33rd Turbomachinery Symposium Case Study #5

Revamping-Leveraging Technology for Efficiency and Cost Savings

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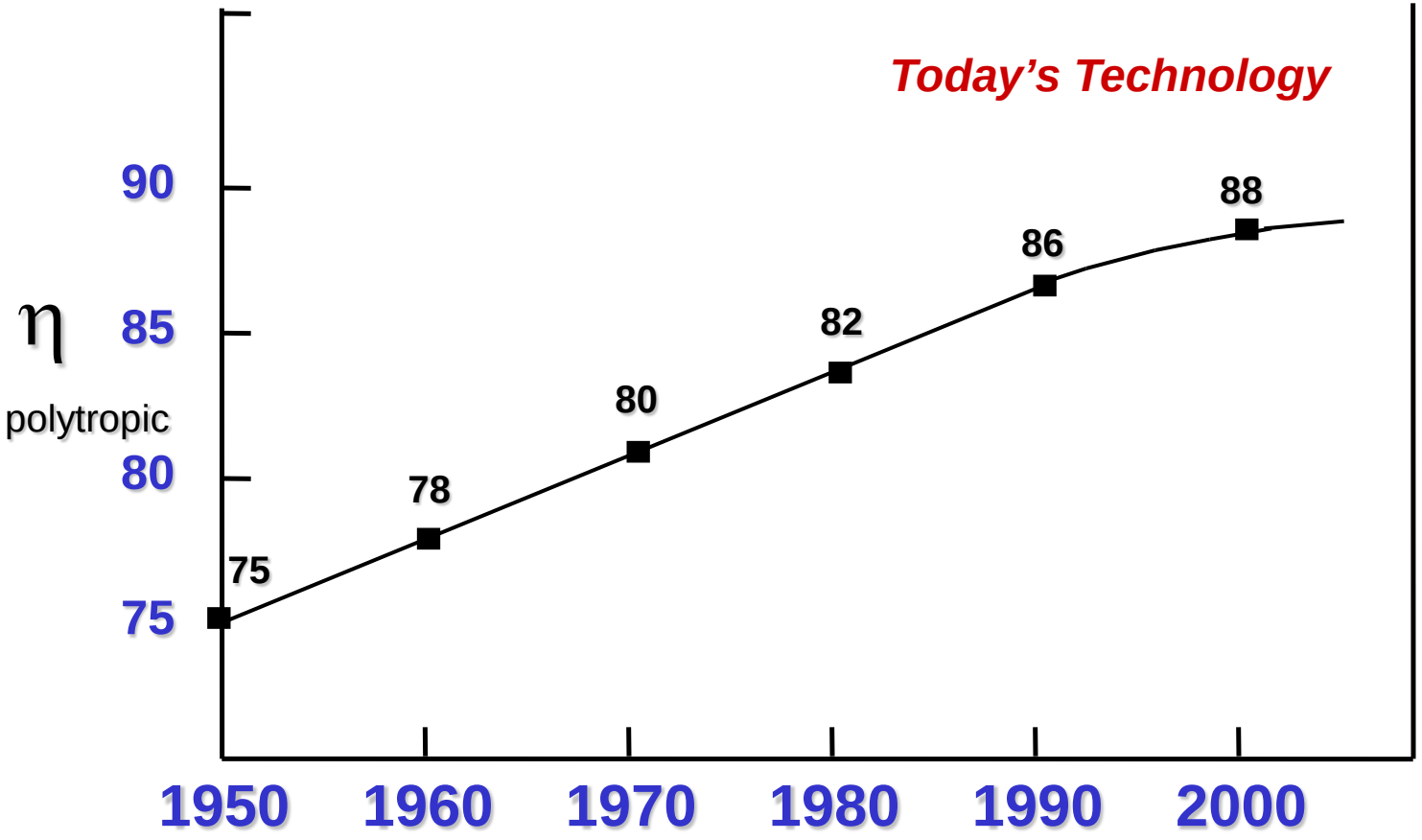
Presentation Agenda

Case Study-Revamp Project(s):

- Gas Transmission-Operating Range/Installed Cost
  - Computational Fluid Dynamics
  - Stage Performance-Component Matching
- Ethylene Production-Capacity via Efficiency
  - Flowpath/Stage Design
- Lessons Learned

Evolution of Industry Centrifugal Compressor Efficiency

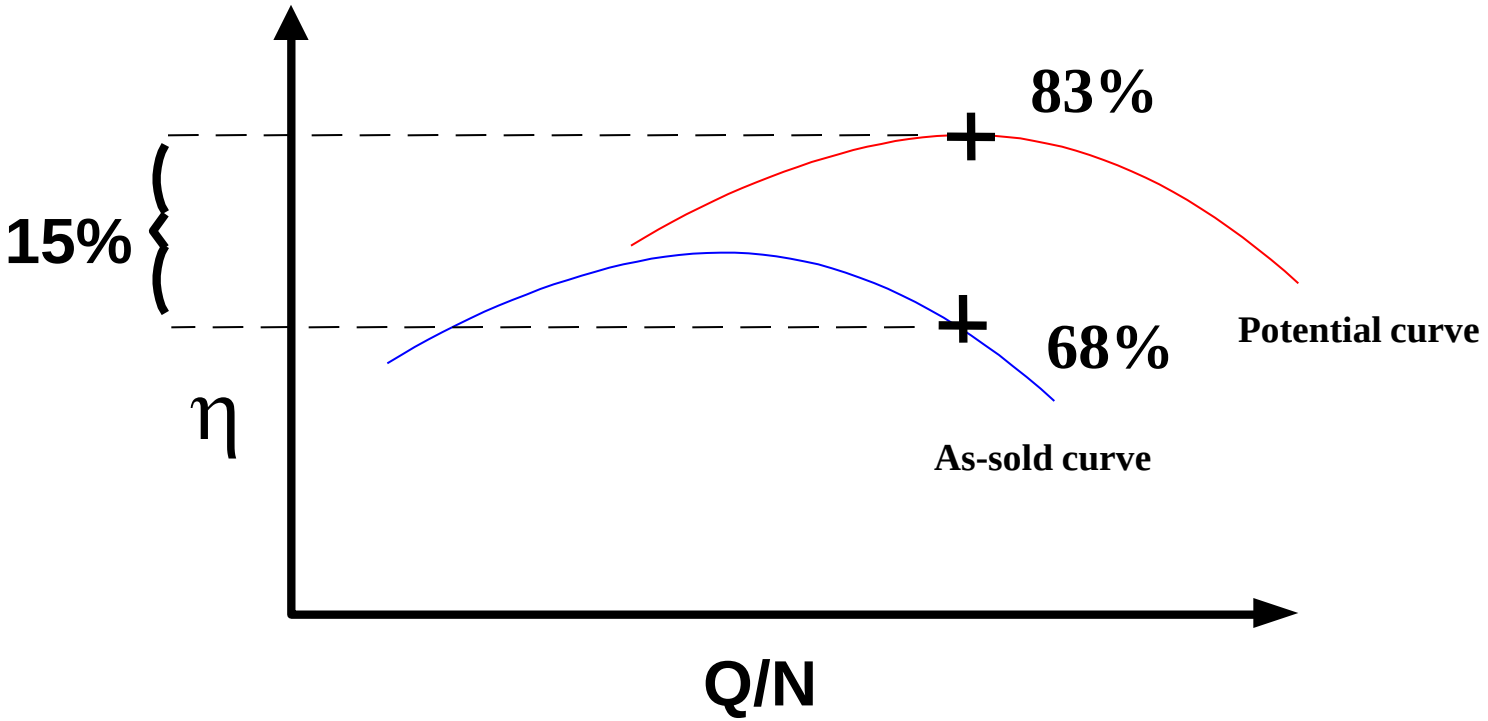


"Typical" Efficiency Improvement

Revamp to Today's Operating Point

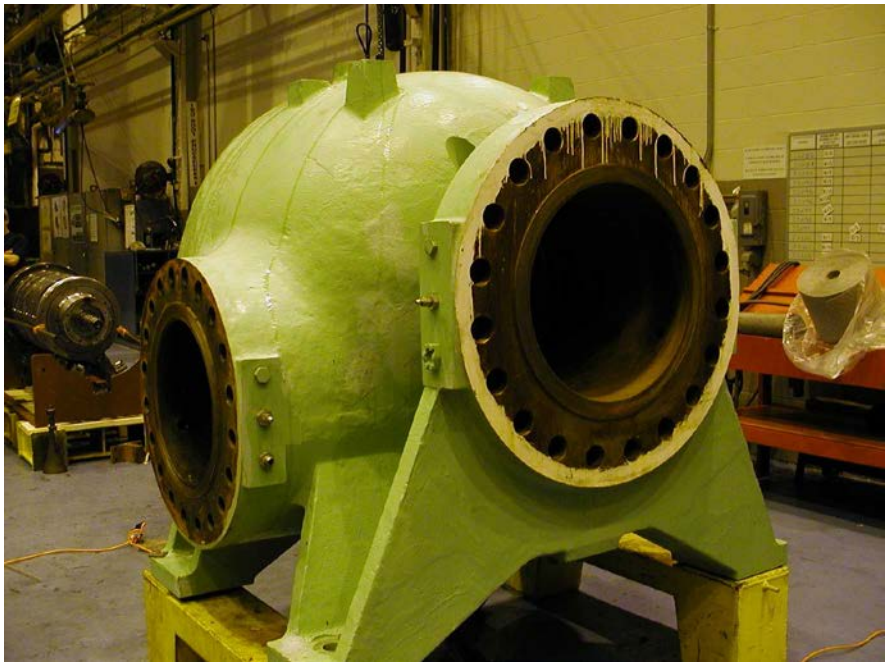
Increased Capacity and Efficiency

Note : Today's efficiency based on off-design point operation and as-sold efficiency of 75 %



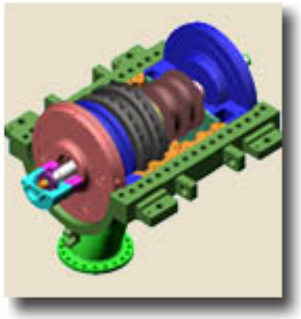
Case #1-Efficiency for Energy Savings

- **Today's Technology**
  - Fully machined flowpath
  - 2 piece Welded Impeller
- **Efficiency Improvement**
  - From 84% to 87.5%
- **Performance Map**
  - Wider operating range



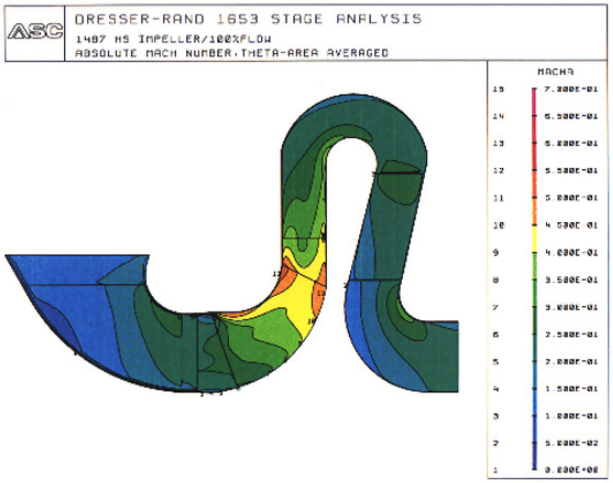
DRIVER: Cost avoidance to install new Unit Piping/Foundation Changes.

Improved Flow Path Design



Computational Fluid Dynamics (CFD)

- Improved flow distribution
- Optimized stage component matching
- All stage components operating with minimum losses (i.e. IGV, impeller, diffuser, return channel)
- Application of low solidity diffusers (LSD's)



Repeated performance testing to validate and refine

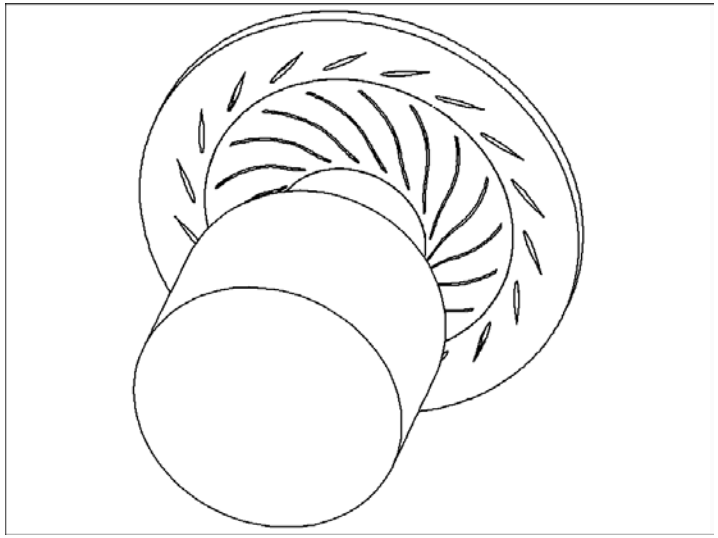
CFD Study of Pipeline Compressor Volute

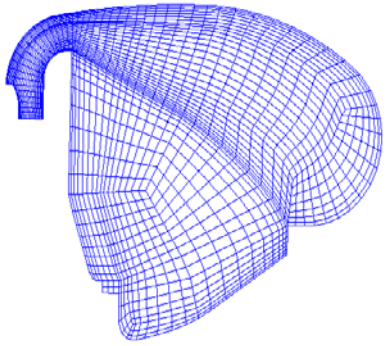
- **CFD Modeling:**

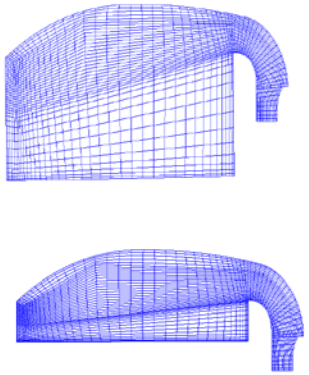
  Coupling the inlet with the impeller and the LSD

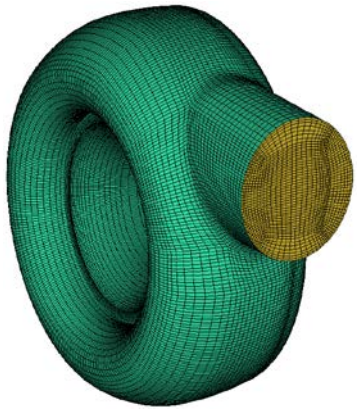
- **CFD Grids:**

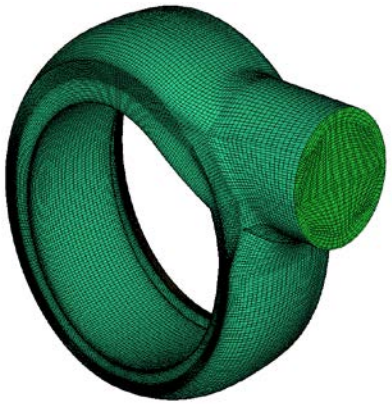
  Collector and Volute







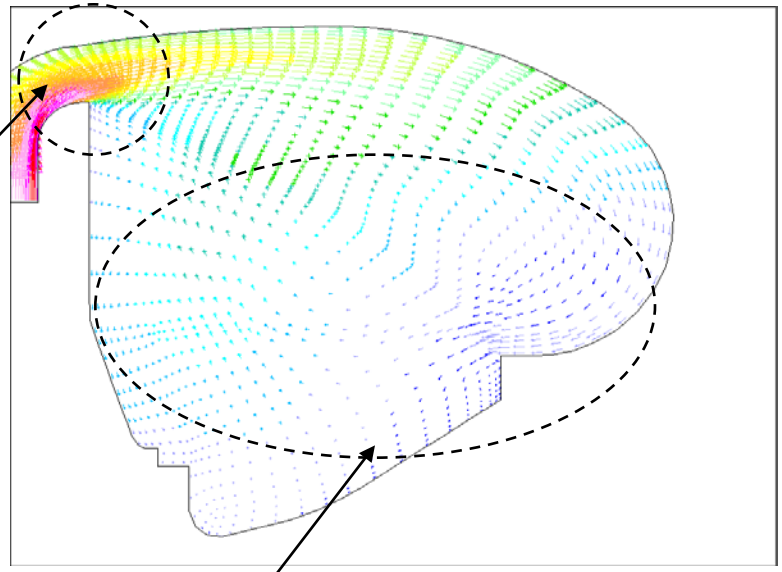




CFD Study of Pipeline Compressor Volute

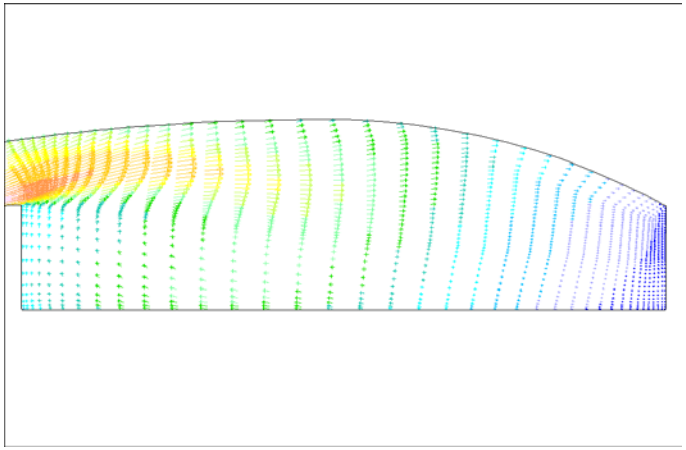
- **CFD Qualitative Results:**

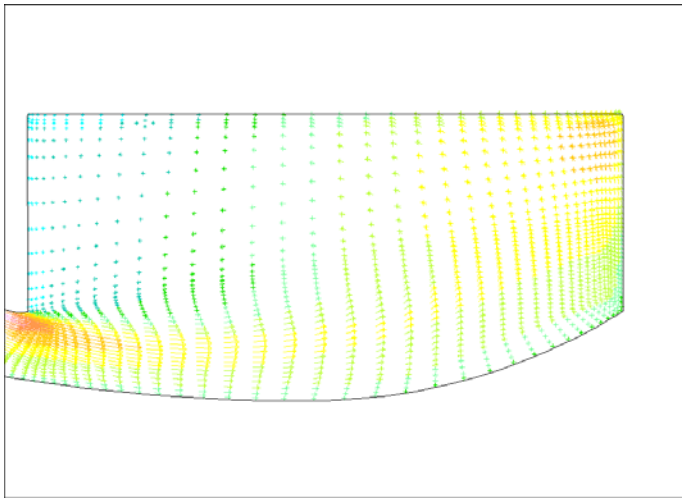
  Velocity vector plot in the collector (left) and volute (right) cross section at design point



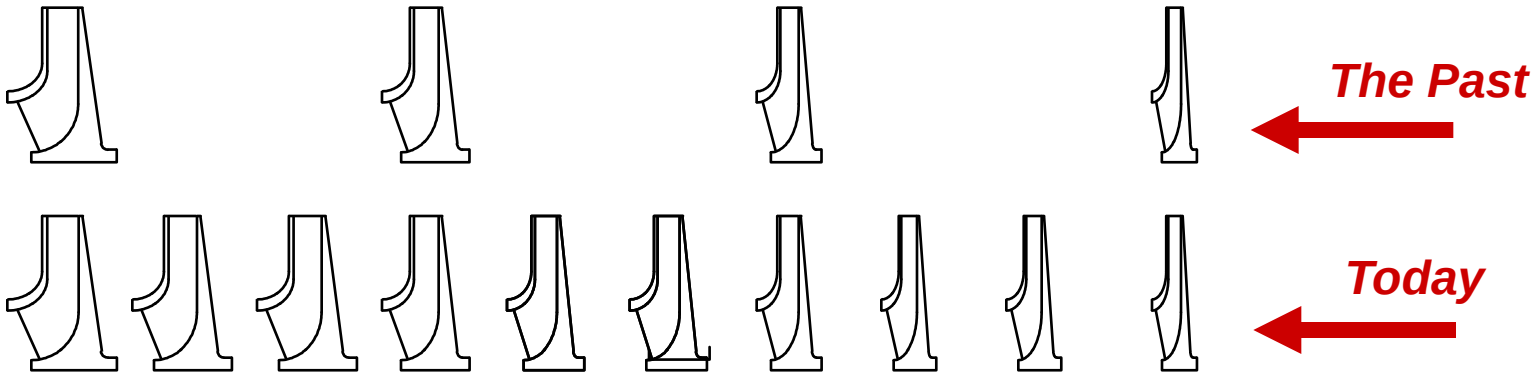
Right LSD and bend geometry is critical to let the flow into the collector without separation

Losses in this region are relatively low because of low velocity values





Stage Performance



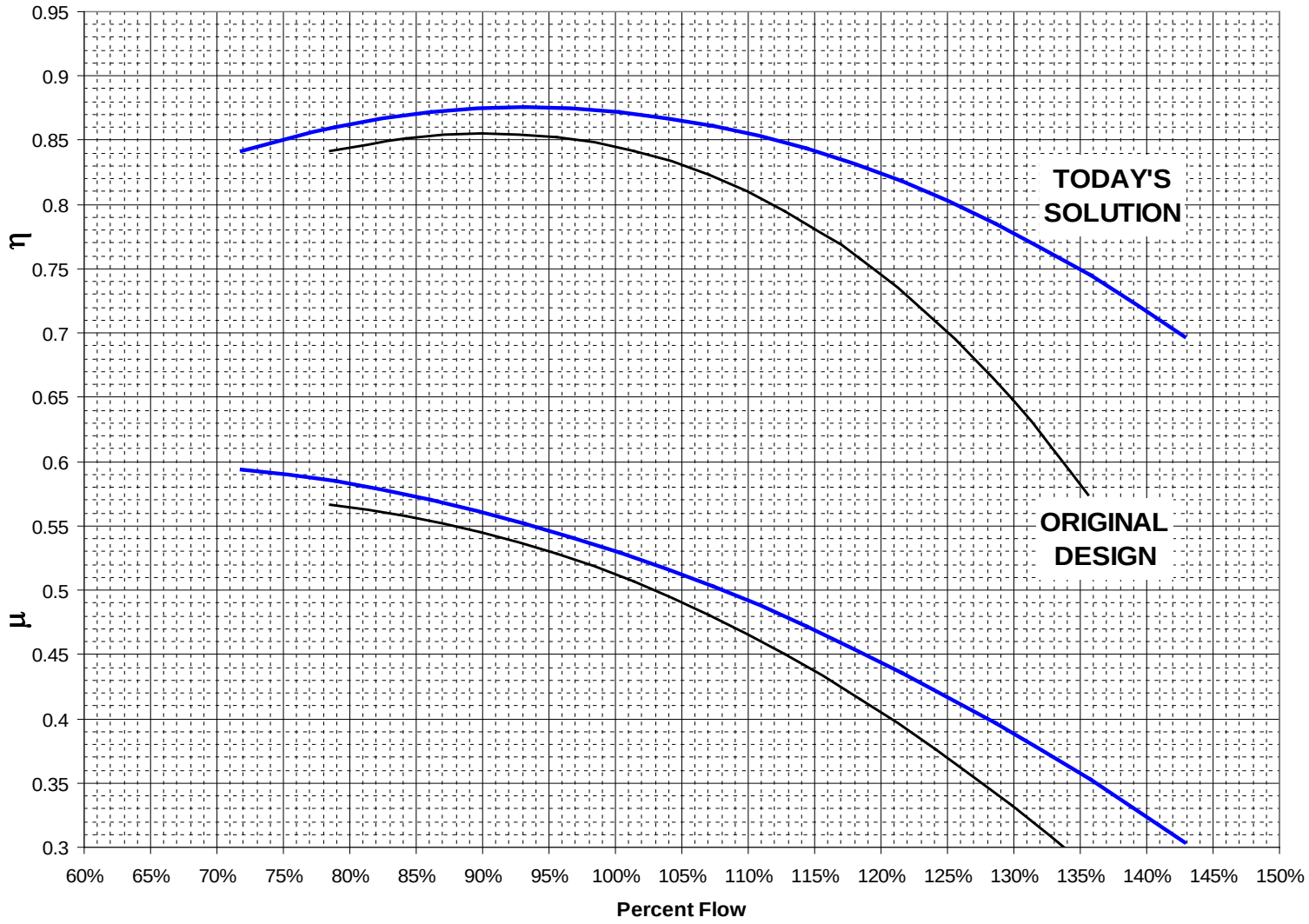
Traditional Line-Ups:

- Large gaps between standard impellers available
- Use of inlet guide vanes to complete the coverage map

Today's Technology:

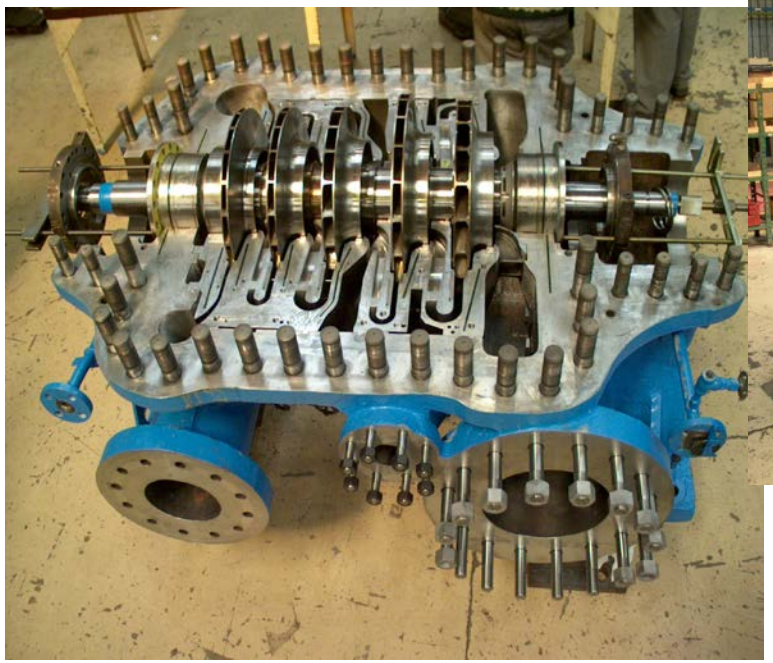
- Elimination of flow inlet guide vanes
- Many more impellers available for selection
- Designed to match "Best Efficiency Point".
- Better stage-to-stage match for peak performance

PTC-10 Factory Test Results



Case #2-Efficiency for Production

- **2 sidestreams**
- **10% flow increase for « same » power/energy**

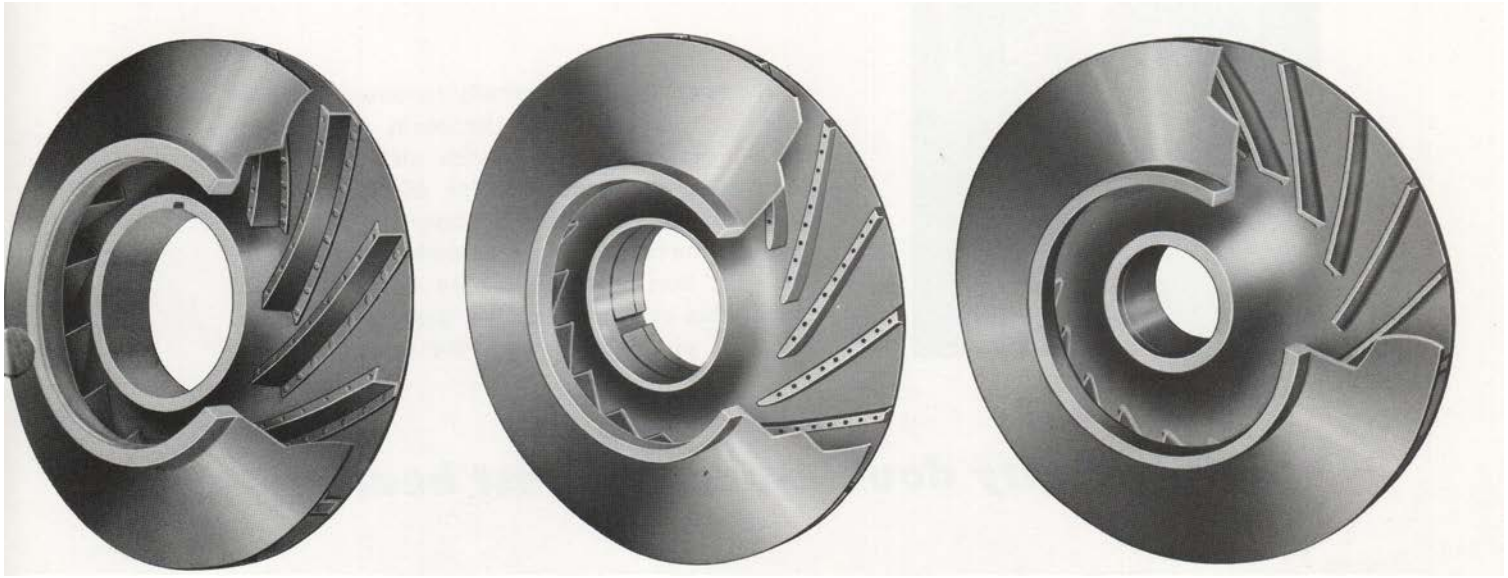


Ethylene Cracker Compressor fitted with Today' Technology

Debottleneck/Capacity-Zero effect to Energy Cost

Riveted, Cast & Welded Impellers

- Simple circular-arc blade design
- Blade forms are bent in a die and riveted or welded to the disc.
- Very difficult to hold tight tolerances
- Rotating stall problems with parallel disc and cover design

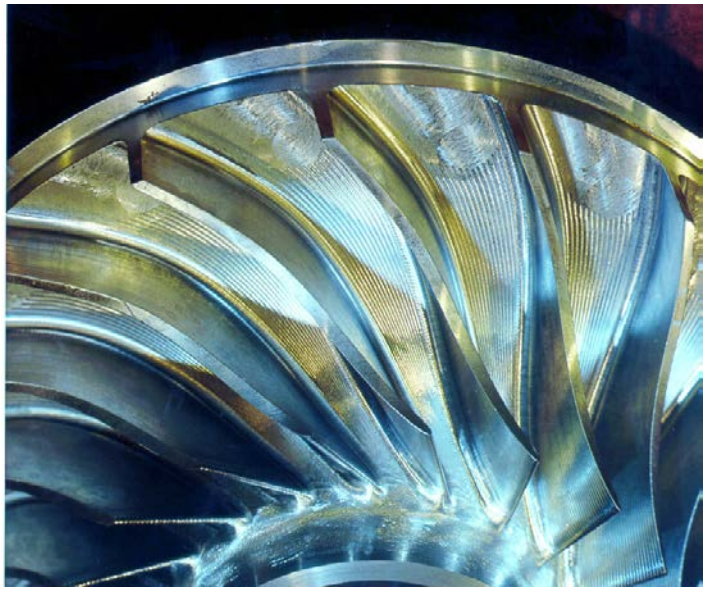


"Z" Blade Rivet

Thru Blade Rivet

3-Piece Welded or Cast

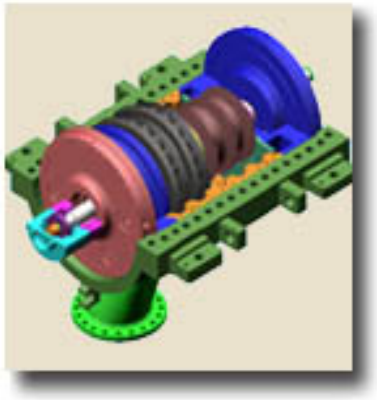
Leading Edge Technology- Welded Impellers



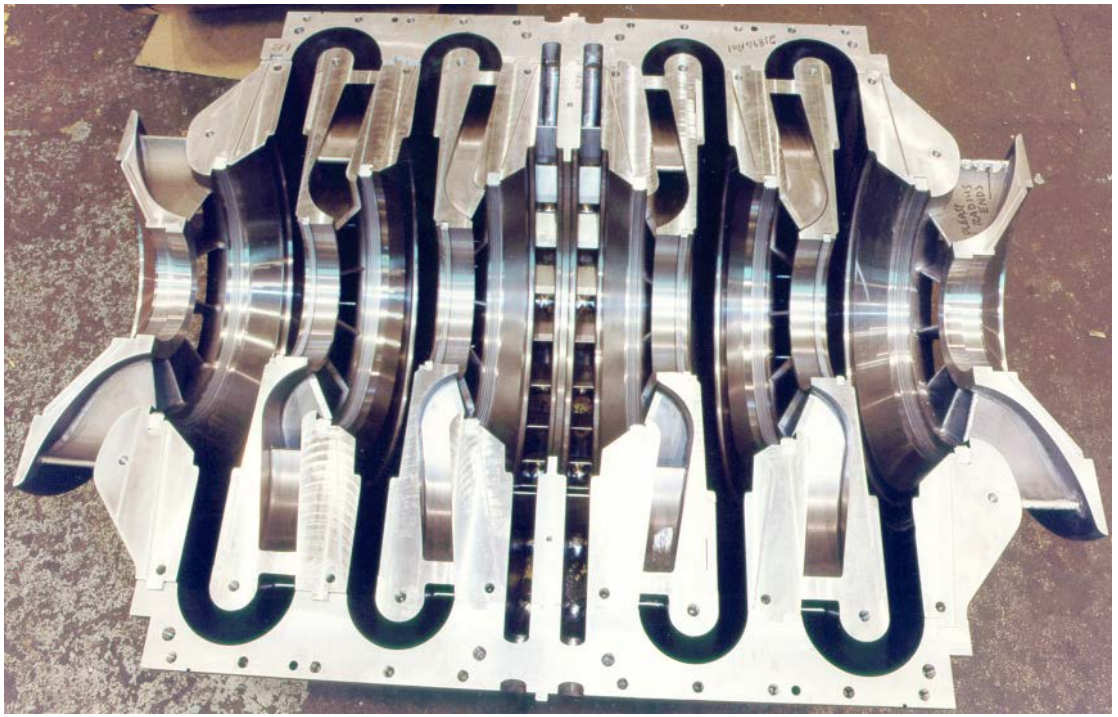
Highlights

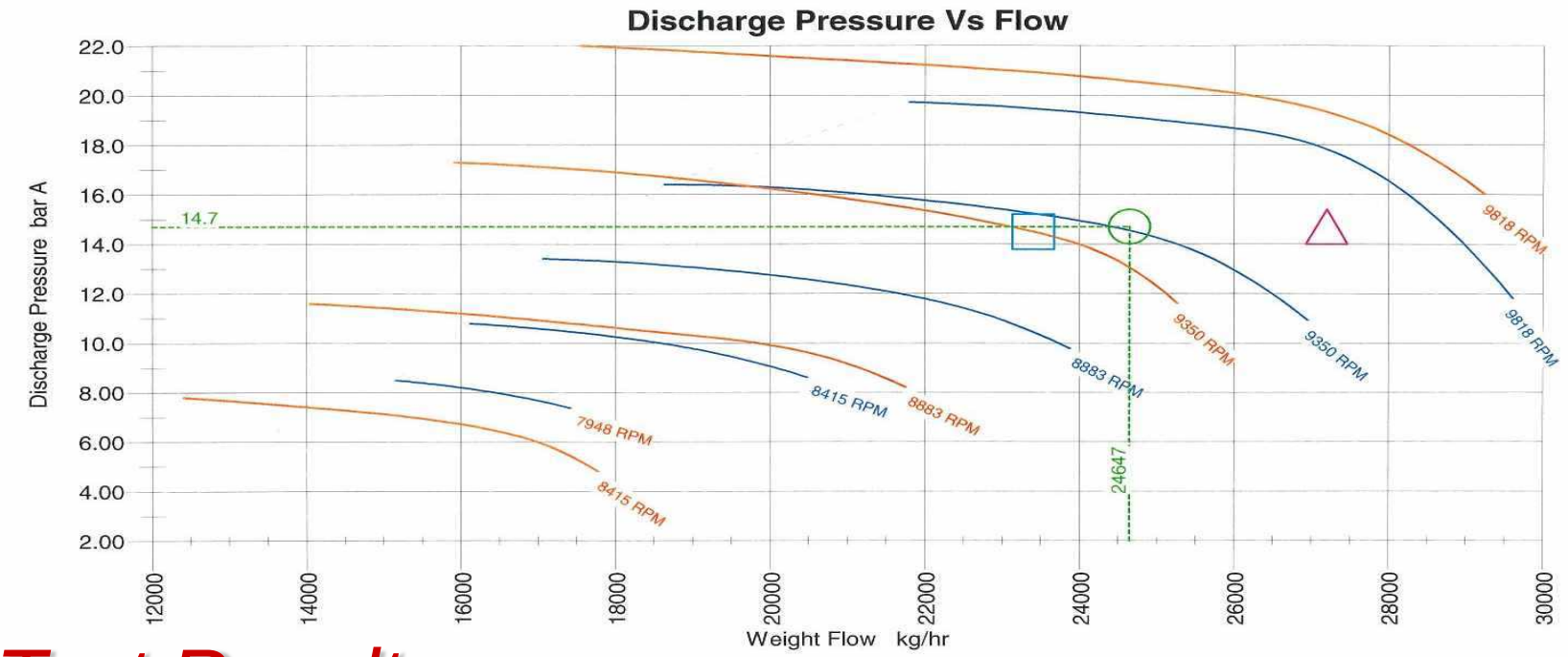
- All 3/5-axis milled
- 2/3 piece Construction
- Welded Construction
- High fatigue strength
- Predictable Performance
- New Materials

Stationary Flowpath Design

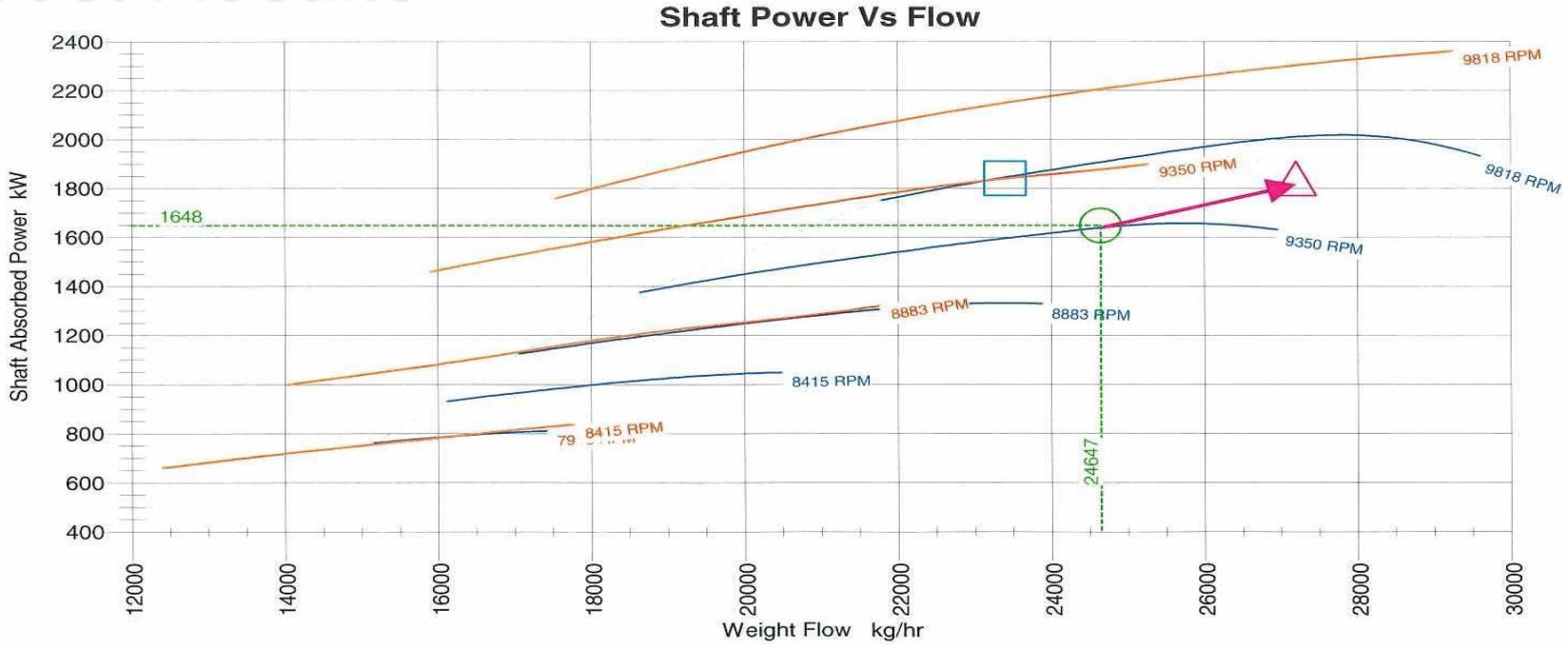


- Precision machined compressor internals
- Smooth surface finishes reduce frictional losses.
- Manufacturing Technology Complicated geometry machined with greater accuracy
- Consistent and repeatable performance





Test Results



Lessons Learned

- Technology driven Performance
  - Significant benefit form New Equipment-R&D
  - Today's Tools can be universally applied.
- Cost and Energy Savings-Economics
  - Evaluate "Total" Installed Cost
  - Energy reduction-Payback
  - Production via Efficiency

Revamping-A cost effective means to leverage "Today's" Technology with "Yesterday" equipment assets.

When to Revamp...

- Changes in operating conditions
  - Gas composition/molecular weight
  - Capacity
  - Temperatures
  - Pressures
- As a means to:
  - Reduce your Energy Consumption
  - Increase your Productivity
  - Reclaim lost Efficiency from Off-Peak Operation
  - Reduce Capital Investment-New Equipment and Installation

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