

Natural Gas Infrastructure R&D and Methane Mitigation Workshop Nov. 12-13, 2014

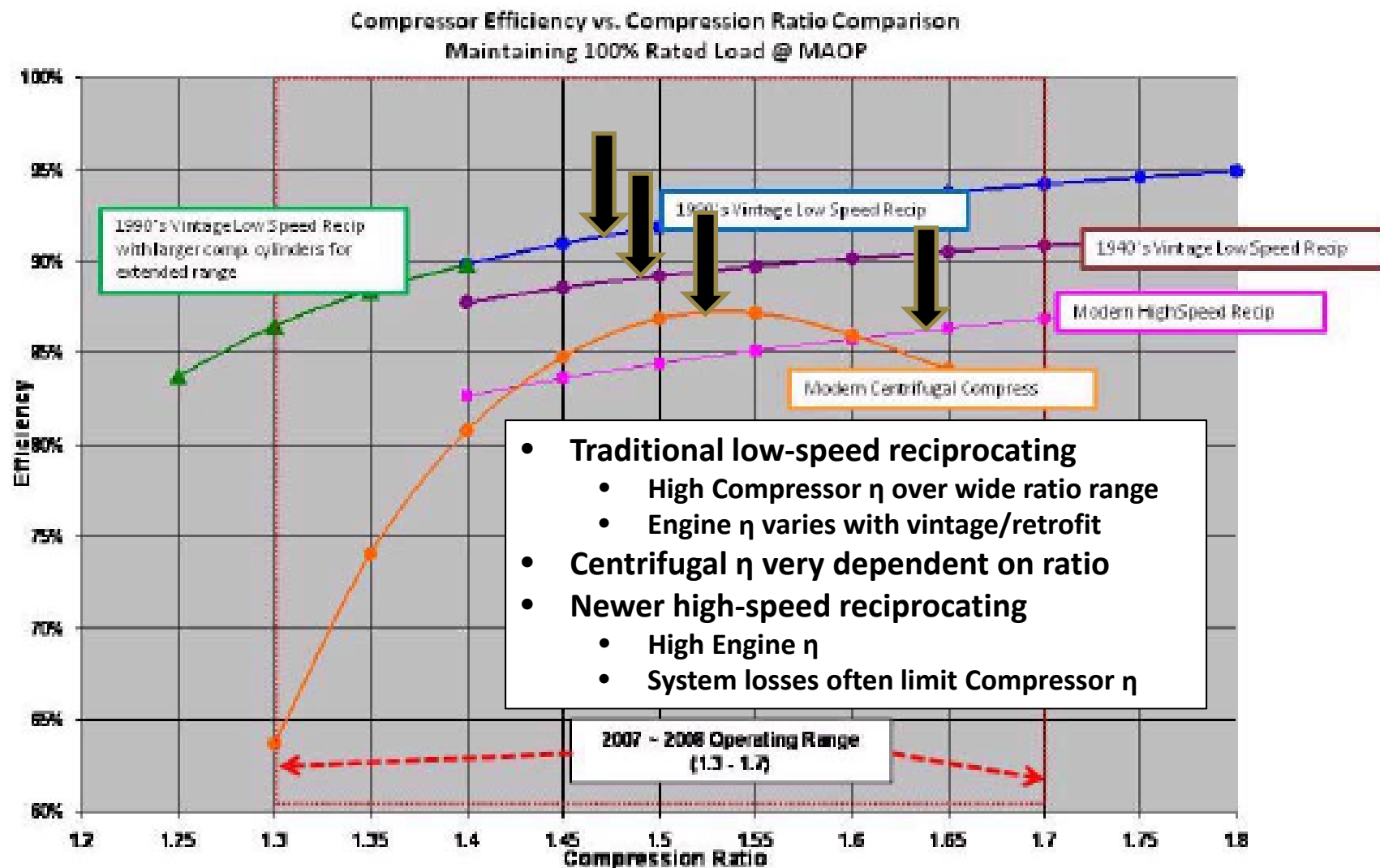
Improving Compressor System Operational Efficiency

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Compressor Equipment

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

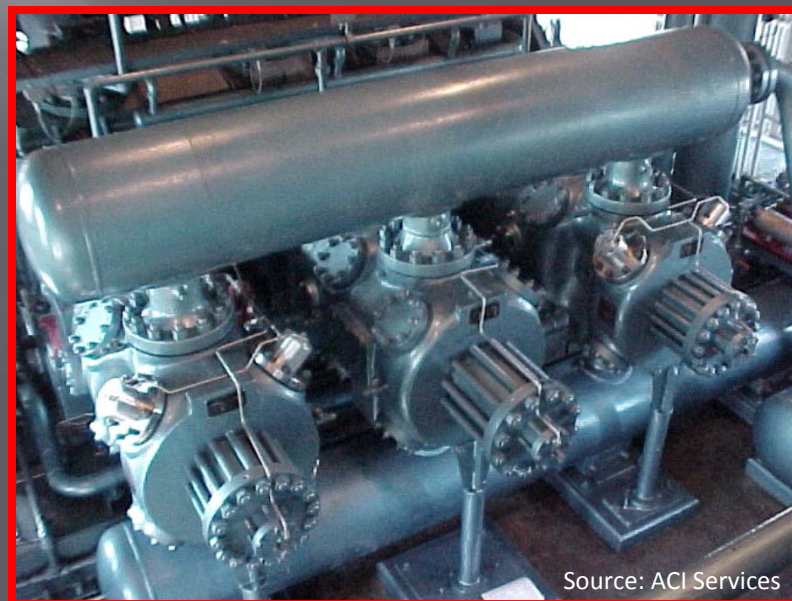
Current Compressor Equipment



Source: INGAA

Low-Speed Reciprocating Compressor Equipment

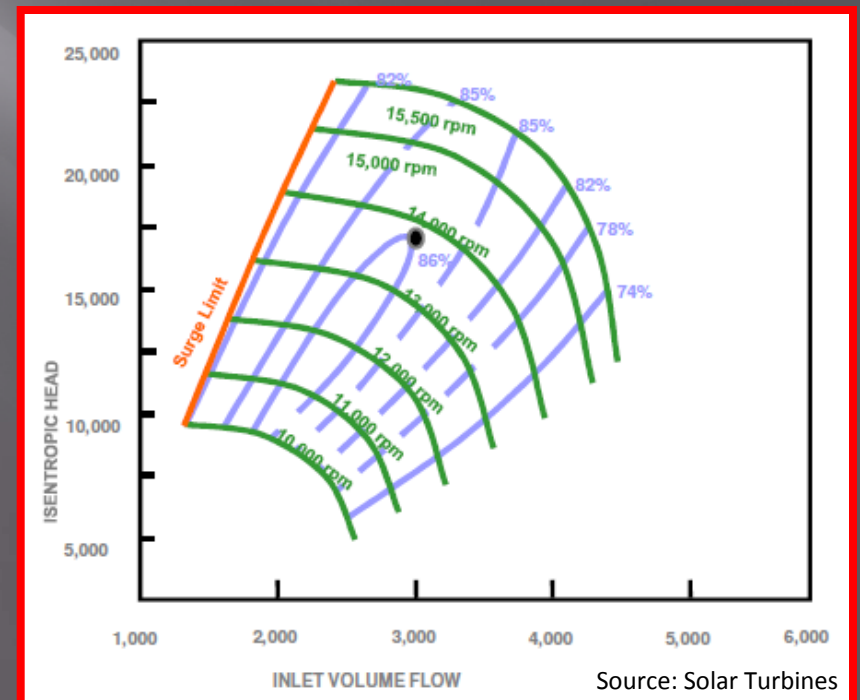
- High reliability
- High compressor efficiency over wide ratio range
- Very flexible (wide flow and ratio range)
- Large no. of legacy integral engine compressors
 - New units no longer manufactured
 - Engine efficiency varies with vintage and retrofit level
 - Various engine retrofits reduce emissions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



Source: ACI Services

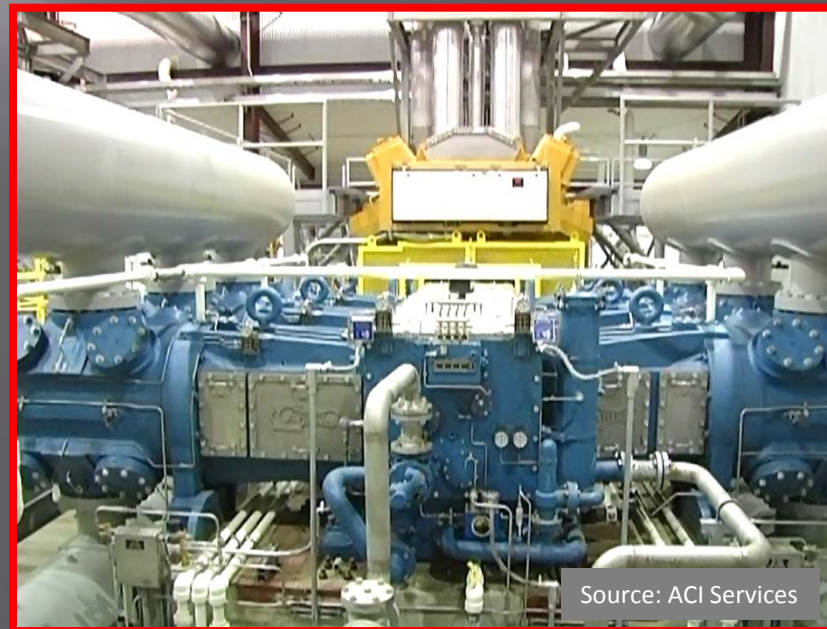
Centrifugal Compressor Equipment

- 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



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

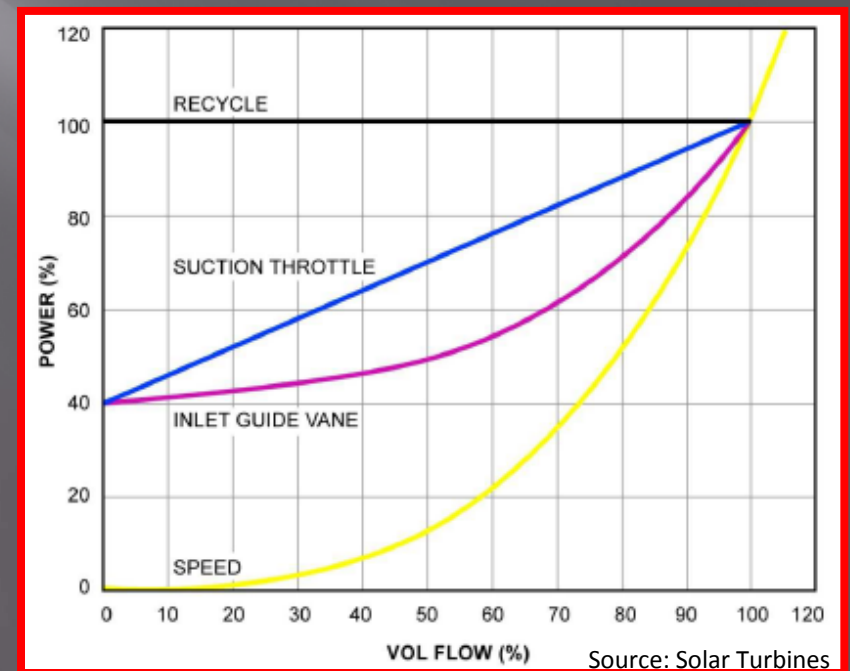
- Improved valves & piston rings
- Better monitoring systems to improve maintenance & reduce internal losses
- Improved rod packing, leakage tracking, better maintenance
- Intelligent PLC automatic unloading control to eliminate suction throttling & bypass (except as last resort)**
- Cylinder upgrades/right-sizing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

** not common in upstream applications
(low hanging fruit?)

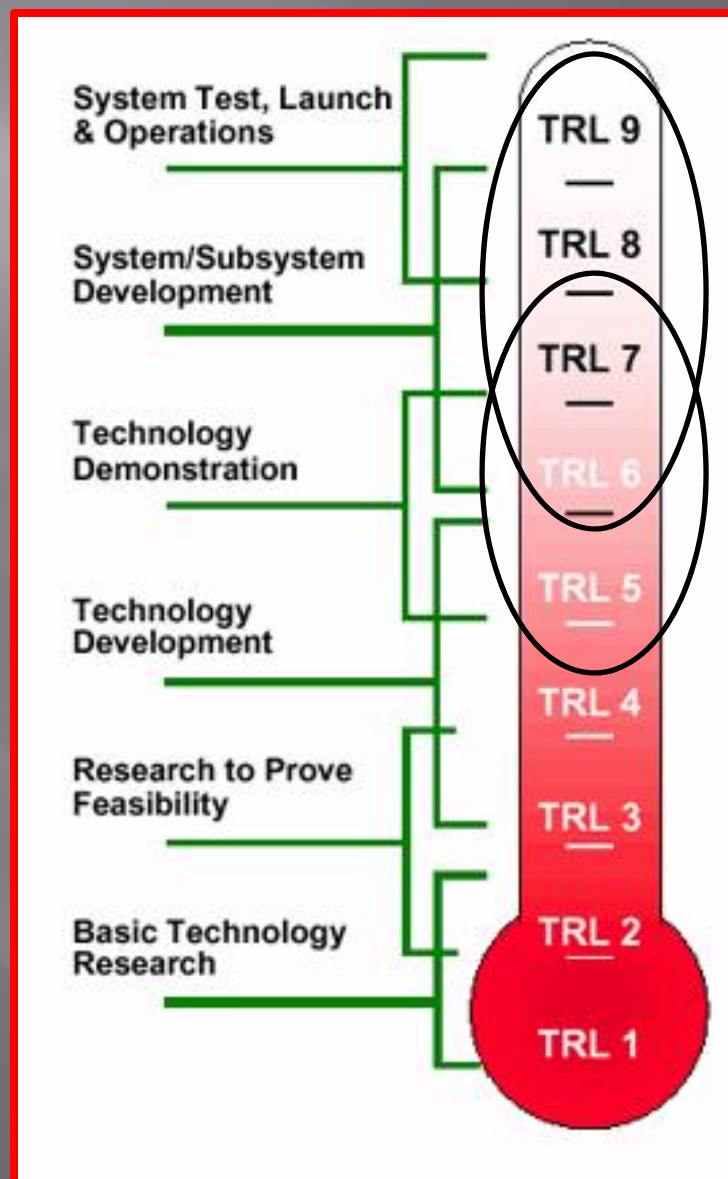


Current Efficiency & Leakage Improvement Options Centrifugal Compressors

- 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



Promising New Technologies / Products



**Technology
Readiness
Level**

7 – 9

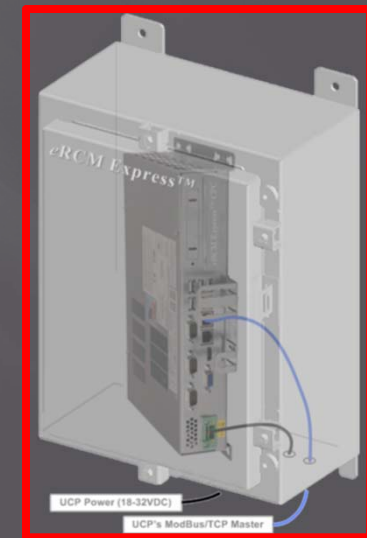
In use

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) **TRL8-9**
 - tunable sidebranch absorber (active pulsation cancellation) **TRL9**
 - pulsation attenuation networks (passive cancellation) **TRL7-8**
 - dynamic variable orifice (adjustable damping) **TRL7**
 - virtual orifice (pulsation cancellation) **TRL7**
 - others reported in GMRC/DOE program 2008-2011 **TRL6-7**
- Efficient cooler fan control **TRL8-9**
 - Variable speed w/o VFD (Voith)



Source: ACI Services

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 **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 **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