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Improving Compressor System Operational Efficiency

W. Norm Shade, PE
Sr. Consultant & Pres.-Emeritus
ACI Services Inc.
Cambridge, OH
Compressor Equipment

- Current Practice
- Current Efficiency Improvement Options
- Promising New Technologies
- Potential R & D Needs
Current Compressor Equipment

- Traditional low-speed reciprocating
  - High Compressor $\eta$ over wide ratio range
  - Engine $\eta$ varies with vintage/retrofit
- Centrifugal $\eta$ very dependent on ratio
- Newer high-speed reciprocating
  - High Engine $\eta$
  - System losses often limit Compressor $\eta$

Source: INGAA
Low-Speed Reciprocating Compressor Equipment

- High reliability
- High compressor efficiency over wide ratio range
- Very flexible (wide flow and ratio range)
- Large no. of legacy integral engine compressors
  - New units no longer manufactured
  - Engine efficiency varies with vintage and retrofit level
  - Various engine retrofits reduce emissions & increase efficiency
- New motor-driven units available
  - High (installed) capital cost
- Good for baseline or flow swings

Source: ACI Services
Centrifugal Compressor Equipment

- High reliability
- Gas turbine and electric motor drives
- Compressor efficiency is very dependent on ratio & flow
  - Recycle and suction throttling control are inefficient
  - Other control options (e.g., variable IGVs) not commonly used
- Unit efficiency increases with size
- Best suited for baseline operation

Source: Solar Turbines
High-Speed Reciprocating Compressor Equipment

• High engine efficiency and low exhaust emissions
• Current product manufacturing and support
• Reasonably good compressor efficiency over wide ratio range
• Very flexible (wide flow and ratio range), but less than slow speeds
• System pressure losses from pulsation control reduce efficiency
• Pulsation and mechanical natural frequency control is challenging
• Good for baseline or flow swings

Source: ACI Services
Current Efficiency & Leakage Improvement Options
Reciprocating Compressors

• Improved valves & piston rings
• Better monitoring systems to improve maintenance & reduce internal losses
• Improved rod packing, leakage tracking, better maintenance
• Intelligent PLC automatic unloading control to eliminate suction throttling & bypass (except as last resort)**
• Cylinder upgrades/right-sizing (new piston/liners or replacement)
• Cylinder upgrades for maintainability (replace problematic vertically split type)

** not common in upstream applications (low hanging fruit?)
Current Efficiency & Leakage Improvement Options
Centrifugal Compressors

• Run centrifugals for base loading and utilize recips for swings (reduces need for recycle and suction throttling)
• Re-aero/right sizing
• A few units with variable inlet guide vanes
• Dry gas seals

Source: Solar Turbines
Promising New Technologies / Products

Technology Readiness Level
7 – 9  In use
5 - 7  Potential Research Needs
Promising New Technologies
Reciprocating Compressors

- Step-less capacity control without compromising valve performance
  - Head end automatic variable volume clearance pockets in field trials (ACI, Ariel, D-R, Hoerbiger) TRL8-9
- End deactivation with minimal losses (various alternatives) TRL9
  - reduced deactivated parasitic loss & activated valve loss (ACI)
- Smart control systems for optimal automatic operation/unloading
  - eRCM Express (ACI) TRL9
- Higher efficiency valves TRL8-9
  - CP high-strength contoured plate (Hoerbiger)
  - high-speed poppet (ACI, CECO)
  - radial poppet (ACI)
  - Straight flow (Zahroof SF)
  - Magnum HammerHead (D-R)

Source: ACI Services
Promising New Technologies

Reciprocating Compressors

• More efficient pulsation control (reduced pressure & power losses)
  • better time-based analysis techniques for more accurate designs and enable optimization (SWRI, Beta, others) \( \text{TRL8-9} \)
  • tunable sidebranch absorber (active pulsation cancellation) \( \text{TRL9} \)
  • pulsation attenuation networks (passive cancellation) \( \text{TRL7-8} \)
  • dynamic variable orifice (adjustable damping) \( \text{TRL7} \)
  • virtual orifice (pulsation cancellation) \( \text{TRL7} \)
  • others reported in GMRC/DOE program 2008-2011 \( \text{TRL6-7} \)

• Efficient cooler fan control \( \text{TRL8-9} \)
  • Variable speed w/o VFD (Voith)
Promising New Technologies
Centrifugal Compressors

• Ways to extend flow range and broaden peak efficiency zone
  • avoid, or at least minimize, recycle TRL9
  • automatically variable inlet guide vanes TRL8-9
  • automatically variable diffuser vanes TRL7-8
• Hermetically sealed compressors TRL8-9
  • spin-off from sub-sea development
  • no leakage, but limited low ratio capacity
Reciprocating Compressor Equipment & Systems
Potential R & D Needs

• Performance augmentation networks $\textit{TRL7-8}$
  • Based on success of tuned engine manifolds
  • Potential to reduce compression horsepower $>>10\%$
  • Optimize compressors as a system (like engines)
    • tuned manifolds
    • optimal crankshaft phasing
    • integrate with cylinder design
• Better damping materials & devices for reducing response to mechanical natural frequencies $\textit{TRL5}$
  • pipe clamps
  • equipment mounts
  • vibration (and noise) absorbing coatings
Reciprocating Compressor Equipment & Systems
Potential R & D Needs

- Piston rod packing improvements TRL7-9
  - better maintenance (smart monitoring of leakage rate)
  - reliable and cost-effective ways to seal the piston rod statically
  - reliable and cost-effective ways to eliminate operating leakage
- Reduce pressure drop at meter stations (replace pulsation bottles and orifices with pulsation cancellation solutions, e.g. PAN) TRL7-8
- Regulation research – incentive/credit for systemized approach to efficiency improvement – e.g., fuel savings; upstream or downstream pressure drop savings (someone else’s problem)
- Linear Motor Recip. Compressor (DOE H2 booster project) – pioneering research, but a long way from pipeline scale TRL3
Centrifugal Compressor Equipment & Systems
Potential R & D Needs & Ideas

• Practical retrofit ways to avoid recycle and operate in high efficiency zone
  • variable IGVs & adjustable diffuser vanes TRL7
  • typically requires OEM involvement
  • system strategies for base loading
• Reduce seal leakage
  • cost-effective vent gas capture and reinjection systems
  • cost-effective N₂ generator and face seal buffer systems
• Hermetically sealed compressors
  • scale up to pipeline high-flow/low ratio needs
Compressor Equipment

Questions