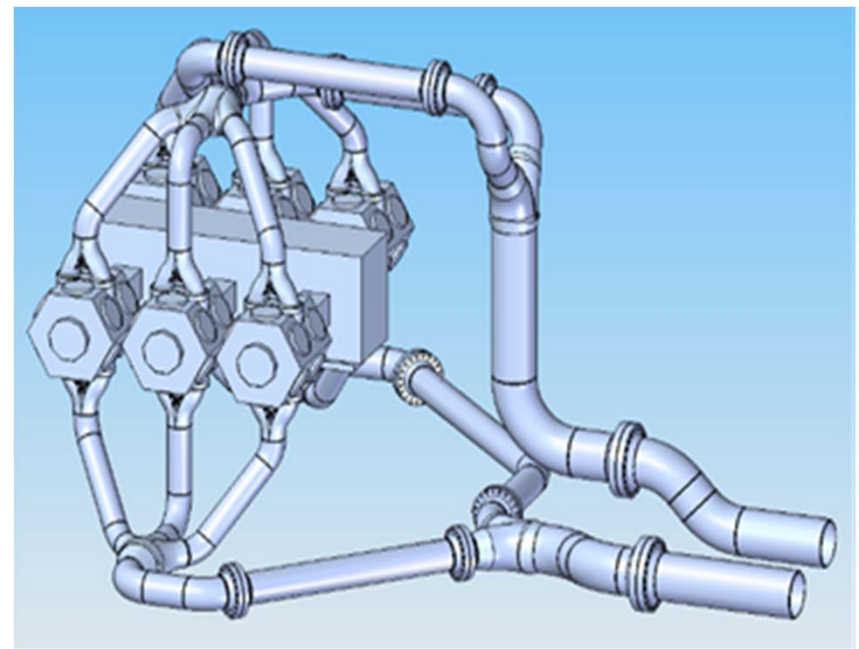
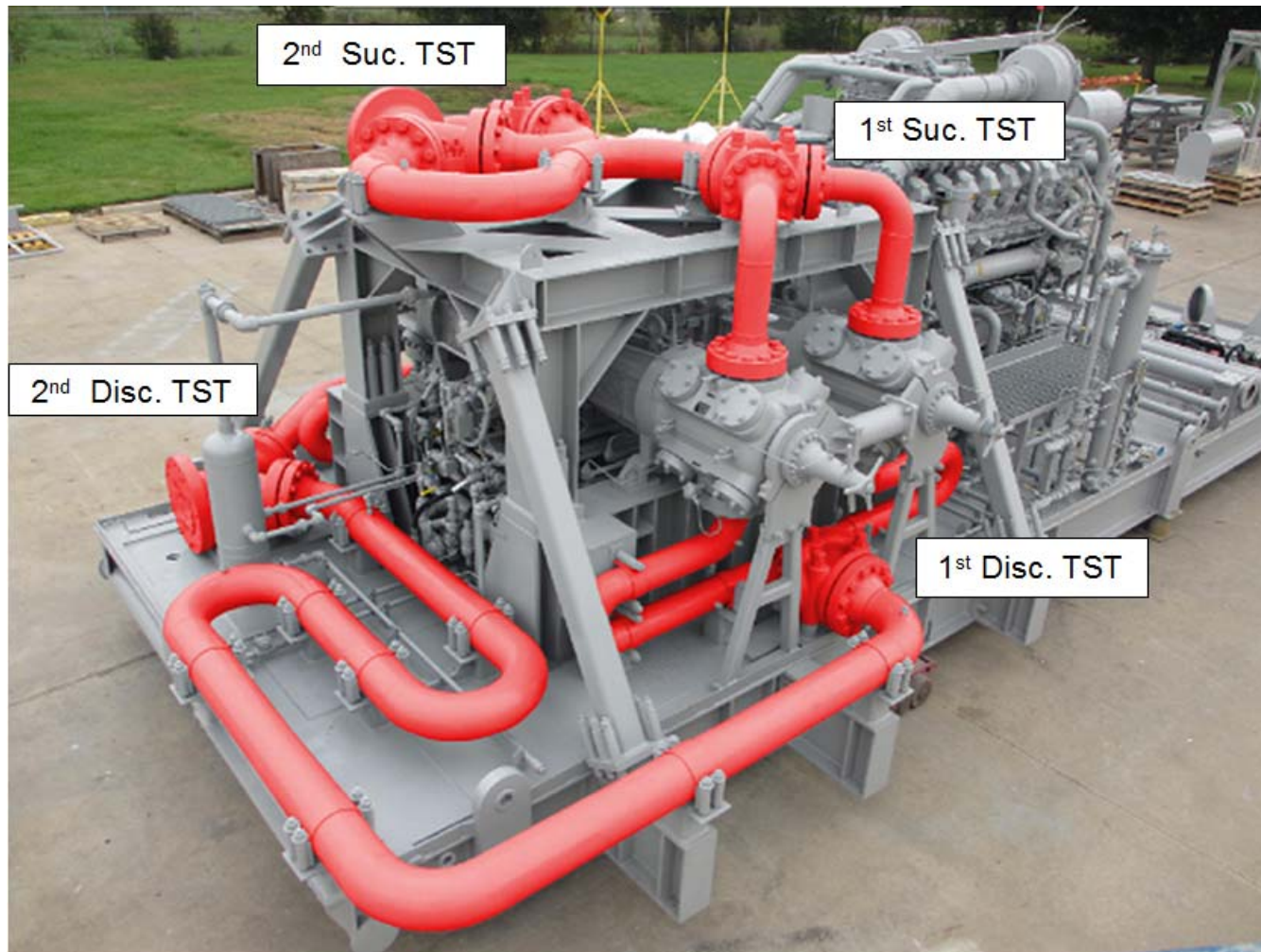


Introduction to Performance Augmentation Network (PAN) High Performance Recip Compressor Manifolds



Williams Midstream Compressor Used for the GMRC PAN Field Test



PANs and Bottles are FUNDAMENTALLY Different

Pulsation Control Bottles

- DISSIPATE 95% of pulsation energy
- **Components**
 - Primary and secondary Bottle volumes
 - Baffles
 - Choke tubes
 - Orifice plates
- **Problems:**
 - Pressure loss
 - Poorly phased cyclical flange pressure that reduces the efficiency of the compressor
 - Bottle vibration problems
- Bottles CANNOT be modified to perform like a PAN

PANs

- RECOVER 95% of pulsation energy
- **Components**
 - **1st TST** junctions recover pulsation energy
 - **2nd TST** junctions join the flows from both sides of compressor and further reduce pulsation
 - **Standard pipe**
 - **OPTIMIZED** TSTs with optimized pipe diameters and lengths
- **Benefits:**
 - **NO pressure loss**
 - **Greatly improved cyclical flange pressure significantly increases compressor efficiency**
 - **Increased flow**
 - **Reduced fuel cost**
 - **Reduced engine exhaust emissions**
 - **Reduced GHG emission taxes**

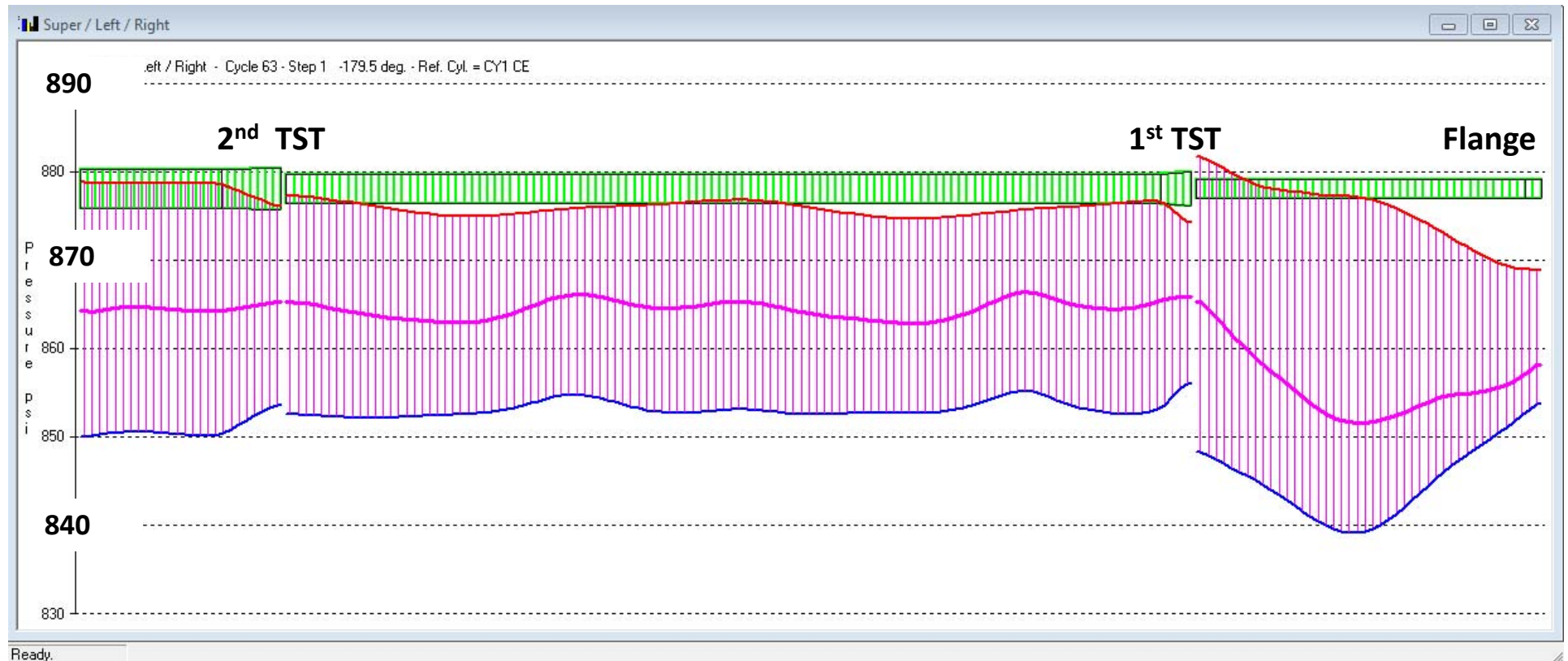
Physics of Pulsing Flow in Pipes

- **There are always 2 Waves propagating simultaneously**
 - One wave travels from left to right
 - The other wave travels right to left
- **What we measure with a pressure transducer is the Superposition Pressure of the 2 Waves**
- **Whenever a Left or Right Wave propagates across an Area Change or Junction, part of the wave continues and part of it REFLECTS in the opposite direction**
- **Simulation/Design software must properly model this physics to accurately predict compressor performance**

Physics of Pulsing Flow in Pipes

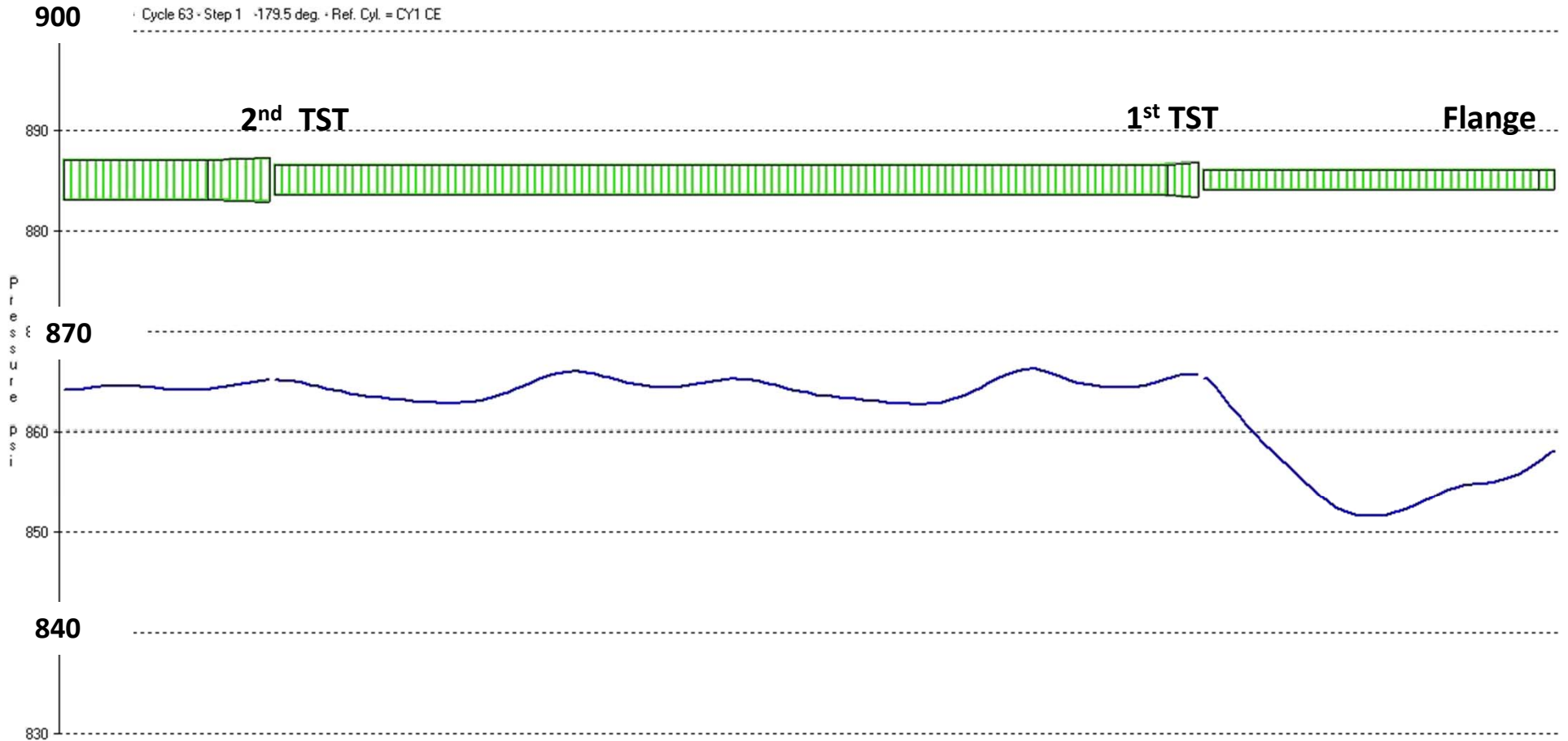
PAN Suction 2 Waves and Pressure VPS Simulation @ 950rpm

Design Pt. 3: 850psig (864.7 psia) suction / 1307psig (1321.7 psia) discharge – fully loaded



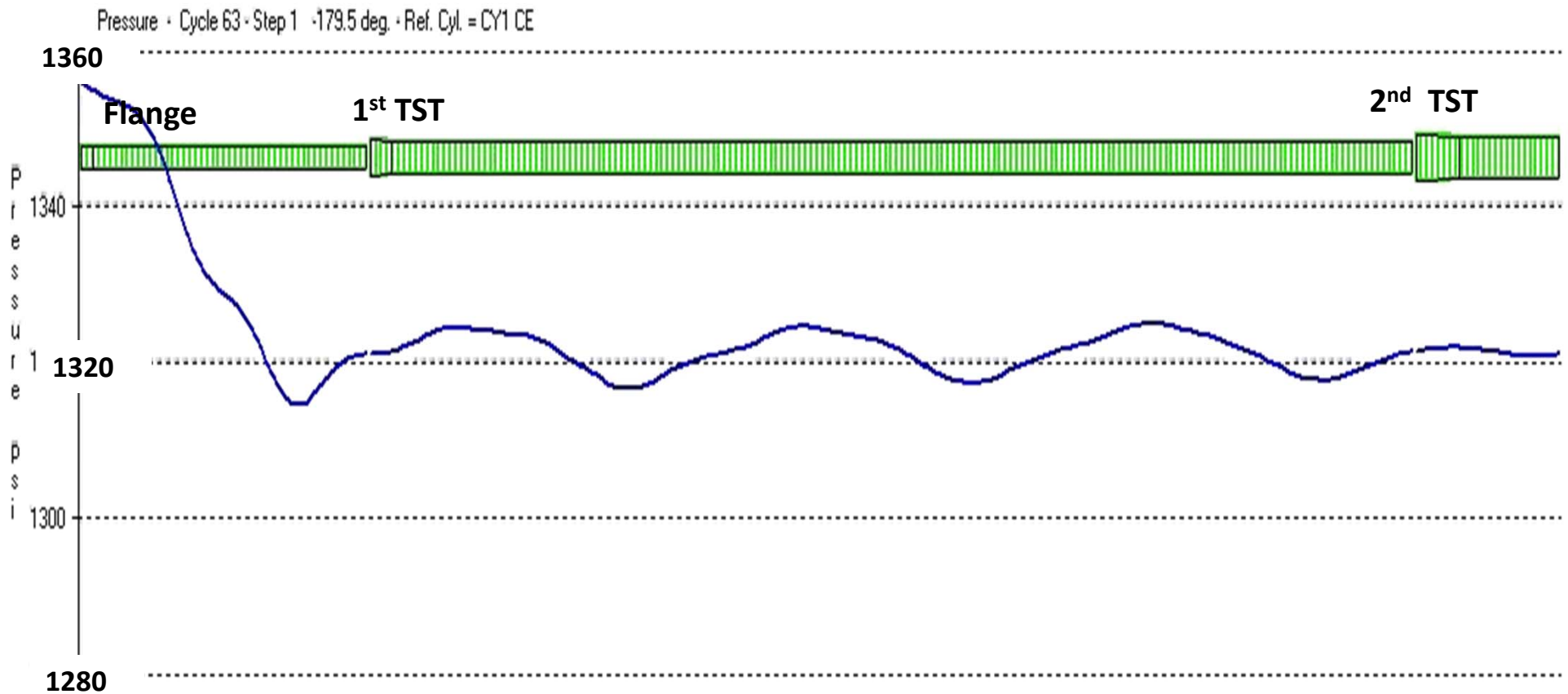
PAN Suction Pressure VPS Simulation @ 950rpm

Design Pt. 3: 850psig (864.7 psia) suction / 1307psig (1321.7 psia) discharge – fully loaded



PAN Discharge Pressure VPS Simulation @ 950rpm

Design Pt. 3: 850psig (864.7 psia) suction / 1307psig (1321.7 psia) discharge – fully loaded

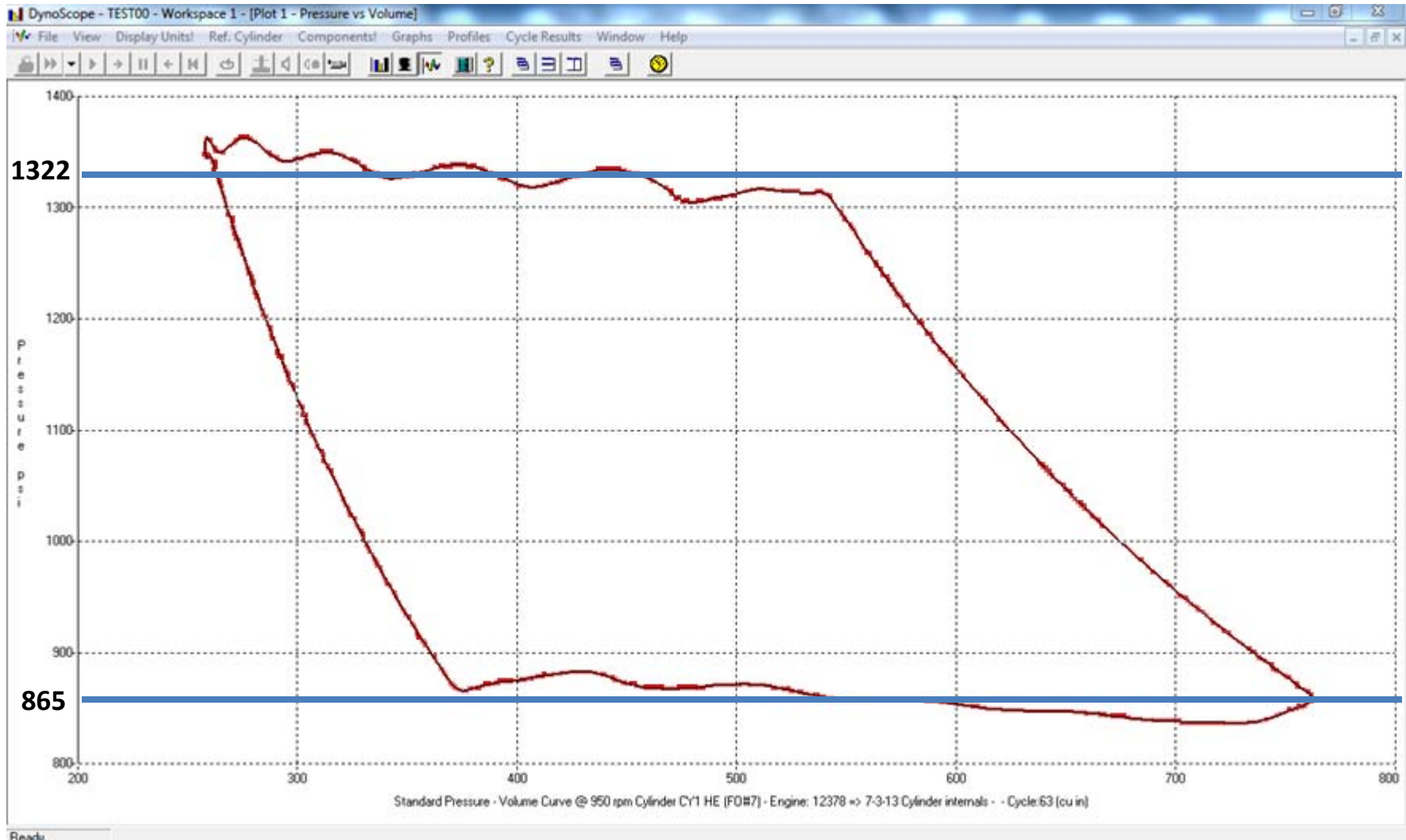


2015 GAS/ELECTRIC PARTNERSHIP

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PAN PV Card VPS Simulation @ 950rpm

Design Pt. 3: 850psig (864.7 psia) suction / 1307psig (1321.7 psia) discharge – fully loaded



Ready

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1st Williams PAN Installed in NE PA Nov. 2014



2015 GAS/ELECTRIC PARTNERSHIP

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**Logged Over 1200 hrs. of Trouble-free Operation
Second PAN Scheduled to be installed April 2015**



2015 GAS/ELECTRIC PARTNERSHIP

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2014 Industry Sponsored Full-Scale Field Test



Gas Machinery Research Council



Proved the Benefits of Manifold PANs

Major Industry Sponsors



Summary of GMRC PAN Field Test Results

- **Ariel JGT/4 with a Cat G3516 rated @ 1380 bhp(1029 kW) @ 1400 rpm**
- **Operating conditions: 450-900psig Suc, 1000-1200psig Disc @ 1400 rpm**
- **Practically Zero Pressure Drop**
- **Pulsations after the Second TSTs were less than 1% of line pressure**
- **Vibration from 1350 to 1400 rpm was within acceptable limits**
- **Efficiency Gains over a hypothetical Zero pressure loss Bottle System**
 - **2.7% at a 2.7 pressure ratio**
 - **6.5% at a 1.7 pressure ratio**
 - **Predicted 15% at a 1.2 pressure ratio**
- **Complete results will be presented at the 2015 GMC**