Combined Cycle Power Plant Design & Modeling

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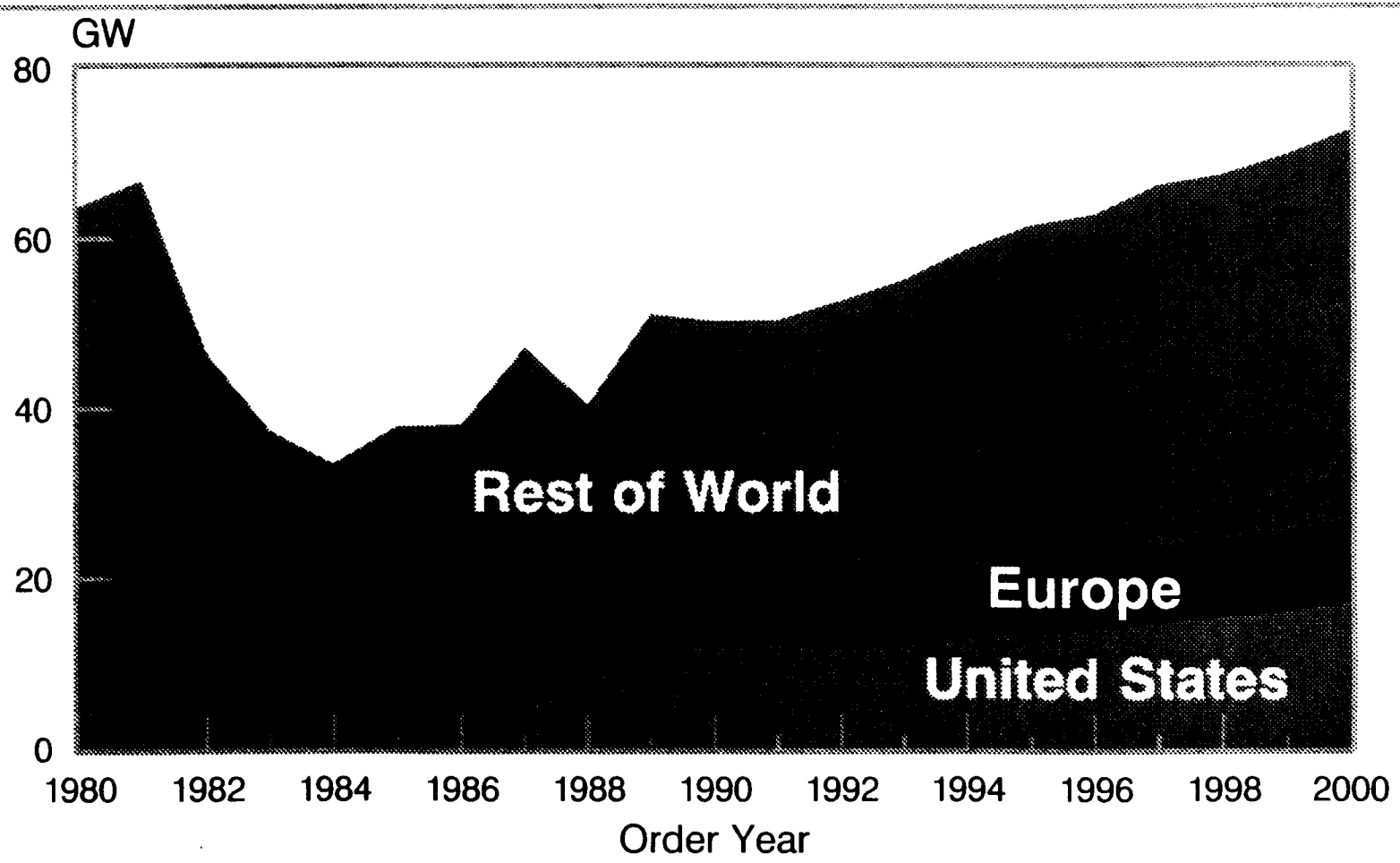
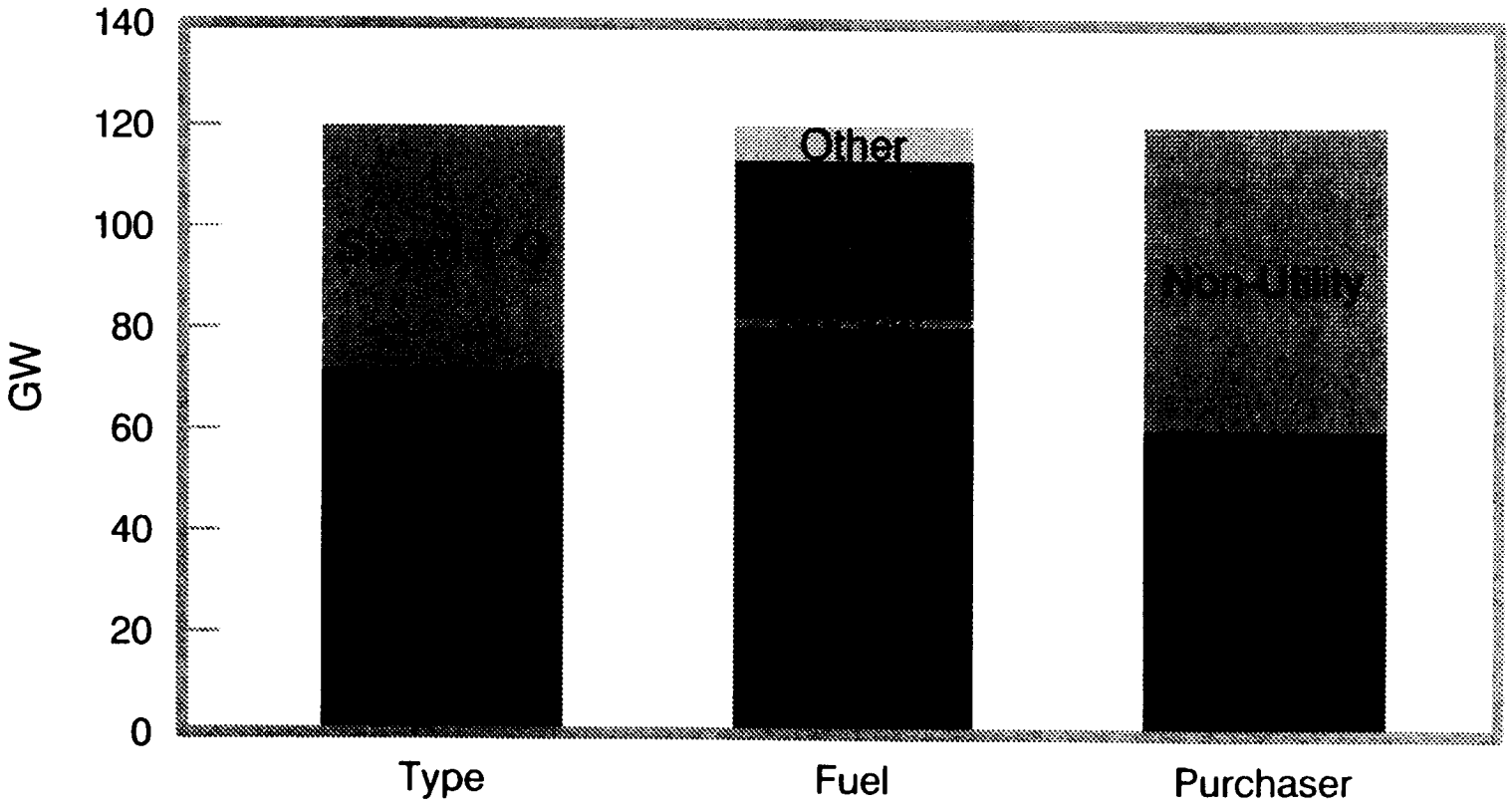
Westinghouse Electric Corporation

World ST-G/CT-G Volume by Order Year 1980-2000



U.S. New Power Plants

1990 - 2000 Orders

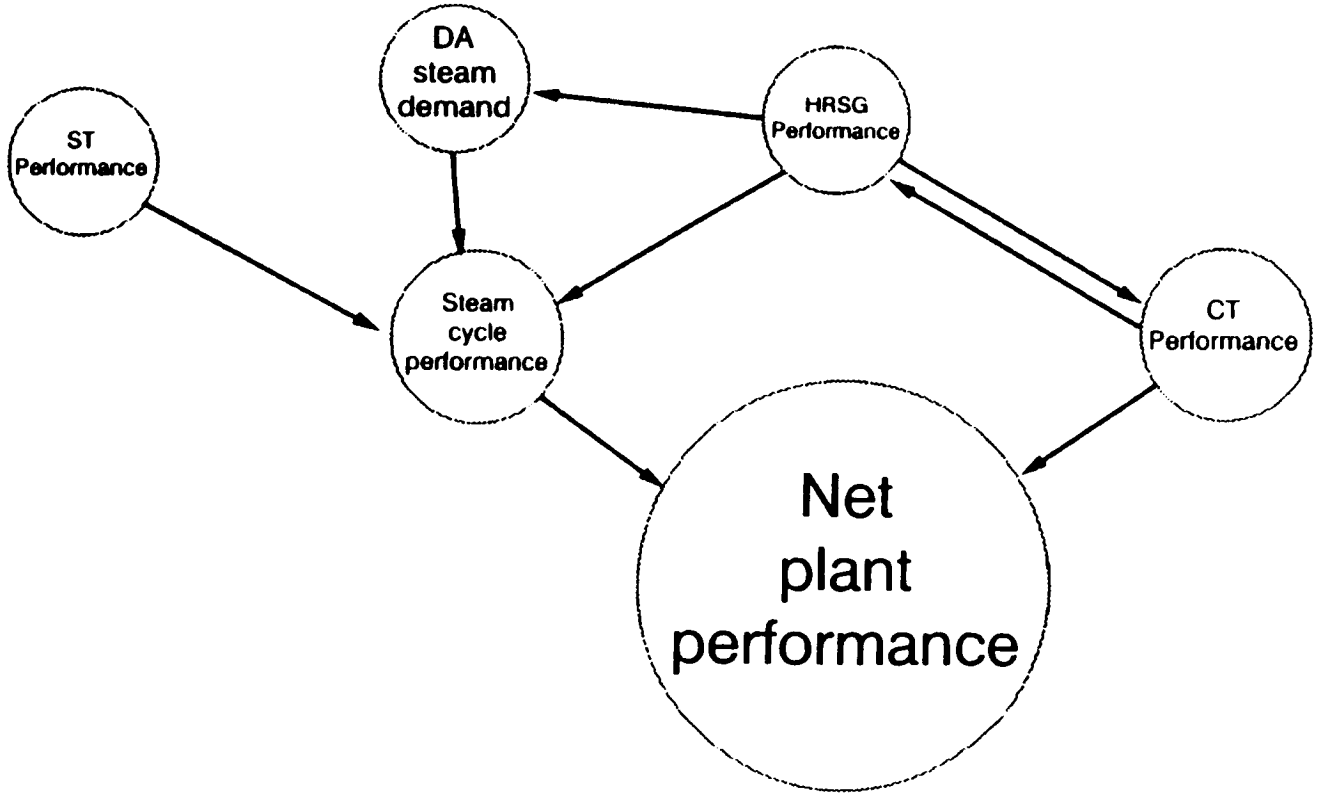


"Other" Fuel includes refuse and renewable sources.

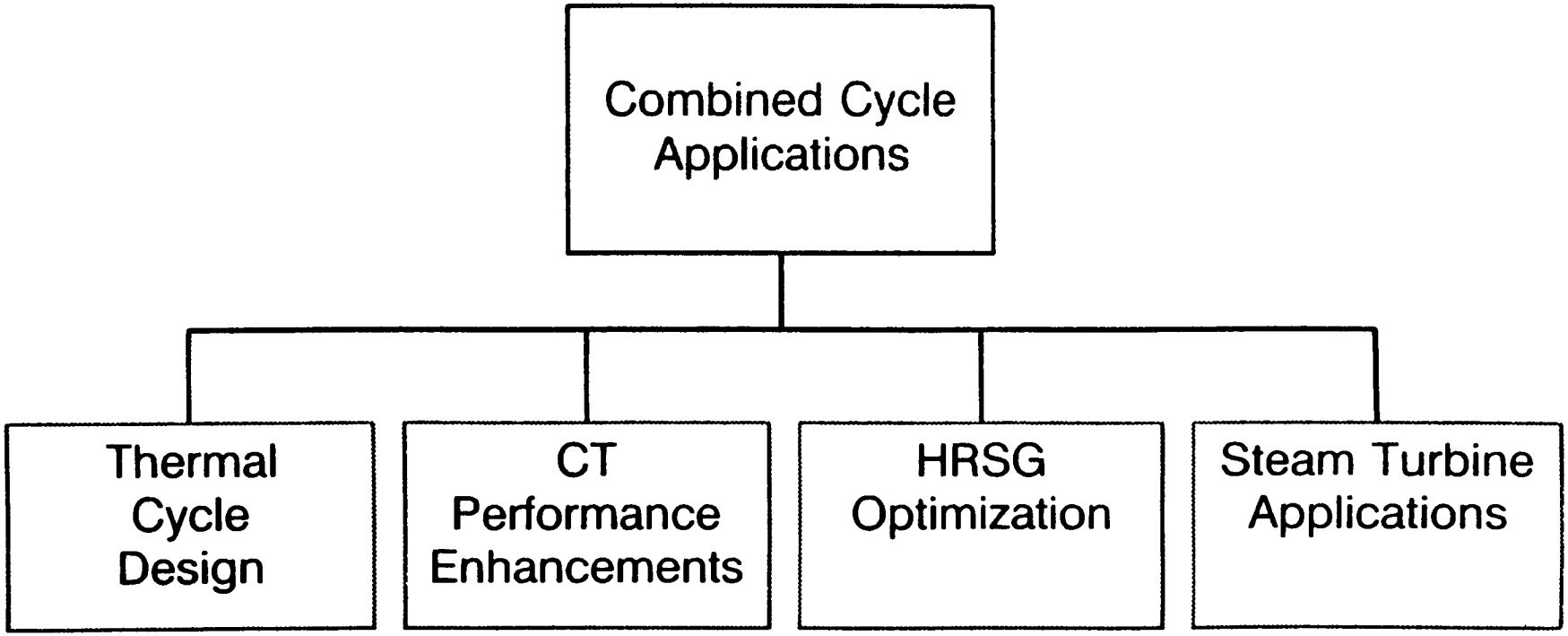
Combined Cycle Applications

Combined Cycle Applications

Performance Relations Diagram



Combined Cycle Applications



Combined Cycle Applications

Performance Enhancements

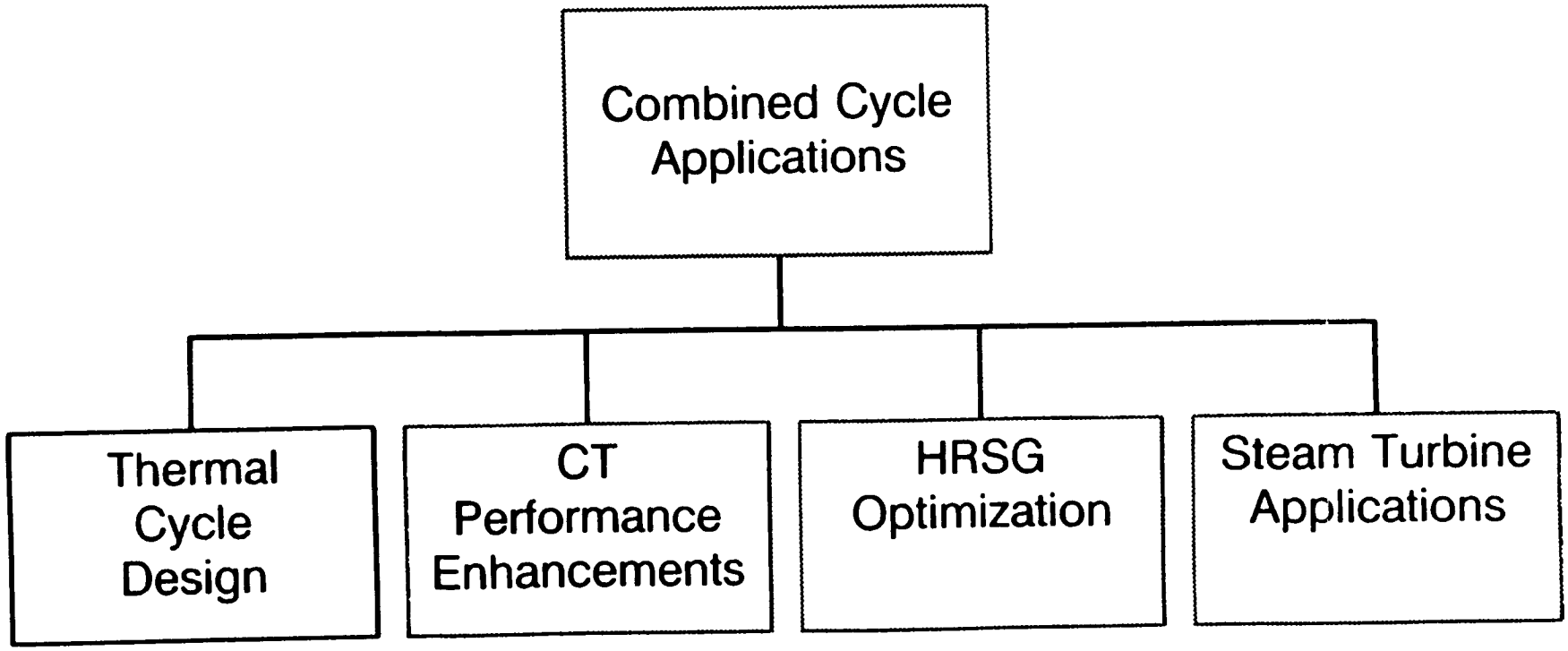
For more power:

- Steam injection
- Evaporative cooling
- Rotor air heat recovery
- ST configuration
- Duct firing

For better heat rate:

- Fuel heating
- Rotor air heat recovery
- ST configuration

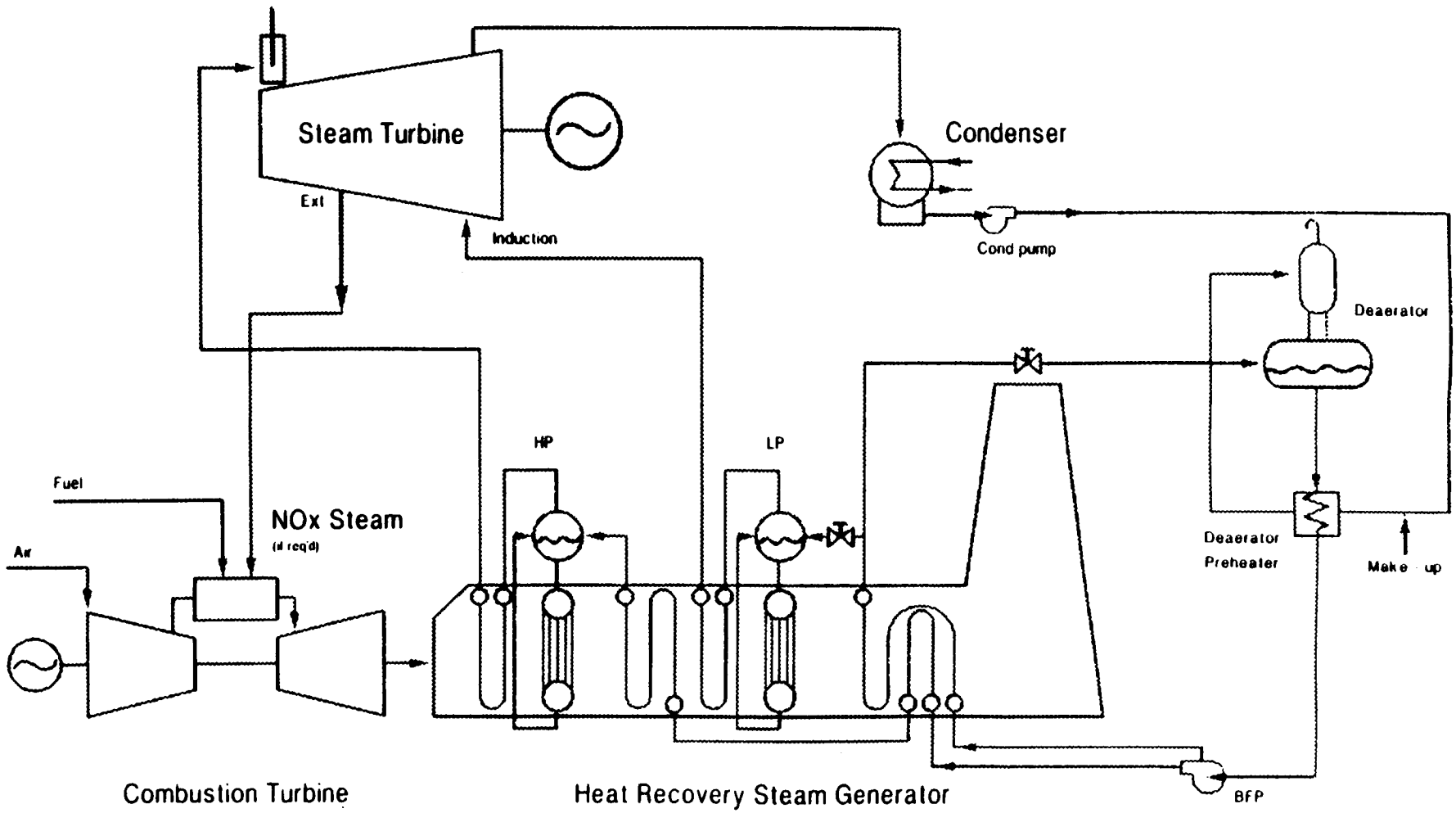
Combined Cycle Applications



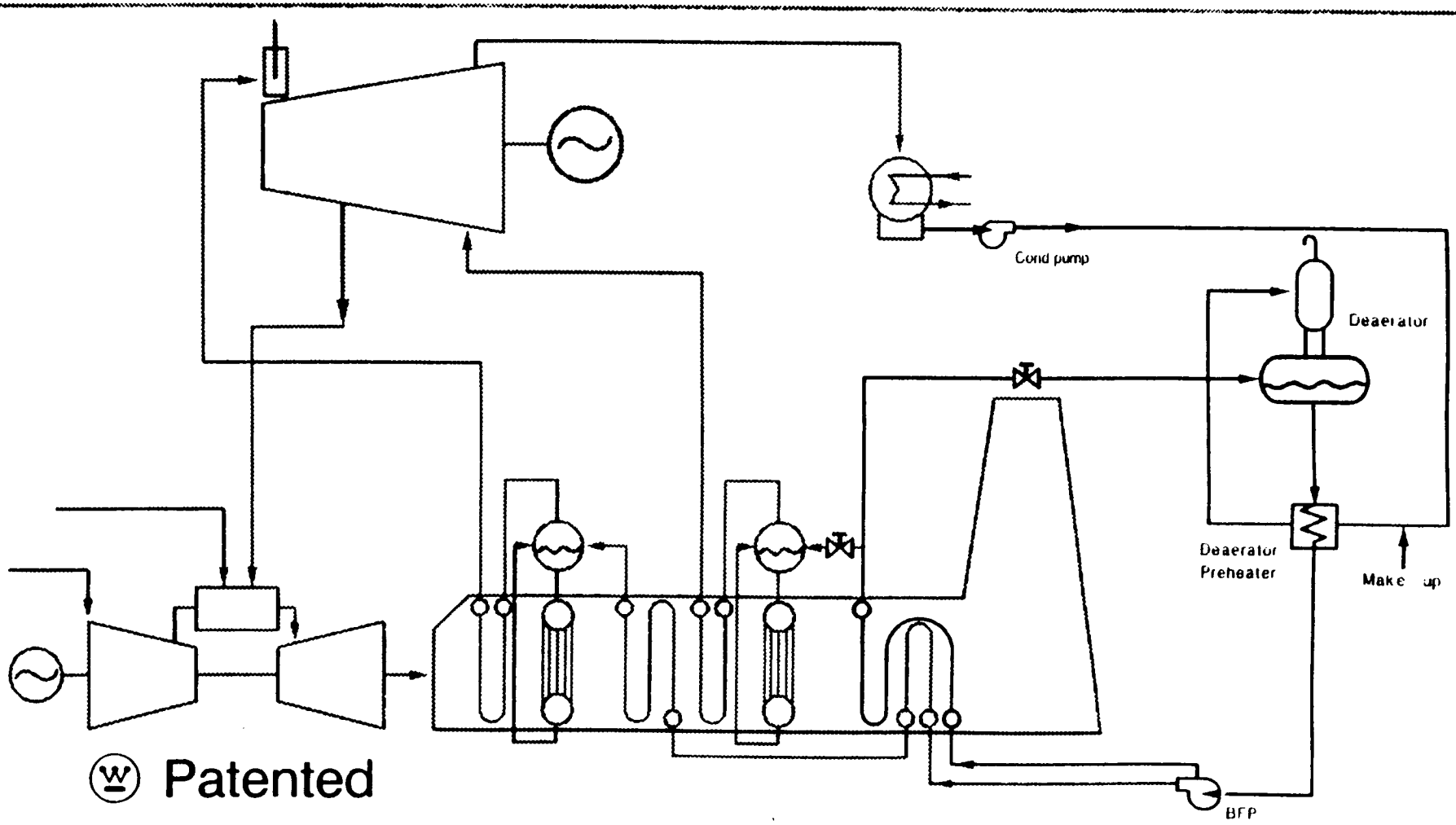
Thermal Cycle Design

- Optimized cycle
- Feed water heating process
- Cycle pressures
- Part load performance

Thermal Cycle Design
Optimized Cycle

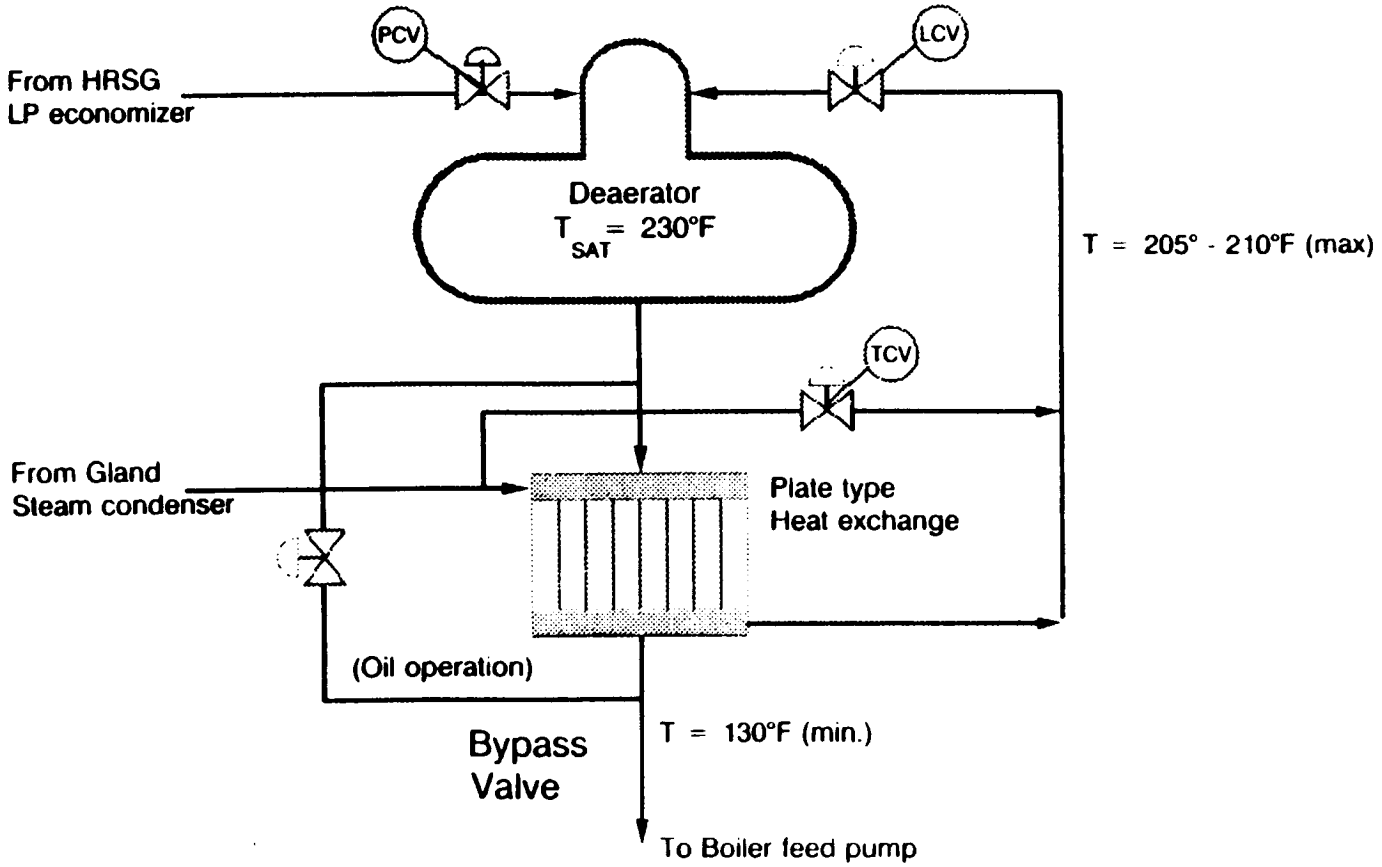


Thermal Cycle Design
Feed Water Heating Process



Ⓦ Patented

Thermal Cycle Design
Feed Water Heating Process



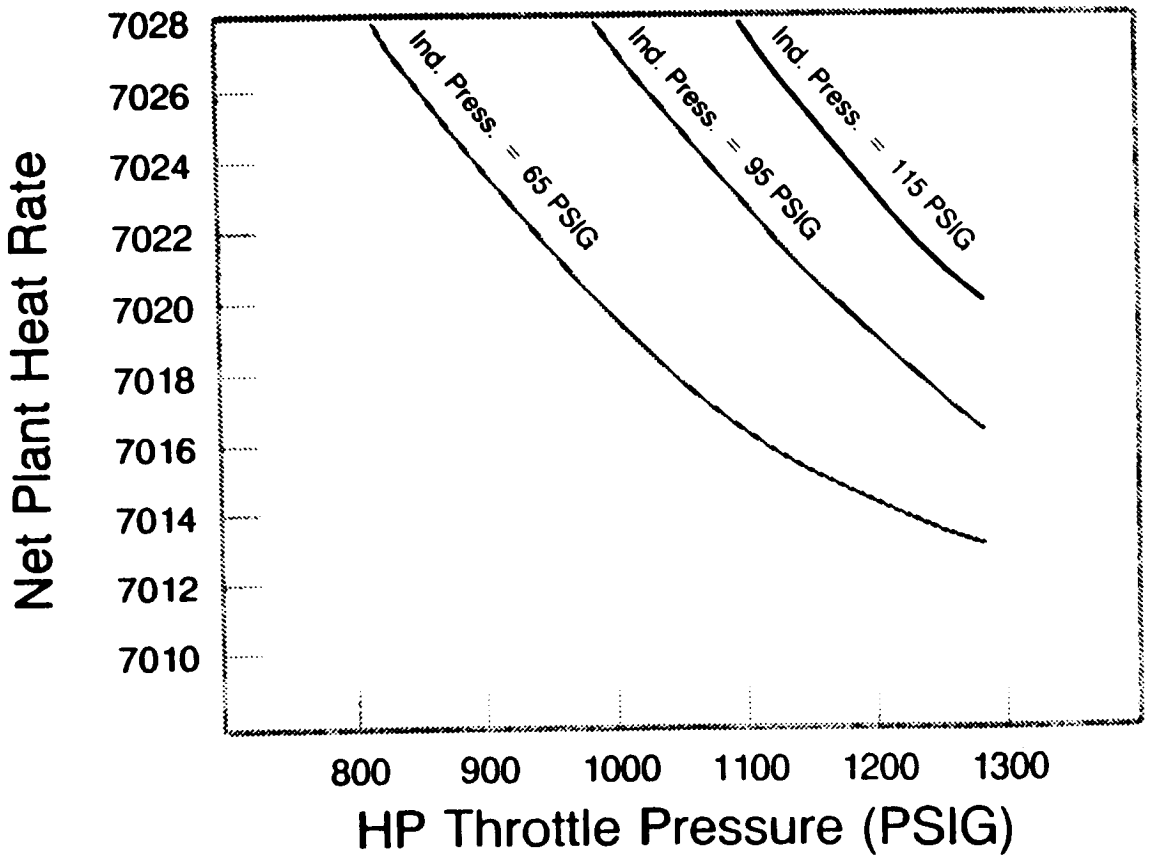
Thermal Cycle Design
Feed Water Heating Process

Feed water heating benefits include:

- Maximizes recovery of HRSG stack energy
- Minimizes use of exotic metallurgy (SS)
- Improves HRSG stability on start-up
- Minimizes potential for erosion/corrosion of HRSG
- Simplifies plant construction
- Reduces number of pumps
- Maintains cost effectiveness

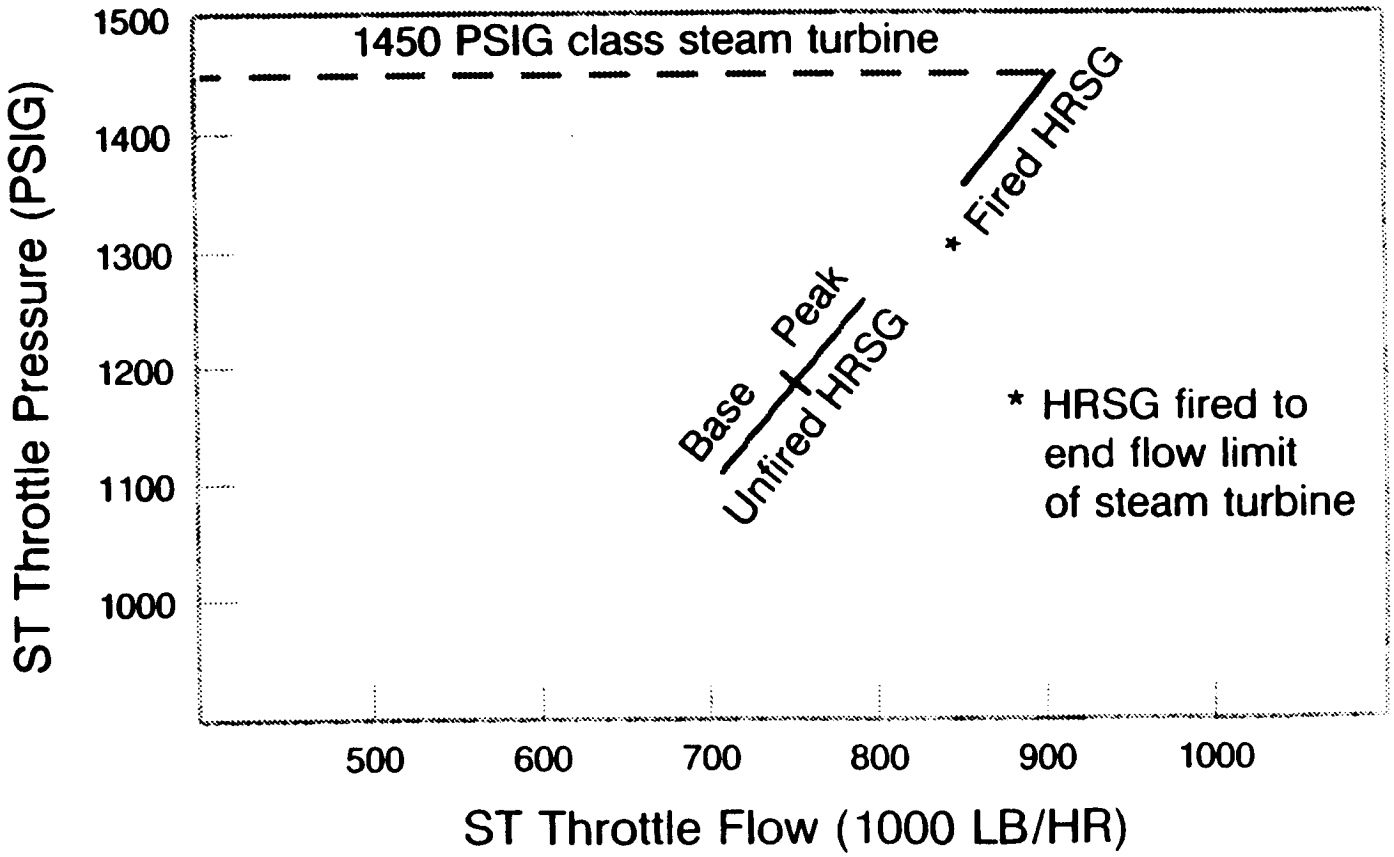
Thermal Cycle Design Cycle Pressures

300 MW CC



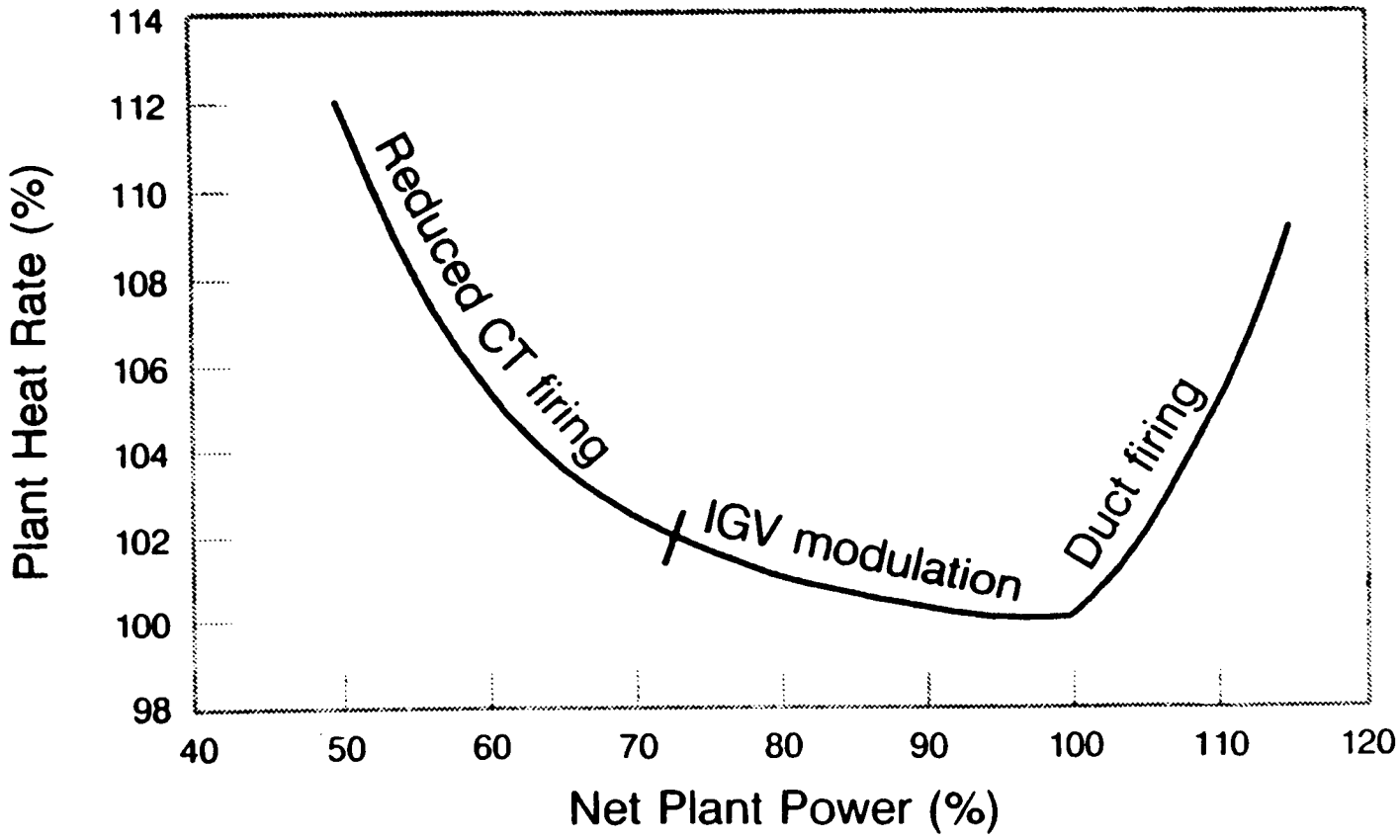
Thermal Cycle Design
Cycle Pressure

Selection of Throttle Pressure - 300 MW CC

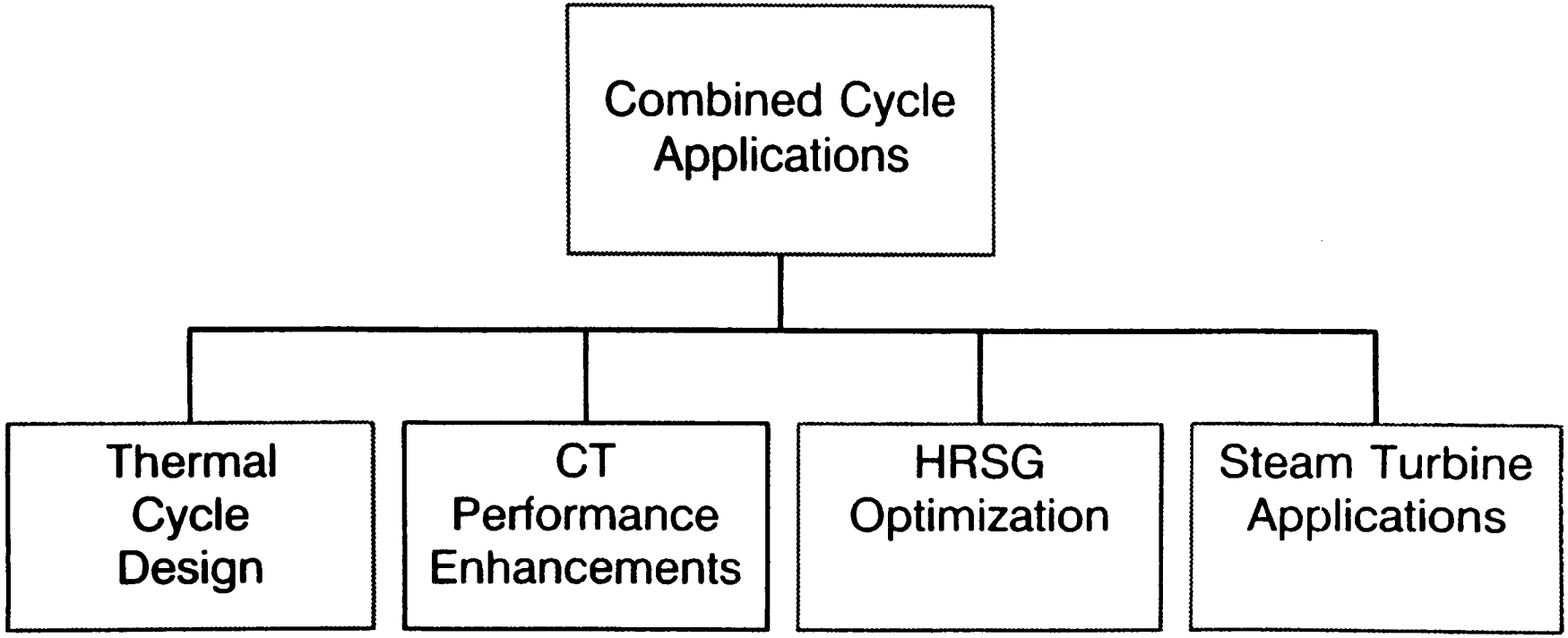


Thermal Cycle Design
Part Load Performance

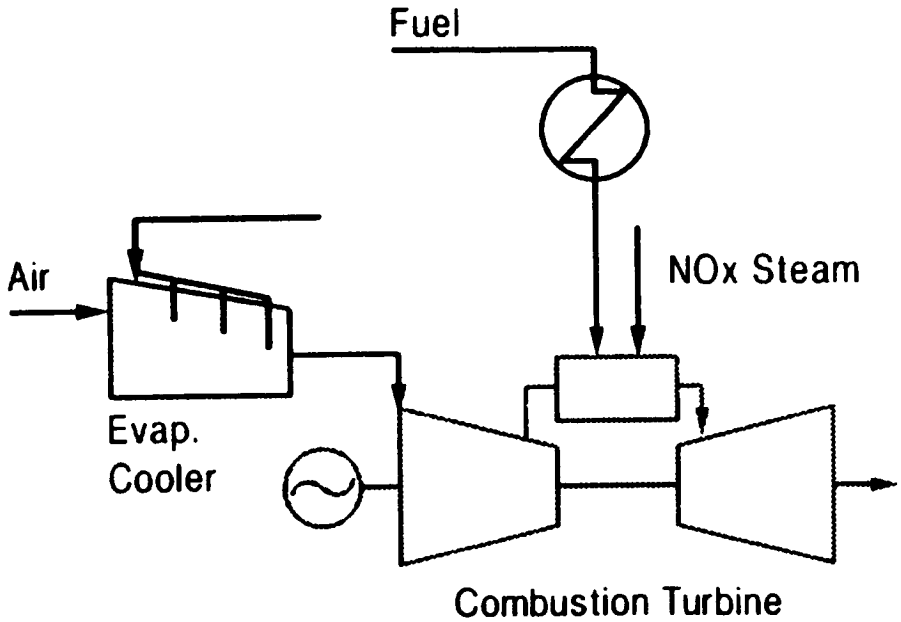
Two on One Combined Cycle



Combined Cycle Applications



CT Performance Enhancements



- Fuel heating process
- Evaporative cooling
- Rotor air cooling heat recovery
- Power augmentation by steam injection

CT Performance Enhancements
Evaporating Cooling

True or False ?

Evaporative cooling is economically justified only when plant sites are in hot, arid locations.

CT Performance Enhancements
Evaporating Cooling

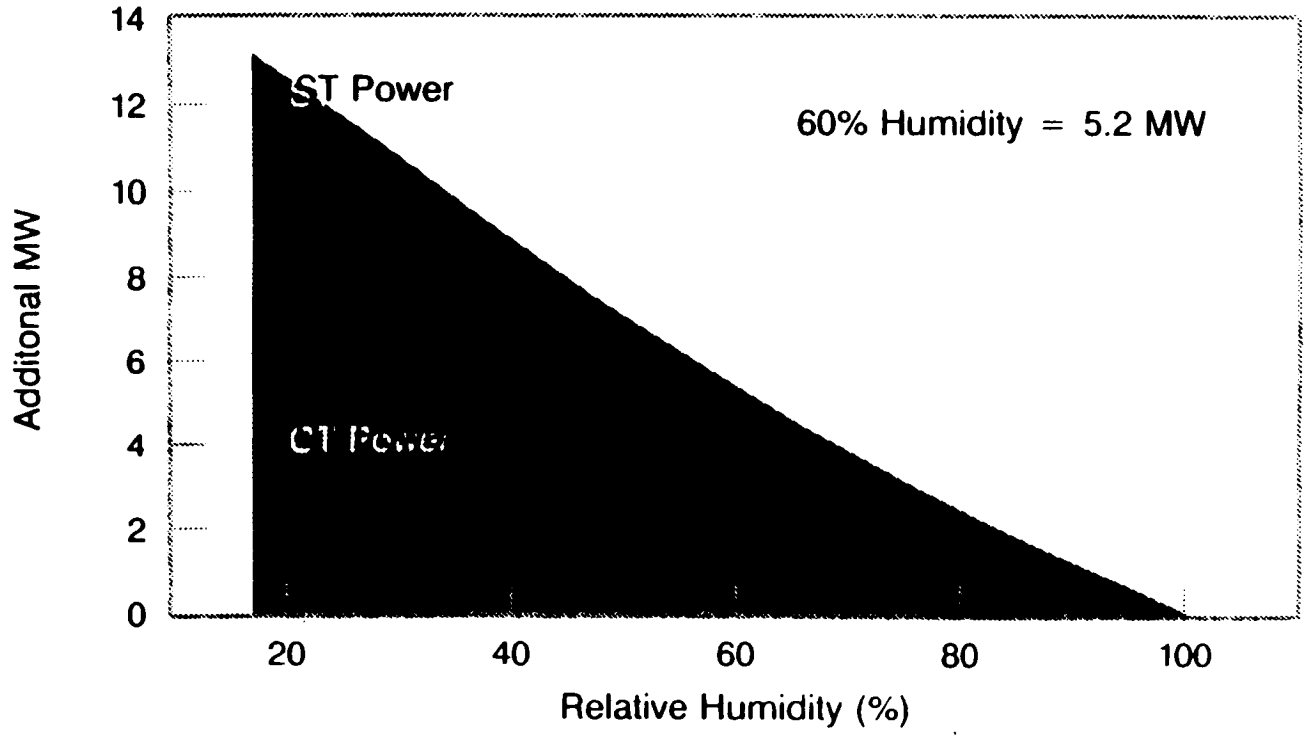
A: False

Evaporative cooling can be economically justified over a broad range of ambients.

CT Performance Enhancements Evaporative Cooling

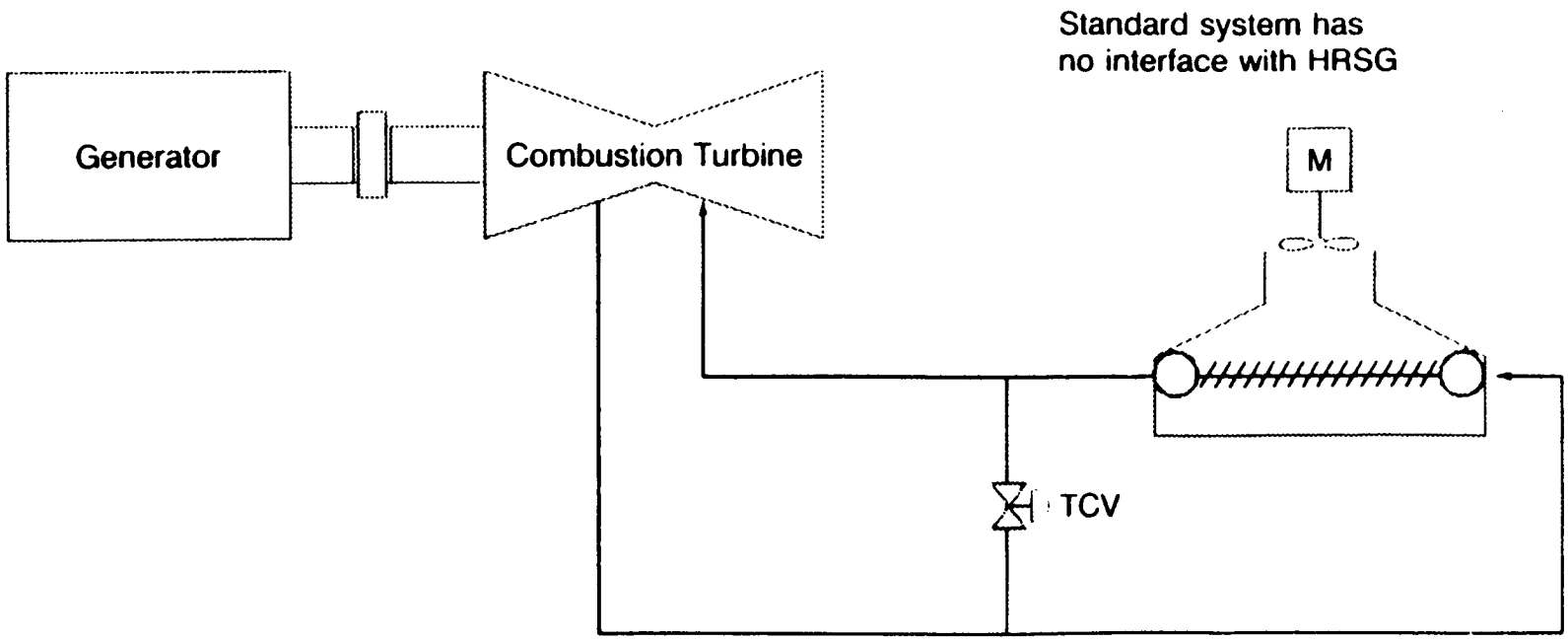
Additional power generation - 300 MW CC plant

T_{amb} = 59 °F



CT Performance Enhancements
Rotor Air Cooling Heat Recovery

Standard Air to Air Cooler Design



CT Performance Enhancements
Rotor Air Cooling Heat Recovery

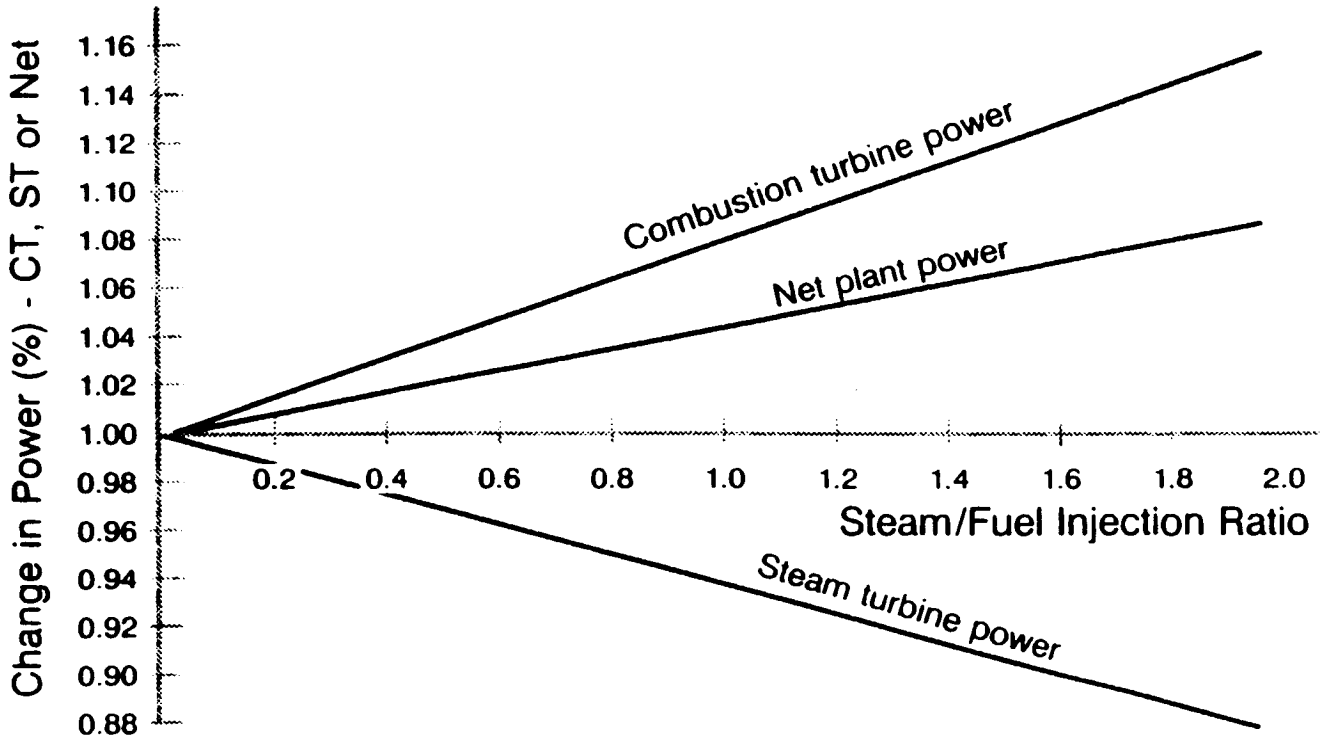
501D Application

- Produces 8,000 - 11,000 lb/hr saturated steam
- Feeds directly into LP HRSG for steam conditioning and subsequent superheating
- Improves net plant heat rate by 10-15 Btu/kw-hr

CT Performance Enhancements
Power Augmentation

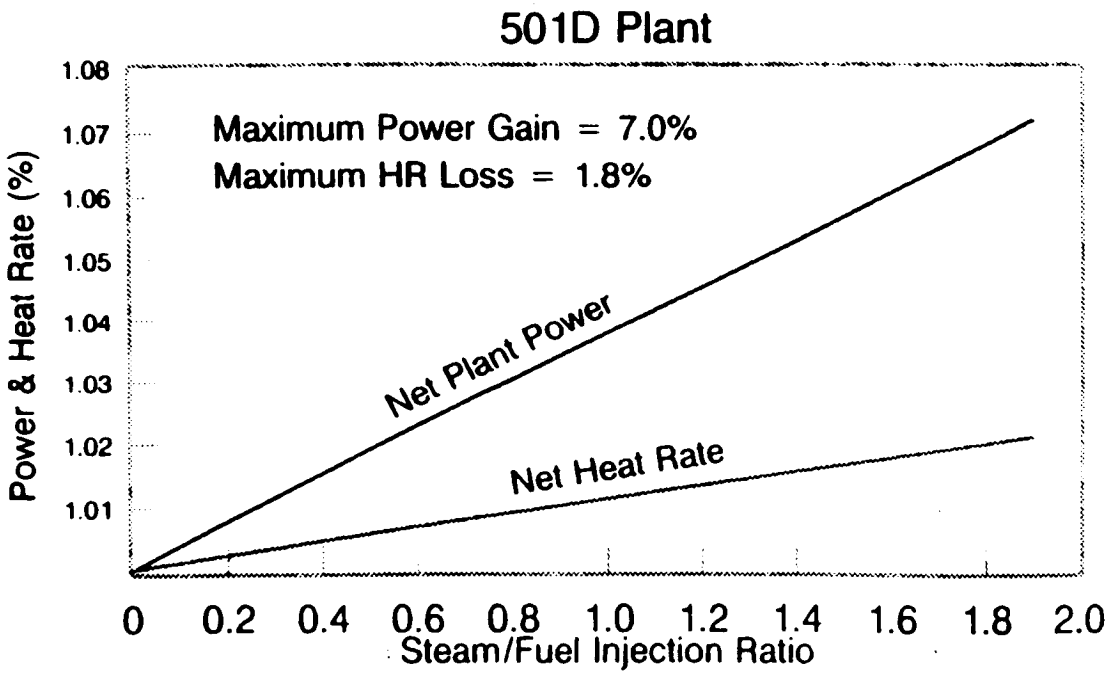
Power versus steam injection

501D plant

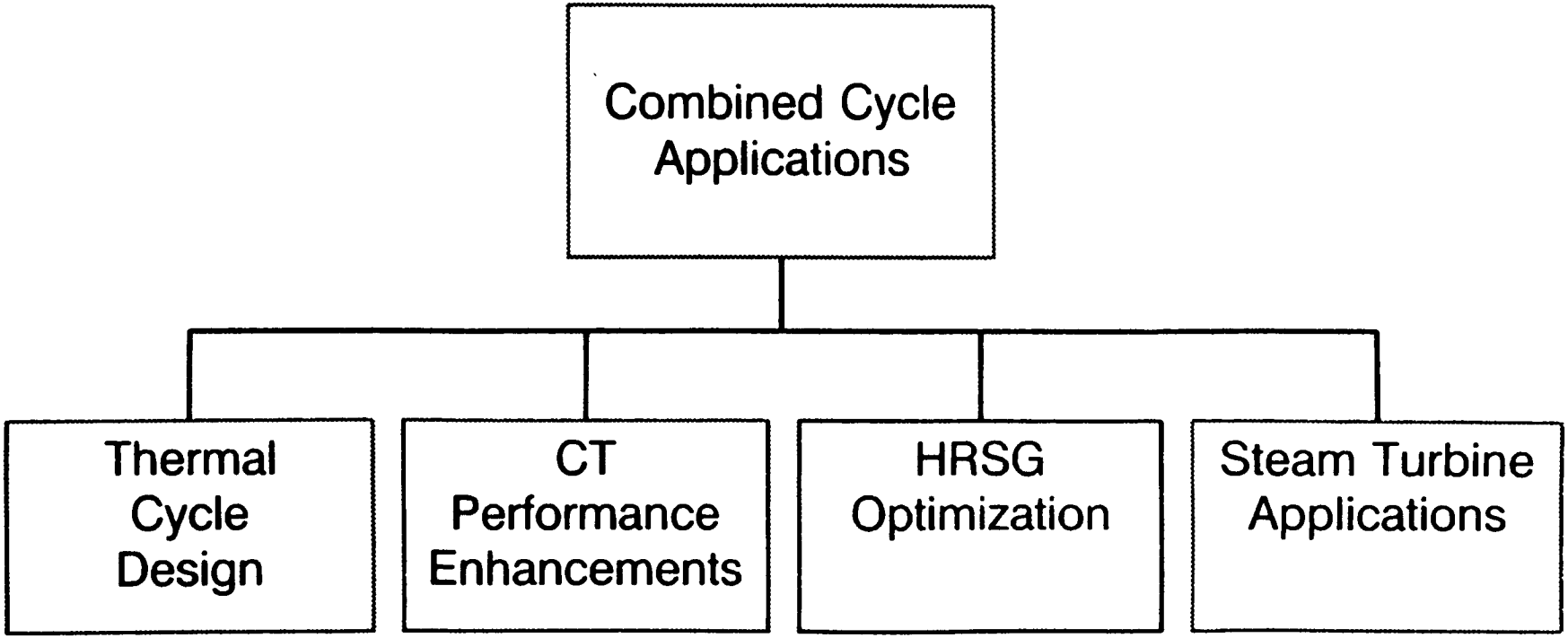


CT Performance Enhancements
Power Augmentation

Net plant power and heat rate
Versus
Steam injection rate



Combined Cycle Applications

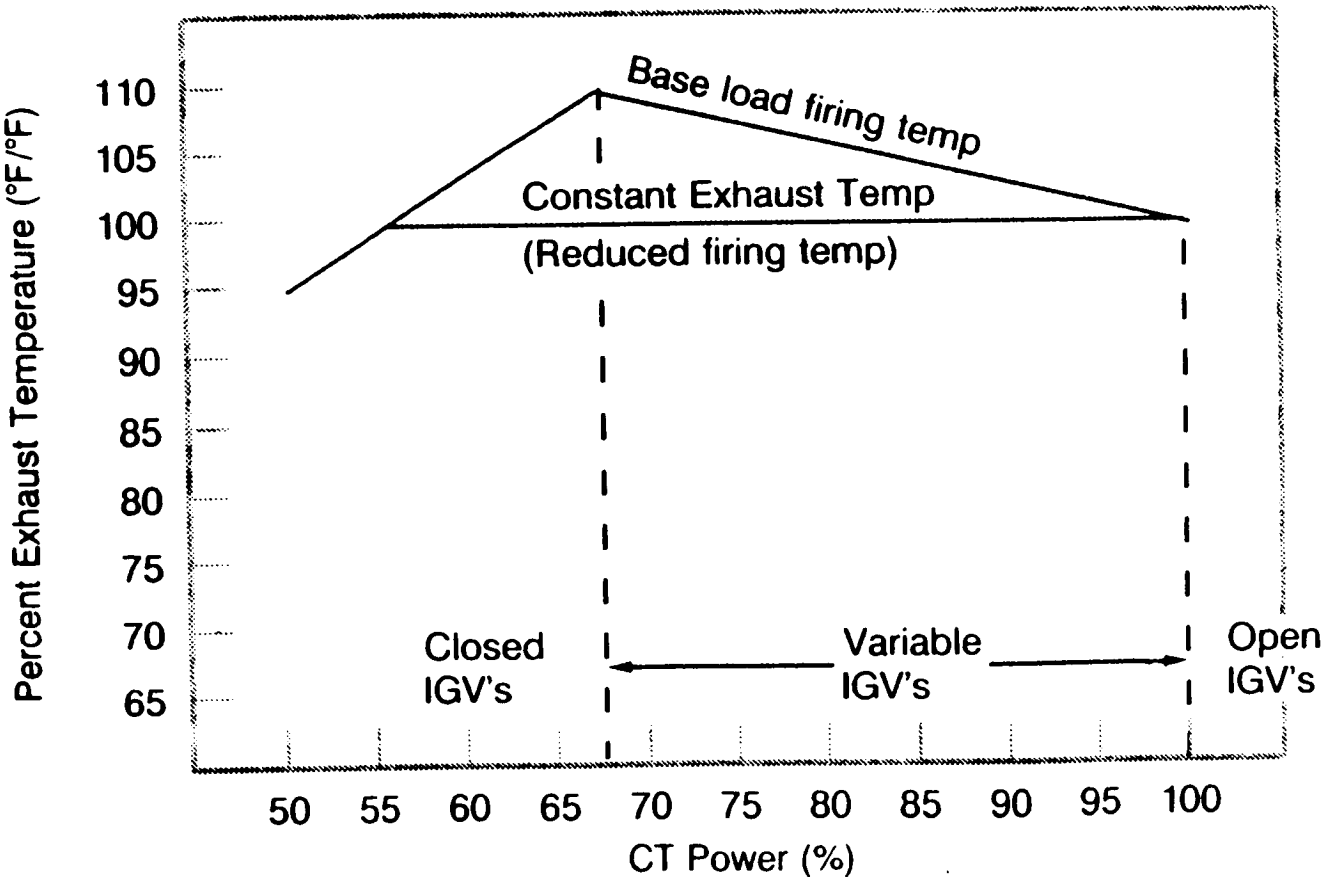


HRSG Optimization

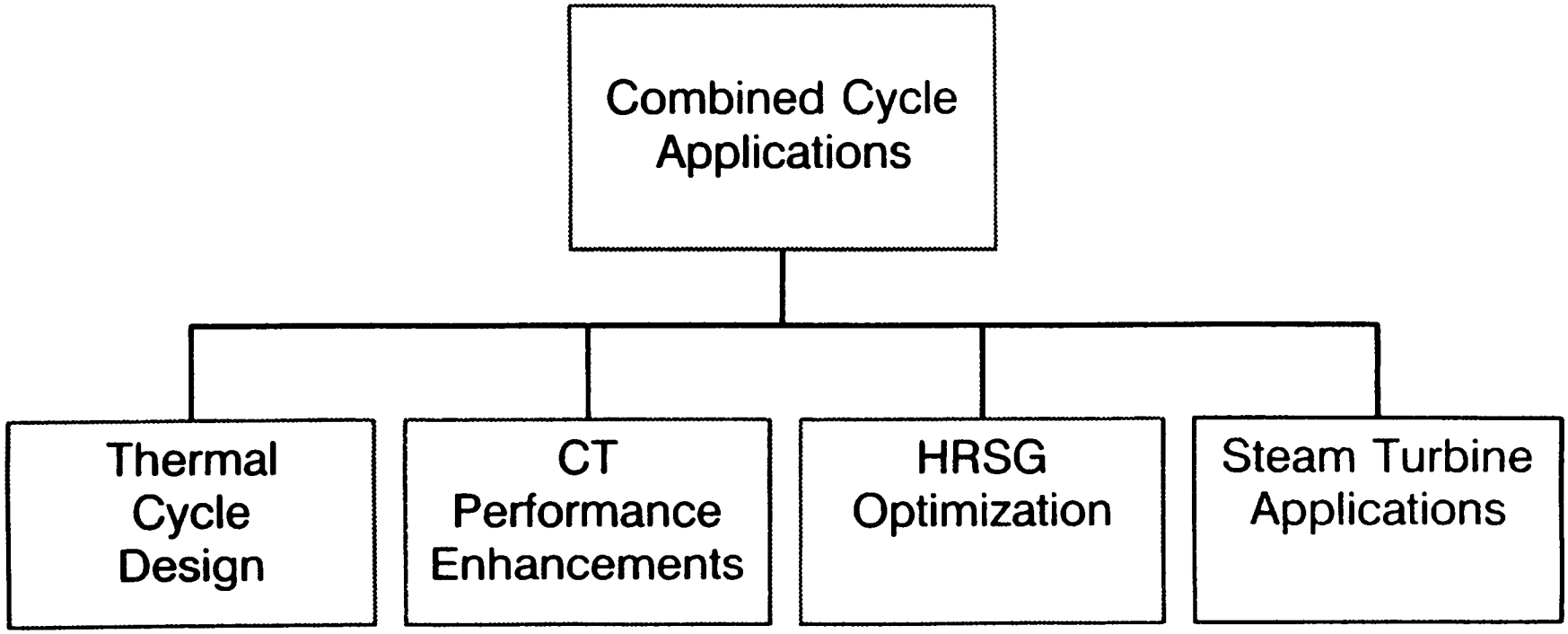
Design Parameter	Range of Specified Values
Superheater approach temperature	40-50°F
HP/LP evaporator pinch temperature	15-20°F
HP/LP economizer approach temperature	10-15°F
Feedwater temperature	130-150°F
Exhaust loss (w/o NOx/CO catalyst)	10-12" H_2O

HRSG Optimization

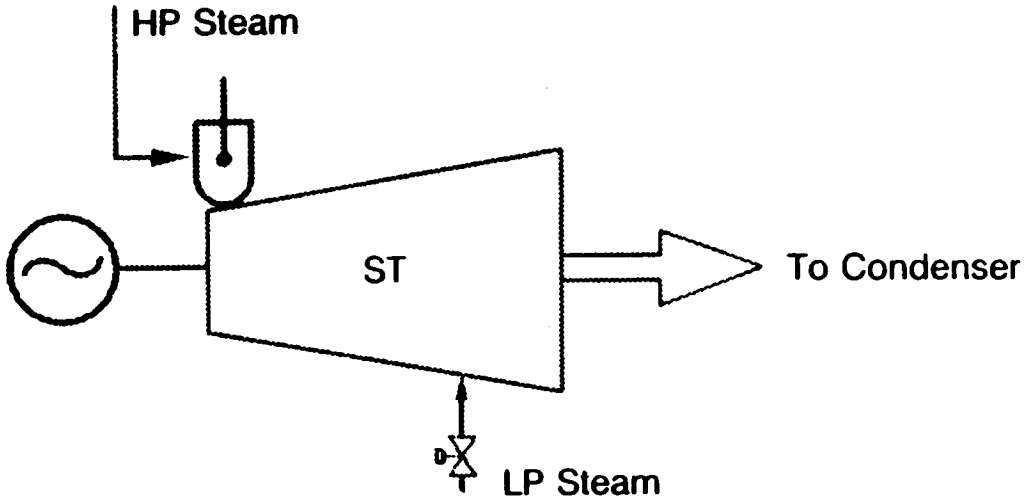
CT Part Load Operation
Effect on Exhaust Temp.



Combined Cycle Applications



Steam Turbine Applications



- Single cylinder design
- Two-case / two-flow design
- ST design options
- ST selection criteria

Steam Turbine Applications Configurations for Combined Cycle

Single Cylinder	Two Case
M34A4	TC2F 26
SC 20	TC2F 29.25
SC 23	
SC 25	
SC 28.5	
SC 32	
SRT-A 28.5 (reheat)	

Steam Turbine Applications
Single Cylinder Design

23" - Axial Exhaust (Sequential Valve)

Steam Turbine Applications
Single Cylinder Design

Advantages of SC Construction

- Axial exhaust configuration
  - Simplifies plant layout
  - Reduces crane hook height
- Can often be shipped fully assembled
- Reduces delivery times
- Reduces erection times

Steam Turbine Applications
Two-Case / Two-Flow Design

TC - 2F General Arrangement

Steam Turbine Applications
Two-Case/Two-Flow Design

Advantage of TC/2F Construction

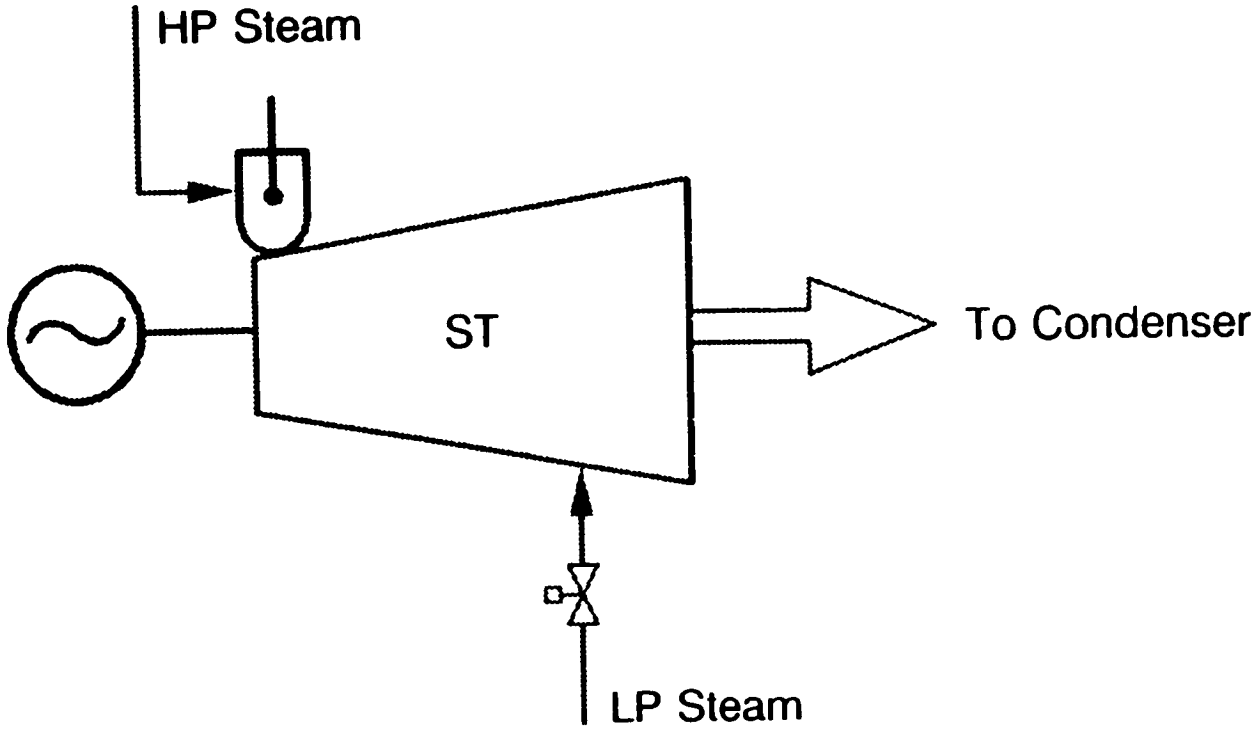
- Excellent low backpressure operation (<2.0" HgA)
- Good for duct fired applications

Steam Turbine Applications Design Options

- Sequential or single valve machine
- Uncontrolled extractions
- Controlled extractions/inductions
- Feedwater heating

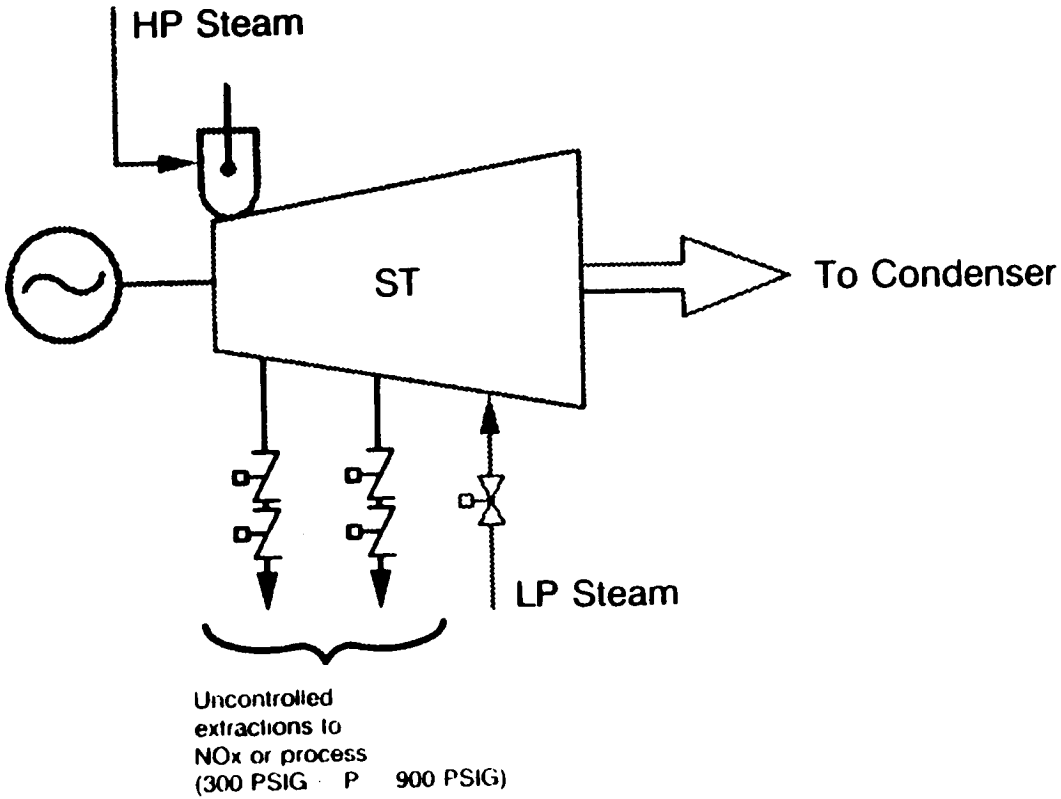
Steam Turbine Applications
Design Options

Basic ST Configuration (Dry Lo-NOx)



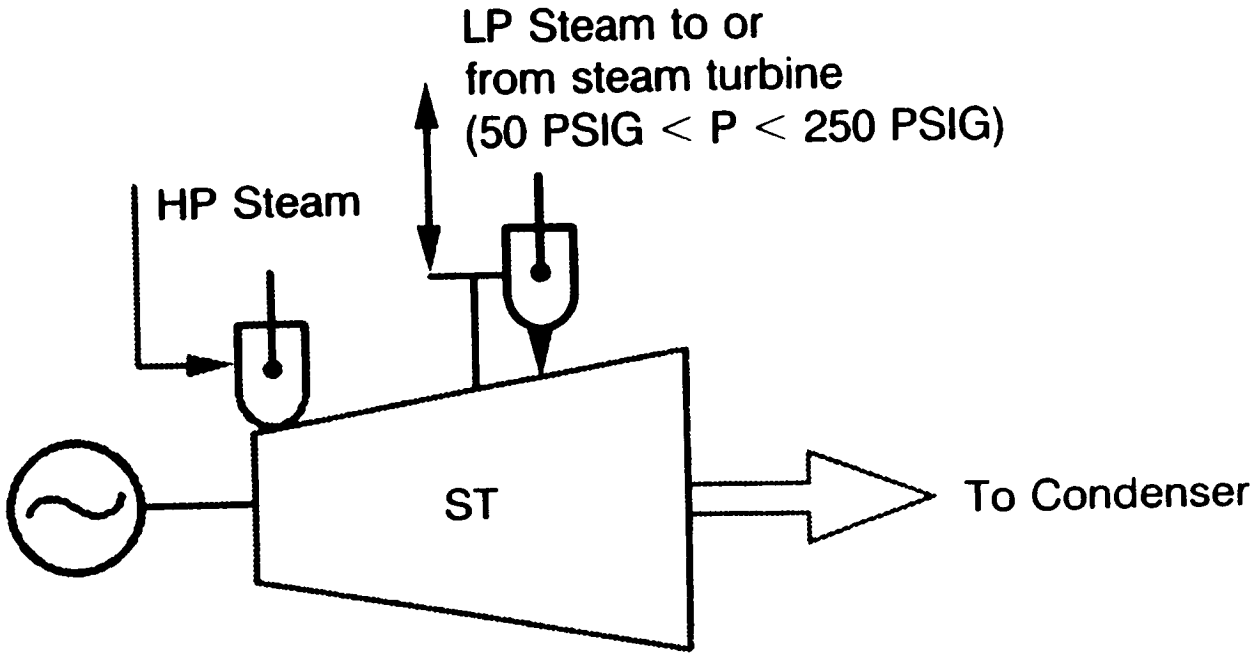
Steam Turbine Applications Design Options

Uncontrolled Extraction Option



Steam Turbine Applications Design Options

Controlled Extraction / Induction

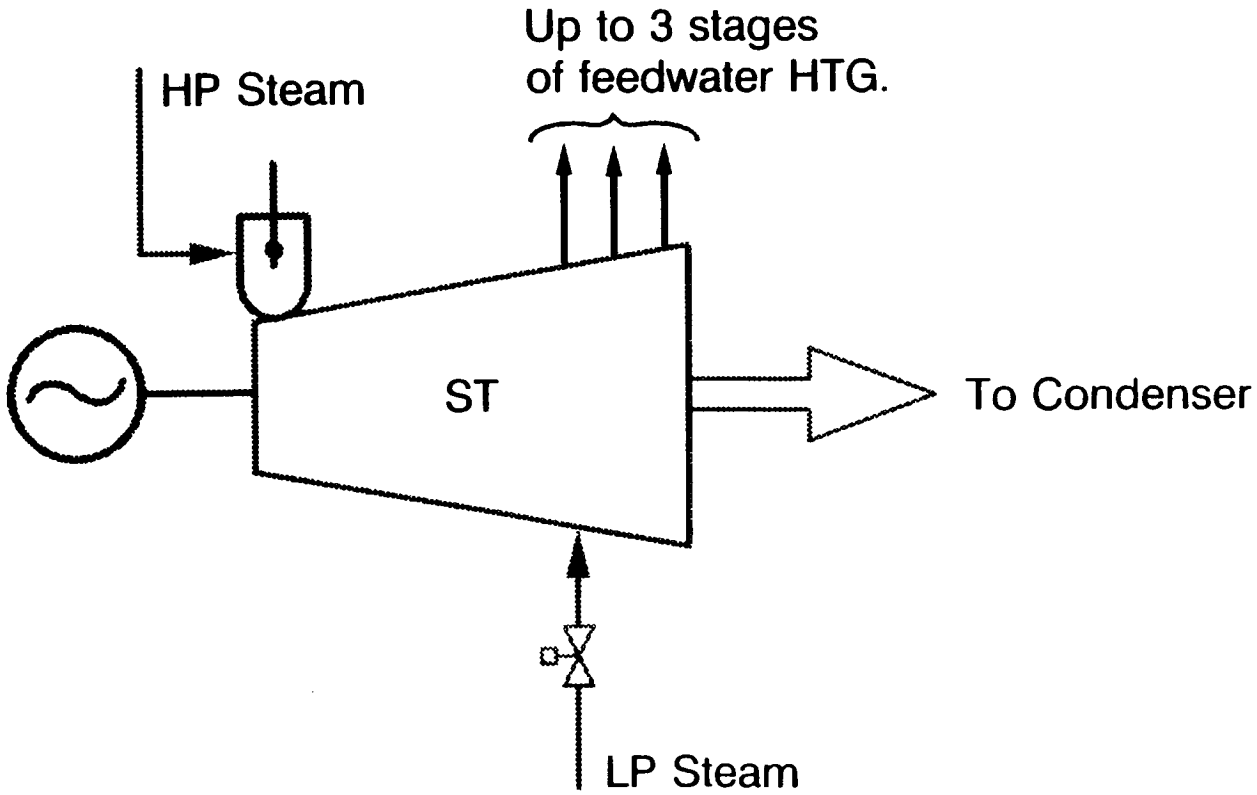


Steam Turbine Applications Design Options

Controlled Extraction / Induction (SC 20)

Steam Turbine Applications Design Options

Feed Water Heating Option (Long Term Oil Operation)



Steam Turbine Applications
ST Selection Criteria

Cycle Designer Needs to Specify

- Maximum throttle flow/pressure
- Minimum extraction pressure(s)
- Maximum induction flow/pressure
- Maximum efficiency point
- Maximum and minimum exhaust pressure

Steam Turbine Applications
ST Selection Criteria

Cycle Designer Must Consider

- End flow limits
- NOx control scheme
- Process steam requirements
- Ambient evaluation point(s)
- Condensing medium (wet vs. dry)

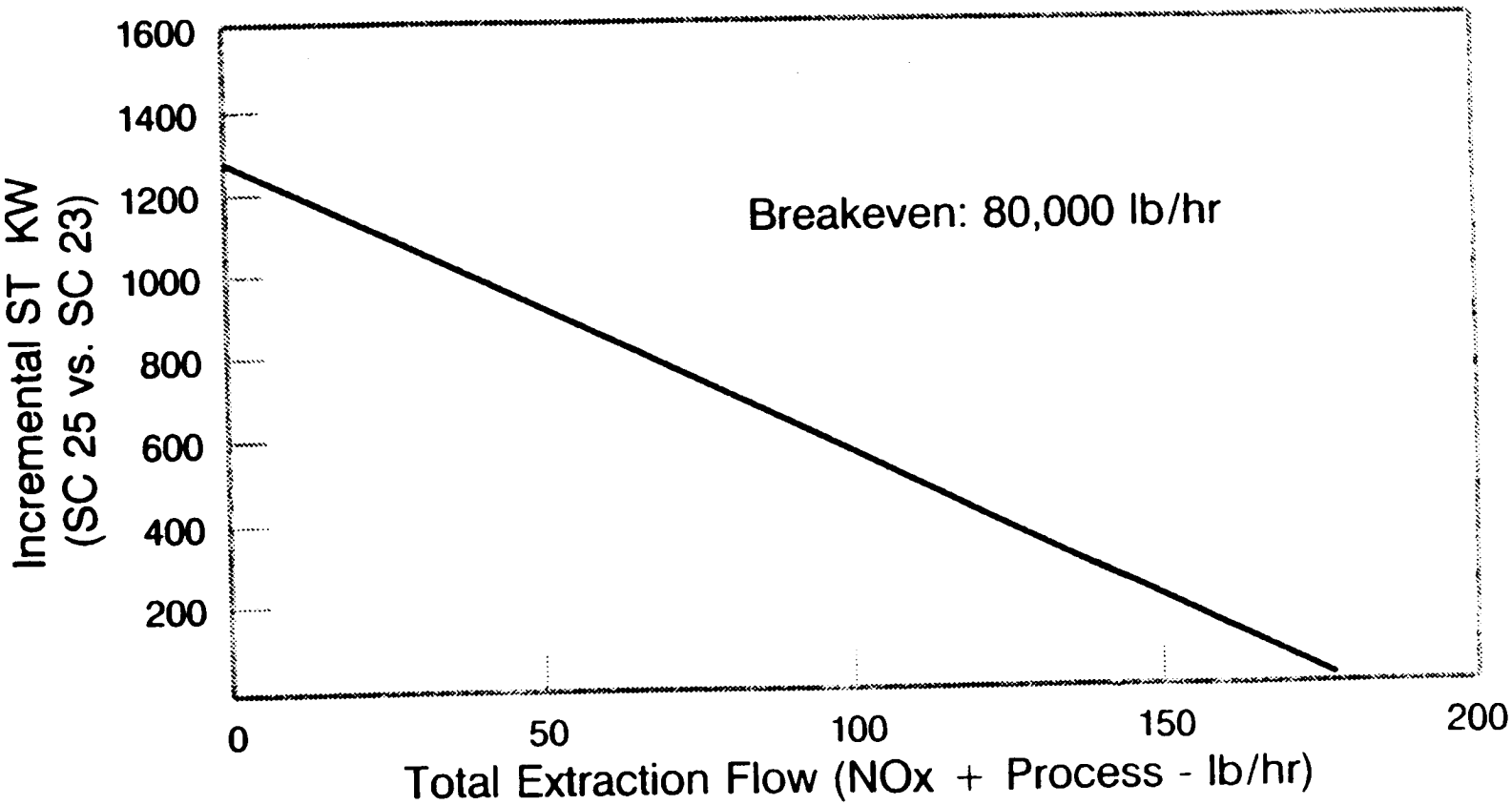
Steam Turbine Applications
ST Selection Criteria

End Flow Limits

ST configuration	Maximum LP end flow (lb/hr)
M34A4	235,000
SC 20	393,000
SC 23	493,500
SC 25	619,500
SRT-A 28.5 (reheat)	797,400
SC 28.5	805,500
SC 32	981,000
TC2F - 26	1,302,000
TC2F - 29.25	1,662,000

Steam Turbine Applications
ST Selection Criteria - 150 MW CC

Effect of Increasing Extraction (NOx and Process)



Steam Turbine Applications
ST Selection Criteria - 300 MW CC

Effect of Backpressure on ST MW