Worldwide Pollution Control Association

WPCA-Entergy

"Increasing Energy Efficiency of Existing Units" Seminar

January 22, 2014

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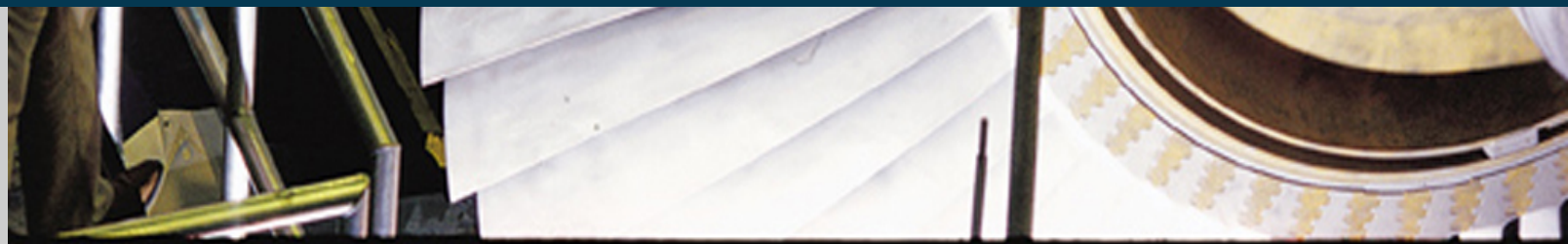
WPCA/Entergy Seminar

Ways to Increase Turbine Efficiency and Improve Heat Rate

SIEMENS

Jim Auman
Steam Turbine Engineering



Improving Efficiency and Heat Rate

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- 3D Reaction Airfoils (Bowed)
  - Increased Stage Count
  - Reaction versus Impulse Designs
  - Proven Efficiency Improvement
- Advanced Control Stage Design
- Optimized Sealing Technology
  - Labyrinth Blade Path Seals
  - Spring-back and Retractable Seals
  - Sustainable Clearances
- Reduce Potential Leakage Paths
- Select LP Annulus Area for Best Efficiency

Industry Development of Airfoils

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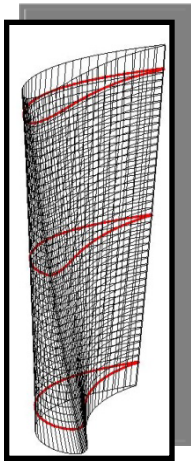
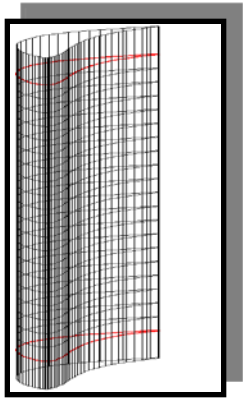
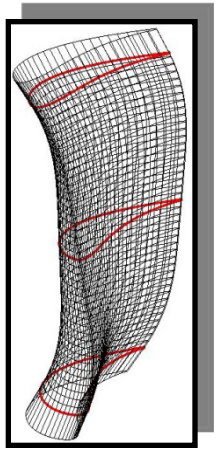




- **Cylindrical Airfoil** (since early 1900's)
  - ⇨ constant profile section

- **Twisted Airfoil (since late 70's)**
  - ⇨ variable profile sections
  - ⇨ adjustment to variable flow angles
  - ⇨ reduction of incidence loss



- **3D (since late 90's)**
  - ⇨ variable profile sections
  - ⇨ application of tangential lean or bow
  - ⇨ influence on radial pressure gradient
  - ⇨ reduction of secondary losses

3DV™ Current Generation Bowed Blading

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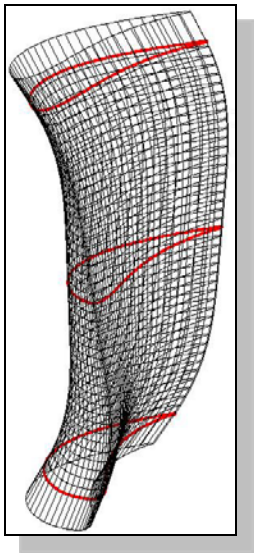
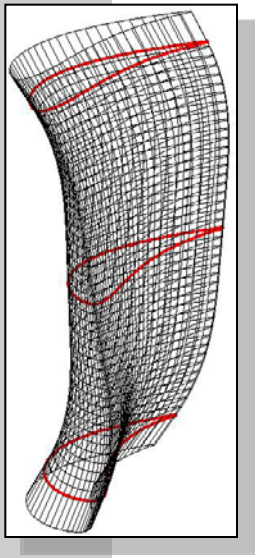


3DS™

- **3D** with reduced **S**econdary losses
- 2nd generation of advanced 3D blading
- based on twisted blades
- superimposed compound lean (bow)



- **3DV™**
  - **3D** blading with **V**ariable stage reaction
  - 3rd generation of advanced 3D blading
  - based on 3DS blades
  - optimized load distribution within the blade path
  - achieve maximum overall blade path efficiency

3DS™ Blading – Reduced Secondary Losses

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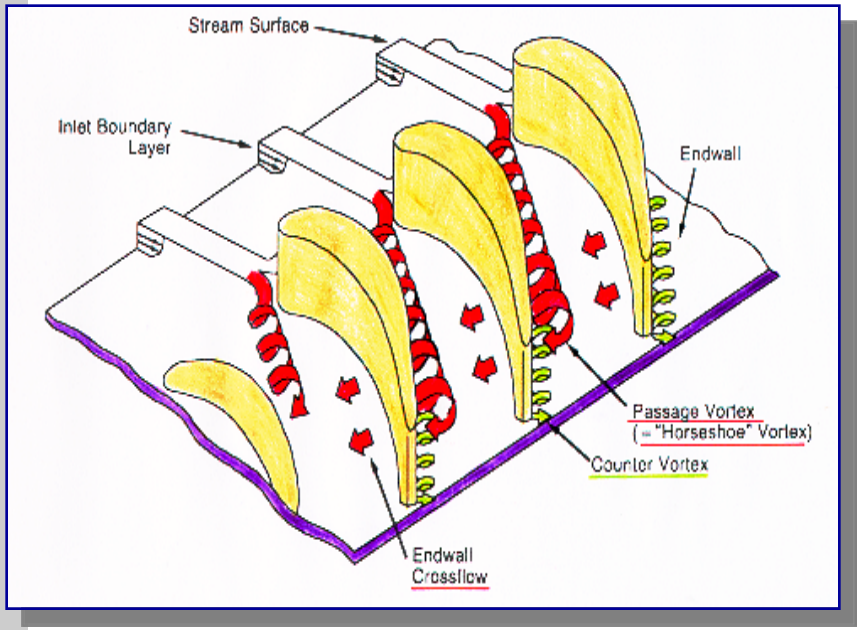
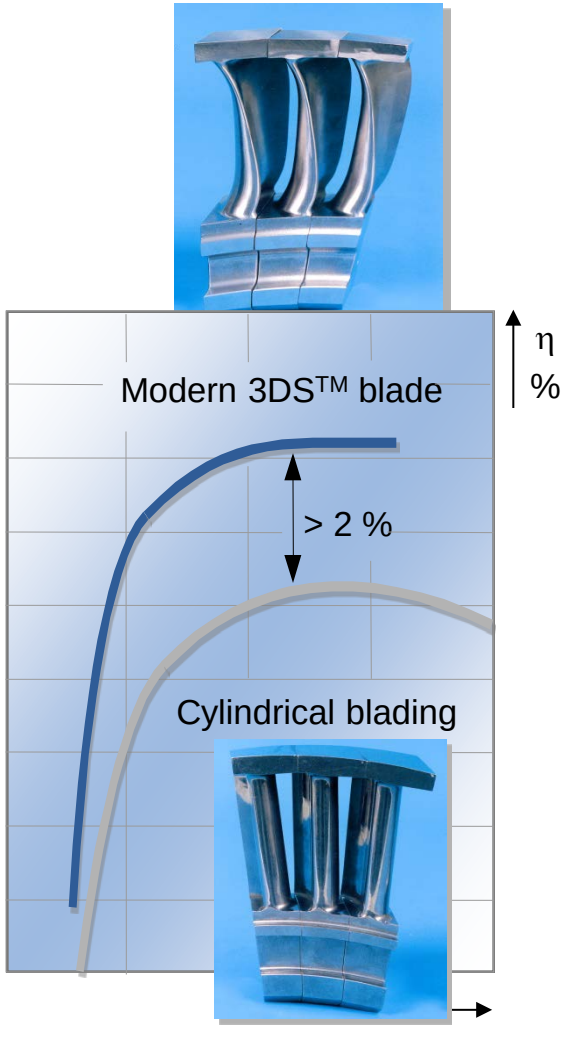


3DS™ Blading Late 1990's

3DS™ blading 2% efficiency improvement



3DS™ Blading – Pictorial

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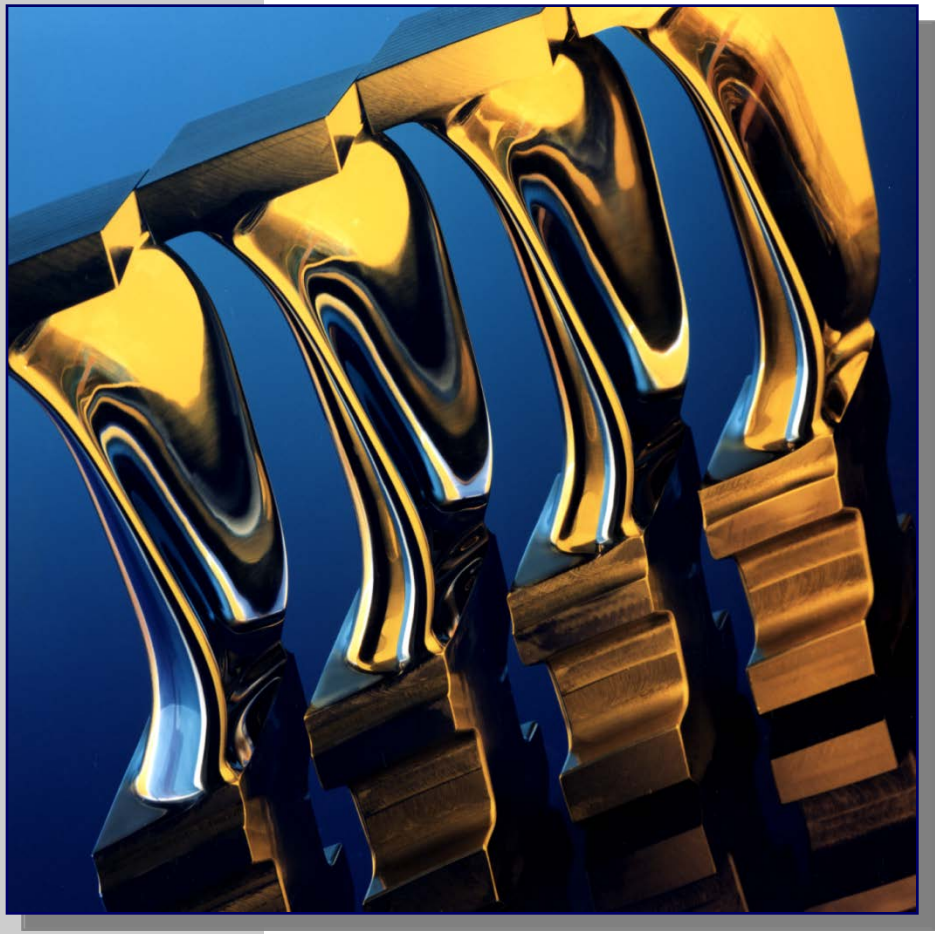

Advanced Control Stage Technology

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Past Features

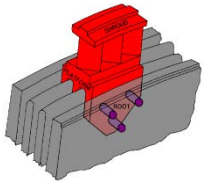
- **Turn around control stage**
- Bolted on nozzle block
- Riveted, side entry rotating blade

Vane chipping calculation

New, increased pitch airfoil section – prevents HCF induced vane

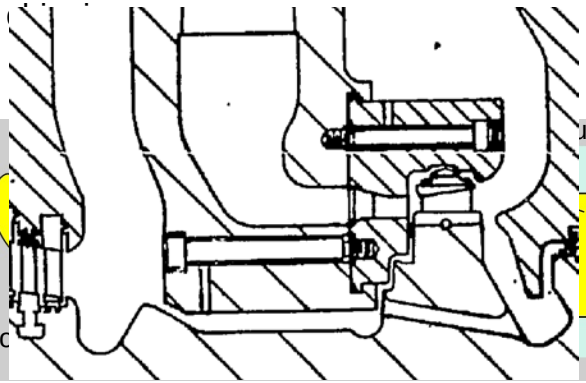
Current - World Class Features

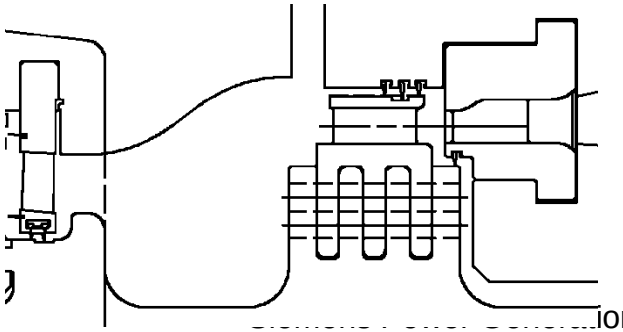
- **Straight thru control stage**
- **Increased Impulse Chamber P & T**
- **Improved airfoil profile design**
- **Contoured endwall nozzle**
- Slide in nozzle block
- Triple pin rotating blade
- Improved materials



Modernized triple pin blade

Est. up to +3-5% CS η over Past Designs





Comparison of Blade Design Principles

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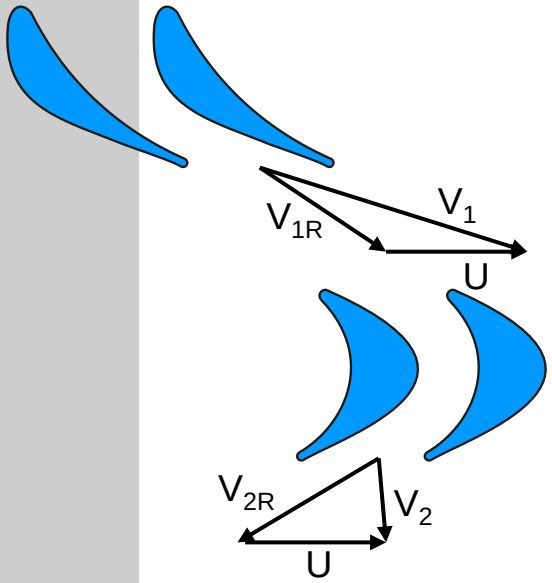
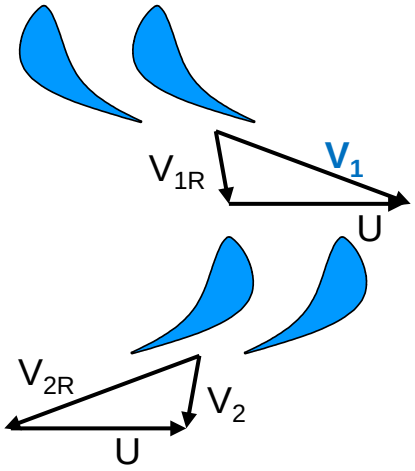
Impulse Stage



- **Fixed blade row accelerates the steam**
- **Moving blade row changes only the direction of the steam**
  - **High Work per Stage**

50% Reaction Stage



- **Fixed blade row accelerates the steam**
- **Moving blade row changes both the speed and direction of the steam**
  - **Lower Peak Steam Velocity V1**
  - **High Stage Count for Efficiency**

Blade Path Sealing Technology

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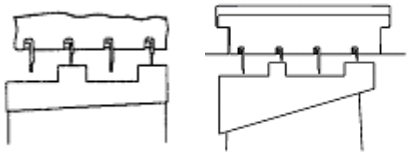
HP

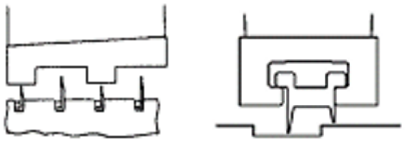
Small Axial Expansion

Casing



Rotating Blade

Stationary Blade

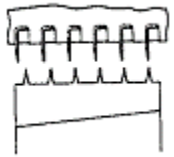


Rotor

LP

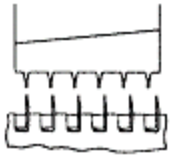
Large Axial Expansion

Casing

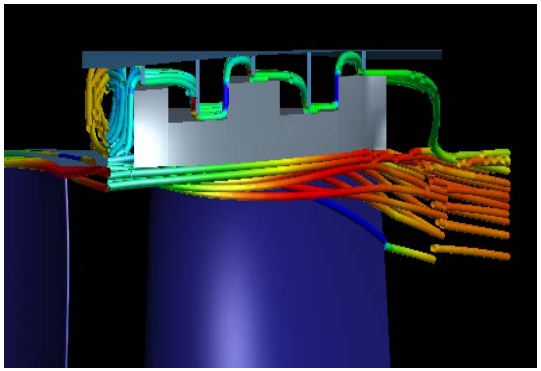


Rotating Blade

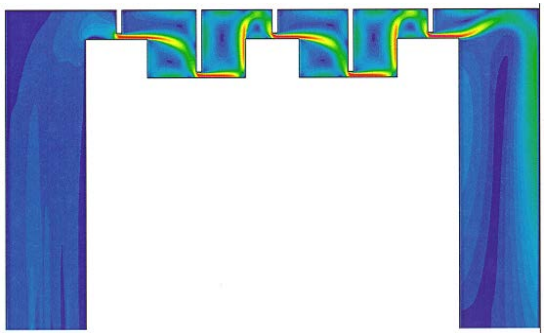
Stationary Blade



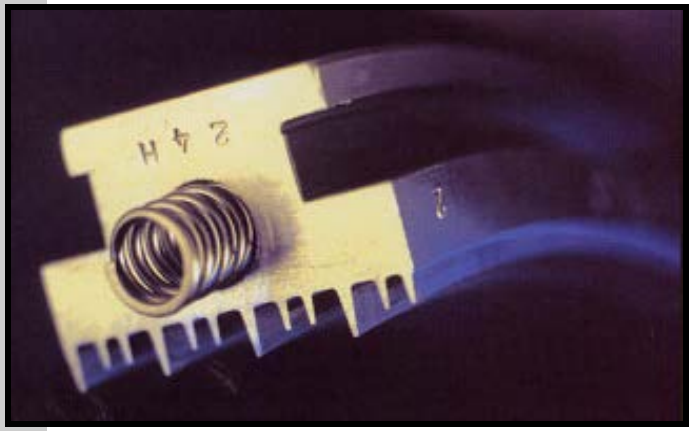
Rotor



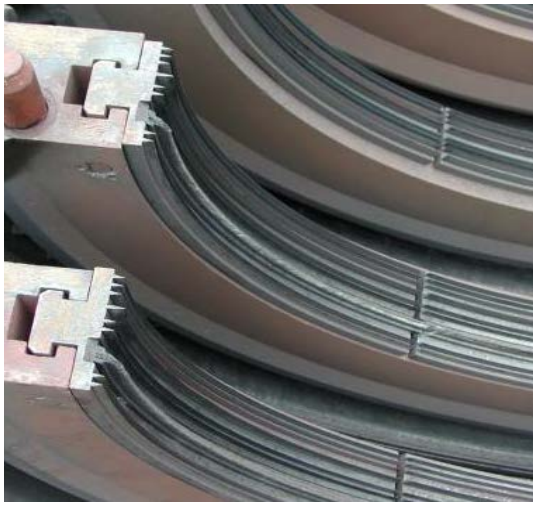
Seal Optimization with Modern CFD-Tools



Retractable Dummy Seal Rings



TurboCare Retrofit: Brush Seals in Impulse Blade Path



Benefits

- **Reduction in leakage flow**
- **Improved efficiency**
- **Favorable wear behavior characteristics**

Turbine Technology – LP Last Stage Design Features

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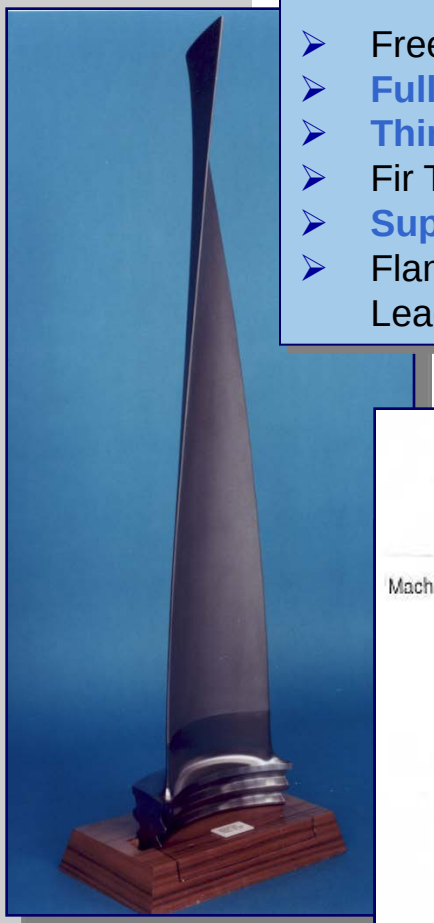
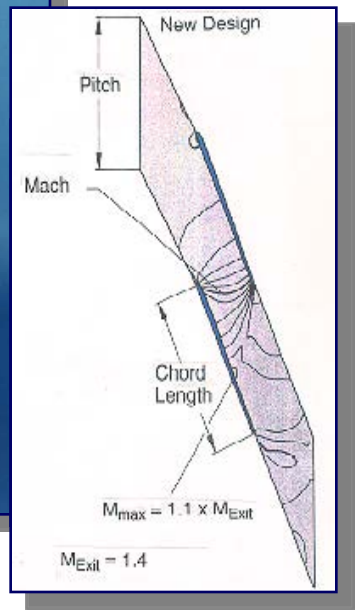


L-0R Design Features

- Freestanding L-0
- **Full 3D Design**
- **Thin Trailing Edge**
- Fir Tree Root Design
- **Supersonic Airfoil**
- Flame Hardened Leading Edges



L-0C Design Features

- **Thin Trailing Edge**
- Welded Diaphragms
- **Full 3D Design for optimum radial flow distribution and low exhaust loss**
- Hollow Vanes
- **Moisture Suction**

Efficiency Improvement Summary

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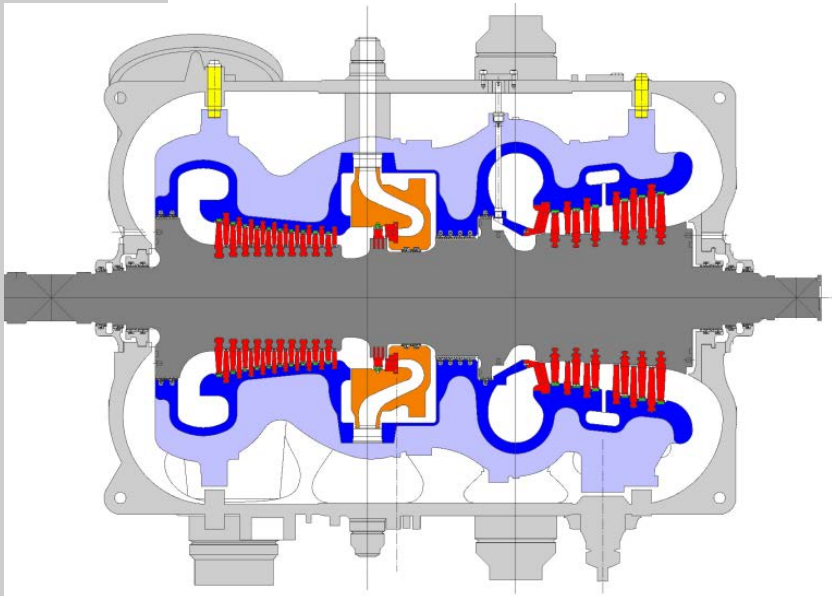
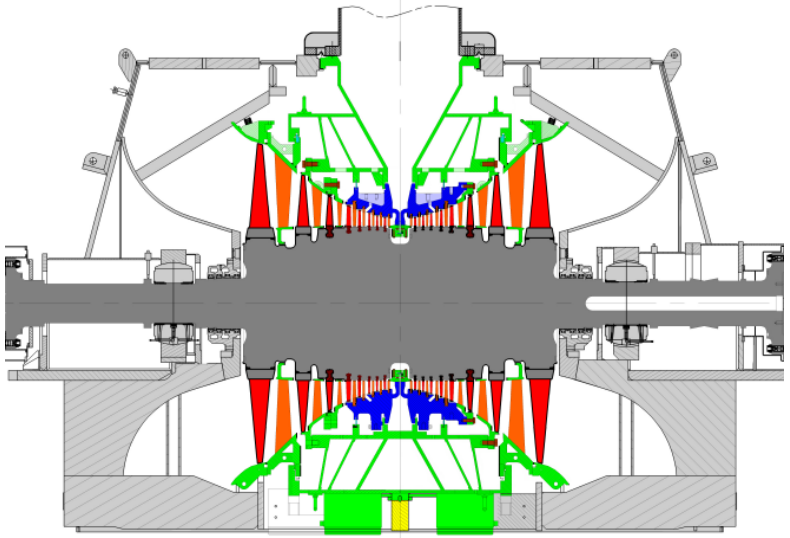
Retrofit Turbine Modules





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Questions ?