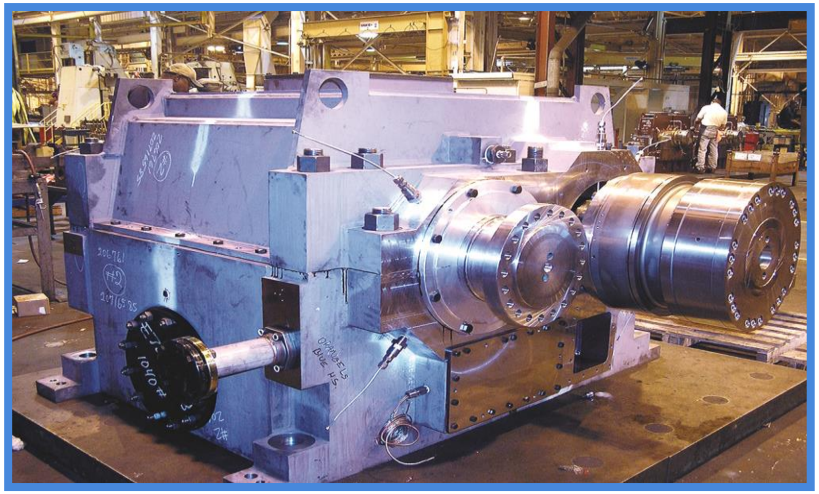
During maximum heating load times this steam is worth considerably more than the value of the electric power generated with this steam in the LP-condensing turbine.

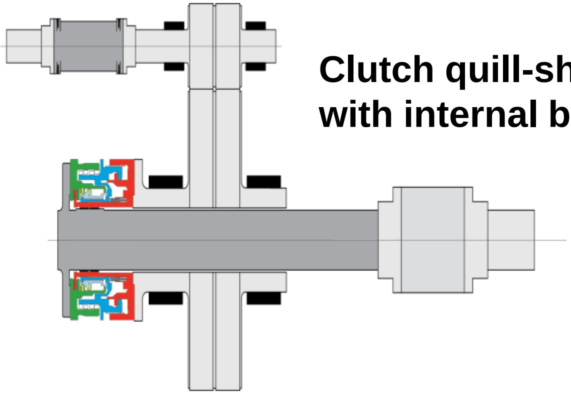
On an annual basis the clutch provides an increased income of approximately $5,000,000

An alternative to the clutch would be a separate LP turbine and generator with switchgear at an added equipment and construction cost of more than twenty times the cost of the clutch.

Clutch Arrangements
Clutch Integrated with Gear or Clutch in Separate Casing

Mounted in Gearbox

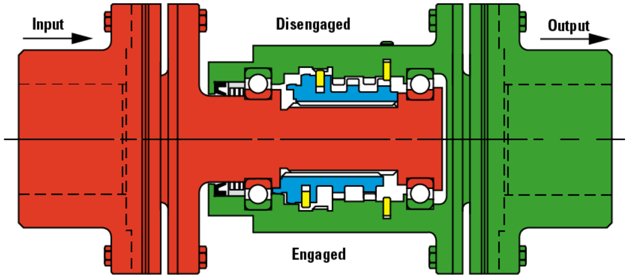




Clutch quill-shaft mounted with internal bearing

Encased Foot Mounted Clutch

Shaft Supported Clutch Coupling



Thank You,

Questions

Thank you to Elliott Group and
Siemens for the steam turbine data used in this presentation

Clutch Company, Inc.