TC 8-1

“What’s loss got to do with it?”

Experimental setup and analysis of indicated losses in scroll compressors

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Learning Objectives

- Explain the need for Experimental indicator diagram of a scroll compressor
- Explain Hardware and Hardware Setup and data flow for Indicator diagram recoding
- Explain the needs and techniques for synchronization signals to experimentally measure the rotational position of the shaft
- Pressure transducer traces, dynamic calibration, pressure diagram assembly
- Indicator diagram: Classification of losses, real-world examples
- Transient indicator diagram analysis for Digital Scroll Compressor

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Outline/Agenda

PV analysis: Why we need it? What are the limitations?

- Hardware/instrumentation setup
- Synchronization. Non –uniform rotation.
- Pressure trace analysis: Dynamic Calibration. Diagram formation
- Loss definition

Conclusions

Questions

General Compressor Loss Definition

- $\boldsymbol{\eta}_{IS} = \boldsymbol{\eta}_{VOL} \frac{N_{IS}}{N_{COMPR}}$ $\qquad\qquad$ $\boldsymbol{\eta}_{VOL} = \frac{M_s}{V_s \rho_s n}$
- $N_{COMPR} = N_{IND} \frac{1}{1-\boldsymbol{\eta}_{MECH}} \frac{1}{1-\boldsymbol{\eta}_{EL}}$ $\qquad$ $N_{IND} = n \frac{1}{360} \int_0^{360} \sum_1^k (P_i - P_S) \frac{dV_i}{d\varphi} d\varphi$

- PV analysis allows to Experimentally obtain Indicator work and explore its loss components
- Motor losses can be accurately predicted based on motor modelling and motor dyno data.
- Mechanical losses can be calculated

PV Analysis: Why we need it?

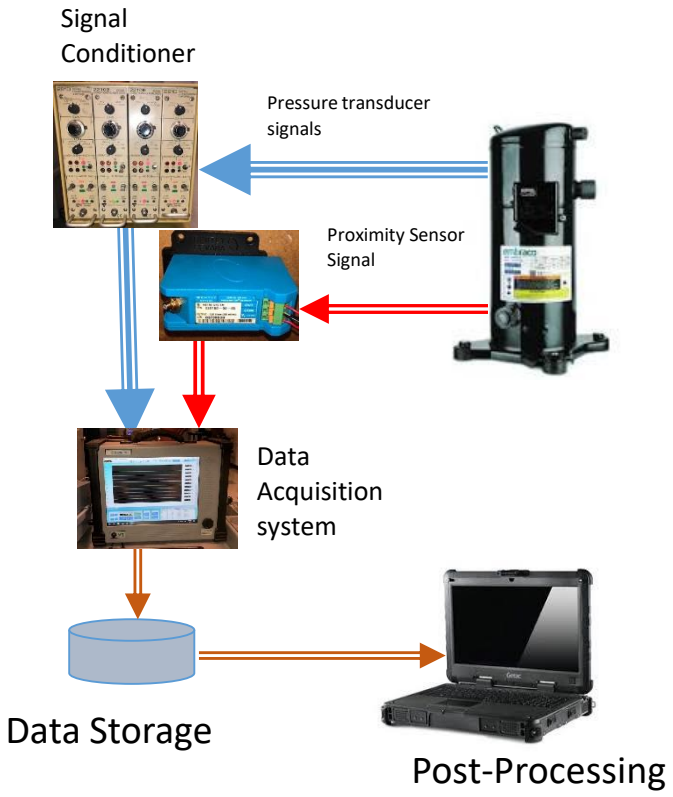
- Better Understand Suction, compression, mixing, Discharge processes
- Understand and address inefficiencies
- Use to tune-up models
- Use for tuning up compliance mechanisms
  - General thermodynamic assumptions:
    - Constant pressure within a control volume
    - Constant temperature within the control volume
    - The volume is defined by calculation and timing signals
- What PV analysis CAN NOT do:
  - Clear separation between leakage and heat transfer
  - Verv difficult to assess pressure distribution within a pocket

PV Analysis: Hardware

- Compressor and a test stand with its "static" measurement equipment
  - ASHRAE 23.1 standard

Instrumented Compressor:

- Equipped with timing mark transduscer(s)
- Instrumented scroll with pressure transducers
- Packing glands to bring signals outside of compressor
- Amplifiers/signal conditioners
- Data Acquisition system
- Data storage
- Data retrieval/post processing software

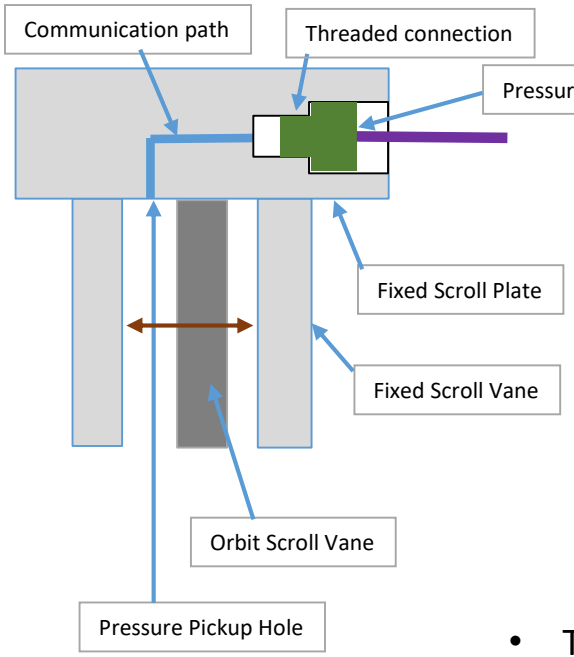


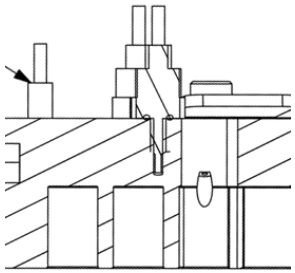
Synchronization and Timing Marks

- Control volume(s) are calculated as a function of crank angle
- Conversion of data from time domain (acquired) to angular domain
- Separate data channel- timing mark from Proximity sensor:
  - Sensing reciprocal motion of Oldham Coupling
  - Sensing rotating component
- Once per revolution- assuming uniform rotation

- Non-uniform rotation can be addressed:
  - Several proximitiy sensors (or multiple signals per revolution)
  - Iterative procedure:
    - Assume uniform rotation, run analysis and calculate gas compression torque within revolution
    - From shaft dynamics calculation, calculate angular acceleration caused by the torque variation
    - By double integration, calculate crank angle Vs time function and repeat computation

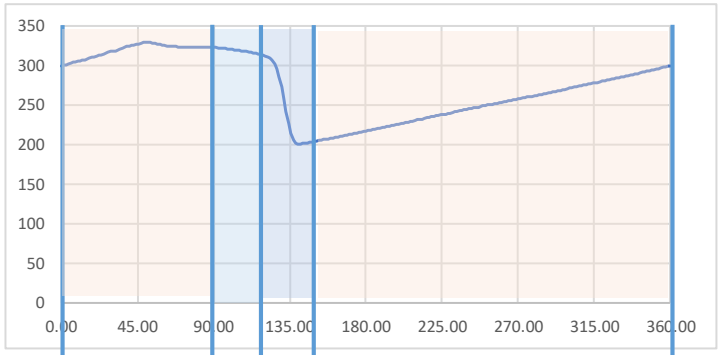
Pressure Transducer Mounting and Communication





Example of the Drawing

Typical Transducer Trace (Synchronized)



Pocket Pressure Reading Zone

Pickup hole closed by Orbit Scroll Vane

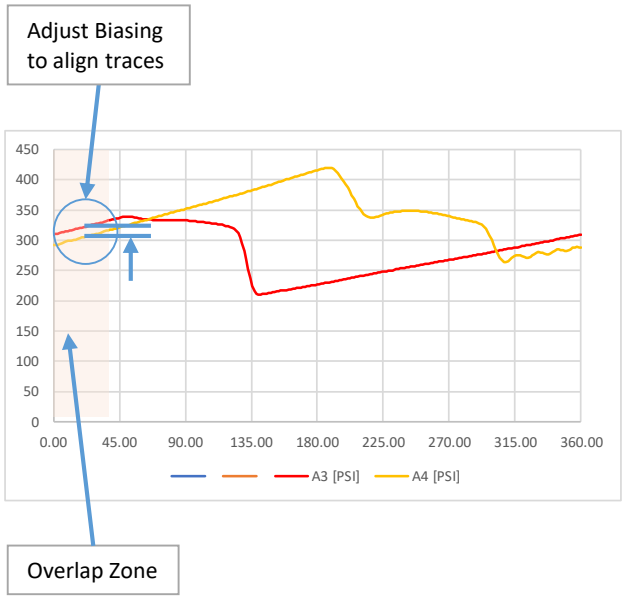
Transient Zone

Pocket Pressure Reading Zone

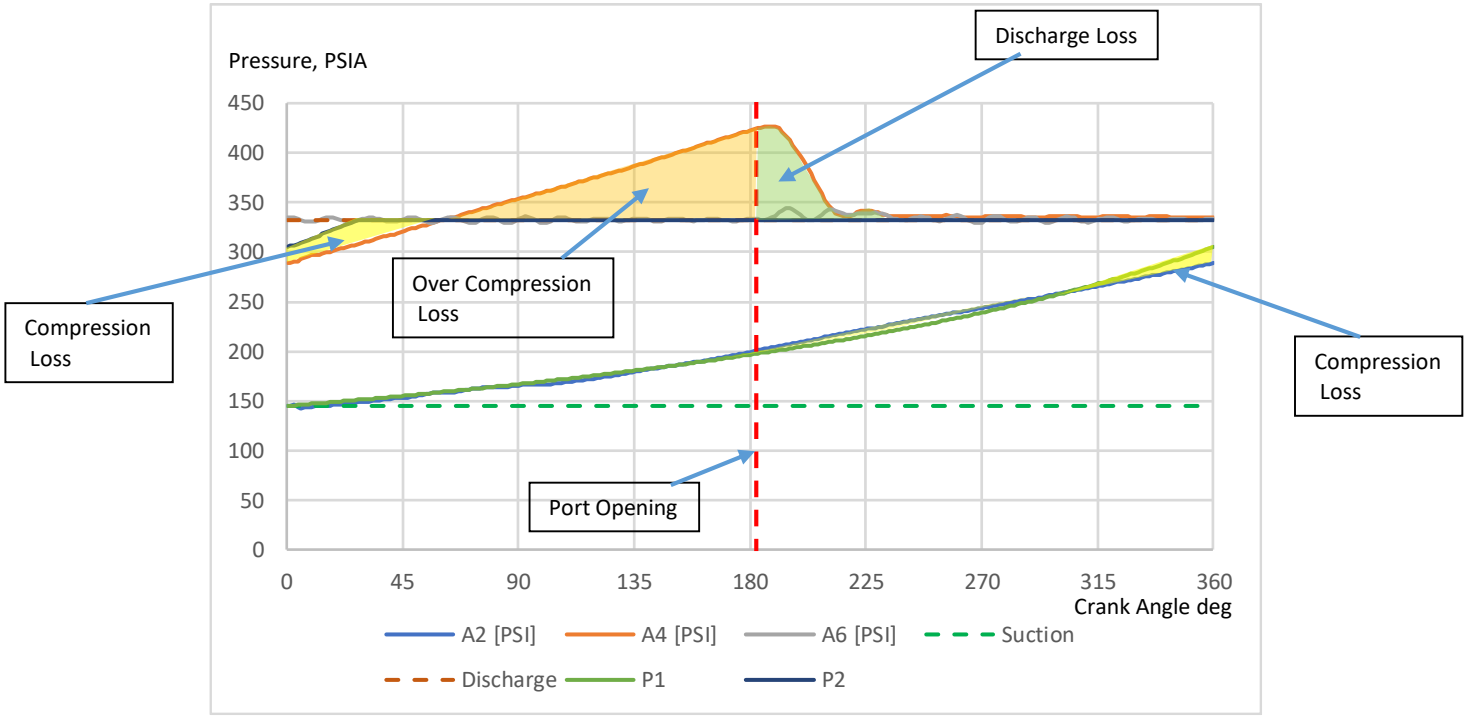
- Typical placement of Pressure Transducers- Fixed Scroll Plate
- Transient Zone depends on length of communication path
- Pressure Transducers need to be placed so that pressure reading zones overlapping

Transducer Dynamic Calibration: Bias and Gain Adjustment

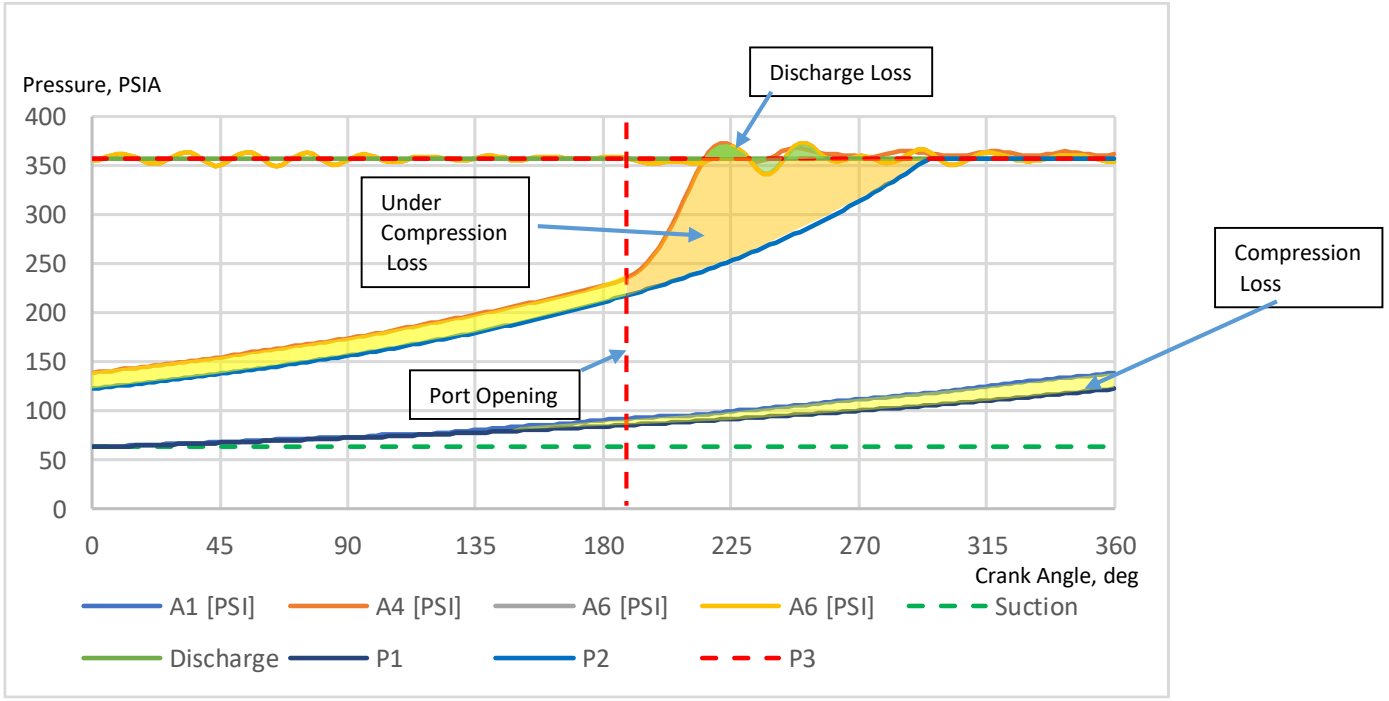
- **Biasing Adjustment:**
  - Select Overlap Zones
  - Adjust biasing: From Suction pocket (Aligned to Suction static pressure)
  - To The next Transducer trace
- **Assemble full diagram- from Suction to Discharge**
- **Gain Adjustment:**
  - Align Discharge overlap zone with Discharge Static Pressure by “stretching” the diagram



Example Of Loss Analysis: Over-Compression

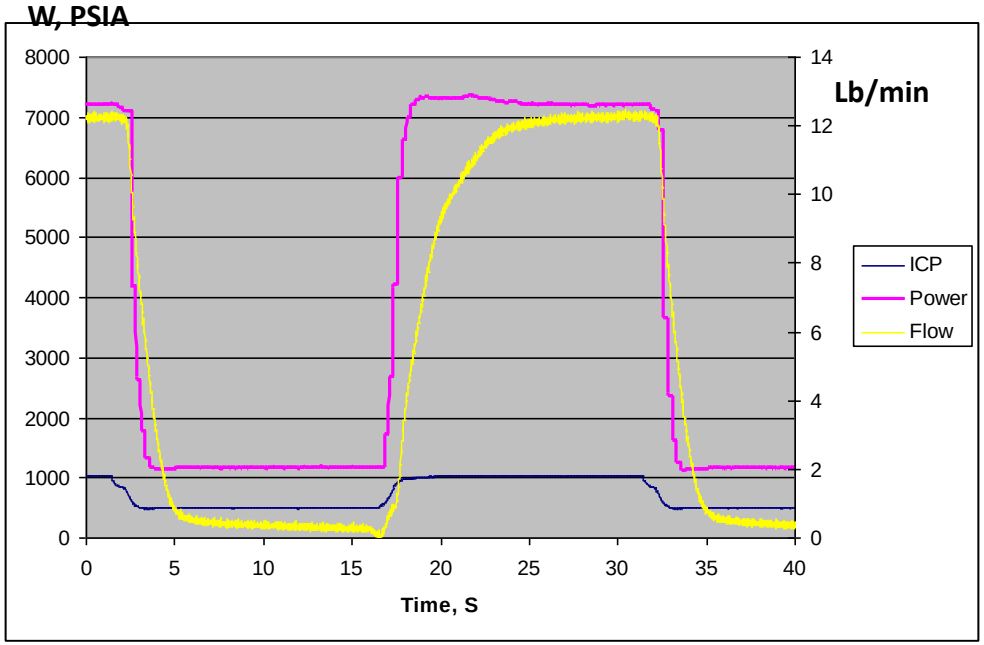


Example Of Loss Analysis: Under-Compression

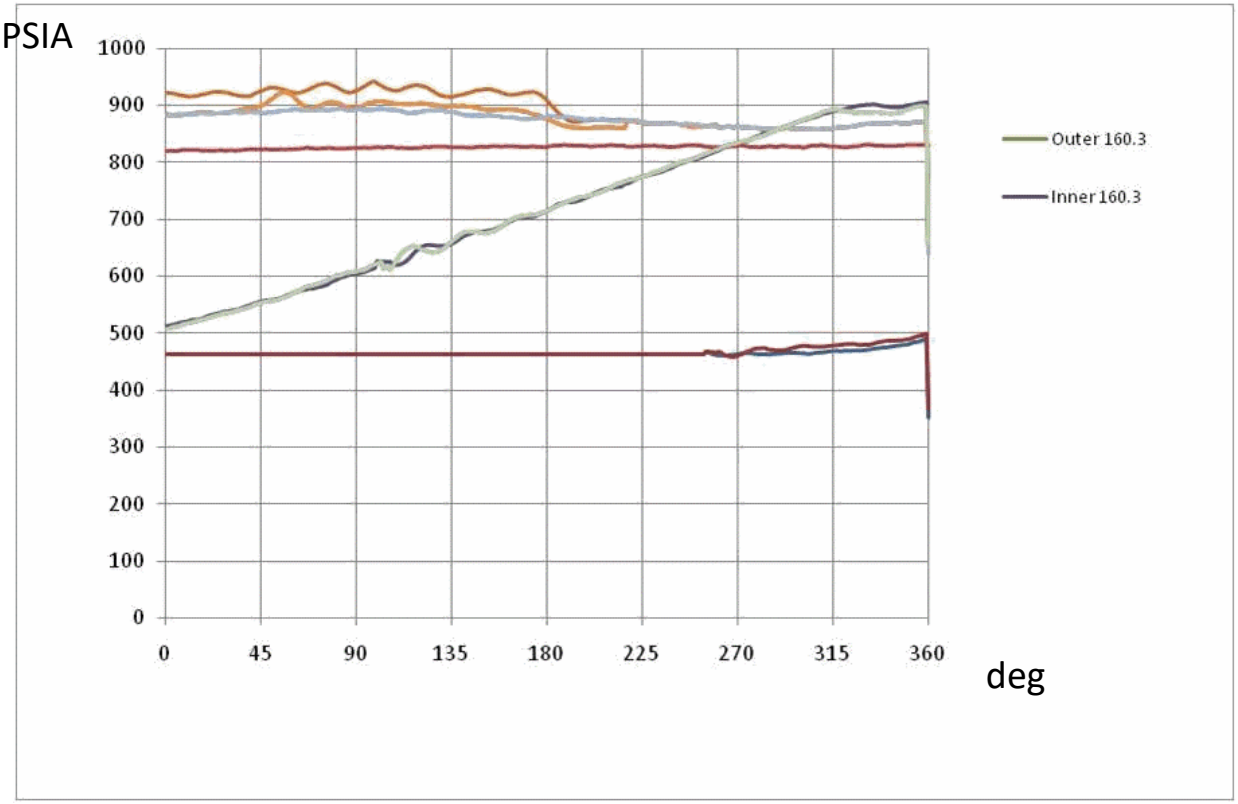


Transient Analysis Example: Digital Scroll

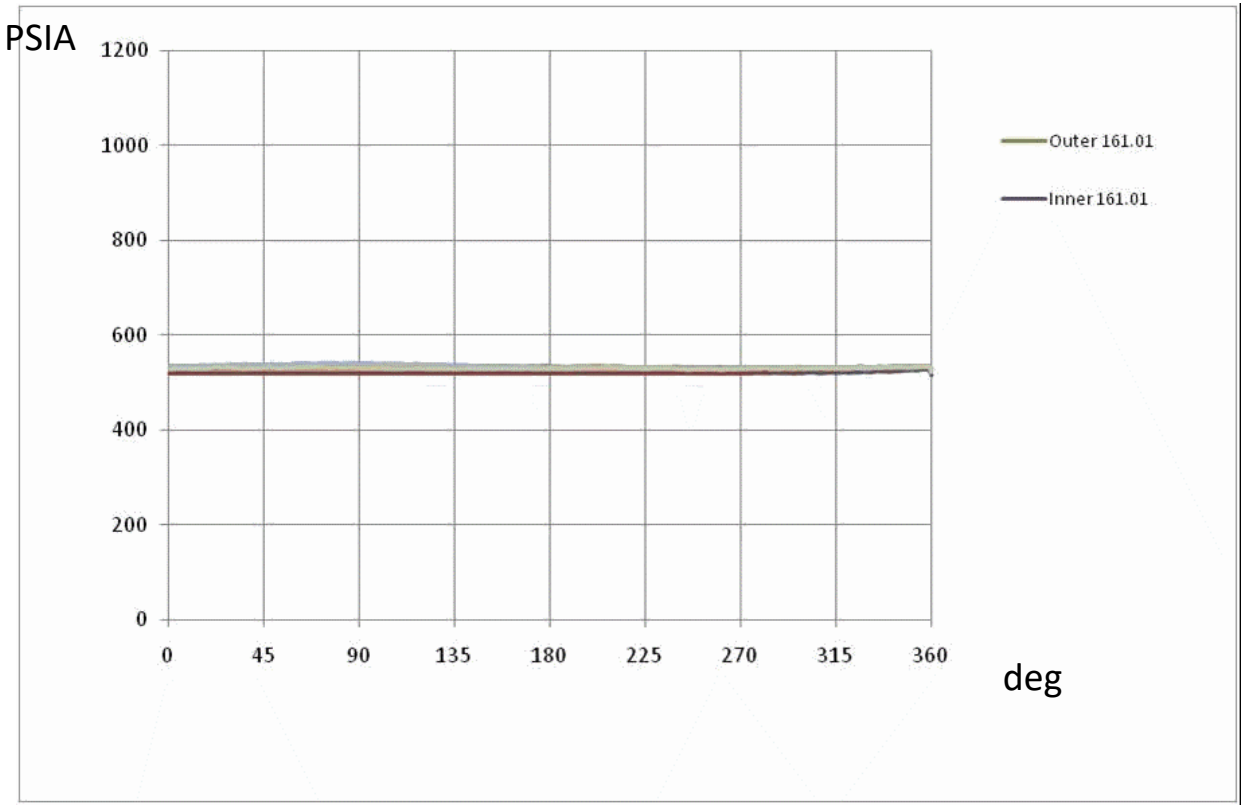
- Analysis was performed for Transient behavior
  - Instantaneous Power (from Yokogawa) and Mass Flow (from Micro-motion) are recorded
  - Voltage from unloading solenoid was recorded
  - Used as a triggering signal to determine loading/unloading events
  - Determined time delay of Power and Flow reaction Vs. Triggering signal
  - Integrate Instantaneous Power and flow over several cycles
    - Calculate Modulated Capacity
    - Calculate Modulated Efficiency
  - Pressure traces/PV analysis:
  - Record traces for 100 revolutions from the triggering signal (loading/unloading signal to solenoid)
  - Perform consecutive analysis for each of the revolution (frame by frame)



Transient PV Diagram: Unloading (84 revolutions)



Transient PV Diagram: Loading UP (80 revolutions)



Conclusion

Techniques illustrated above allow for performing PV analysis on a scroll compressor.

It is a valuable tool to tune up the compressor:

- Optimizing scroll profile
- Porting
- Variable volume ratio valves- location and design
- Axial balancing

Transient analysis can help to evaluate transient compressor behavior

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Questions?

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