METS III
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Root Cause Analysis of vibrations in a Roots Blower system

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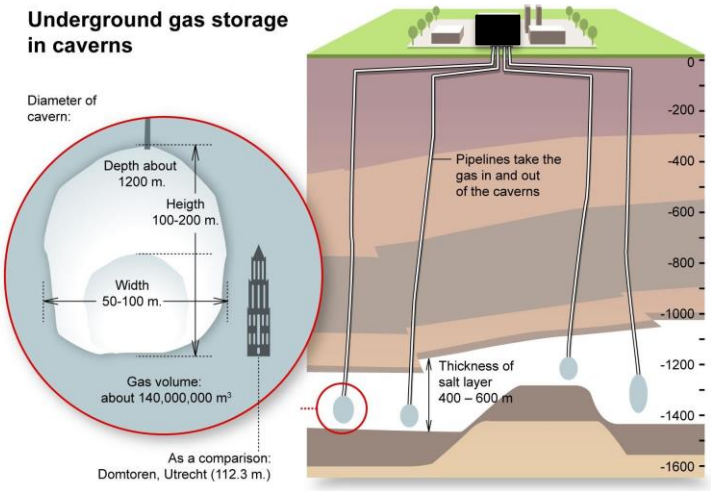
Problem description

- A roots blower system is suffering from excessive vibrations
- A temporary work-around enabled the operation of the plant, at a large expense of additional power consumption
- The fundamental mechanism of the observed vibrations was insufficiently clear, and there was an urgent need for an effective solution strategy

Underground Gas Storage (UGS)

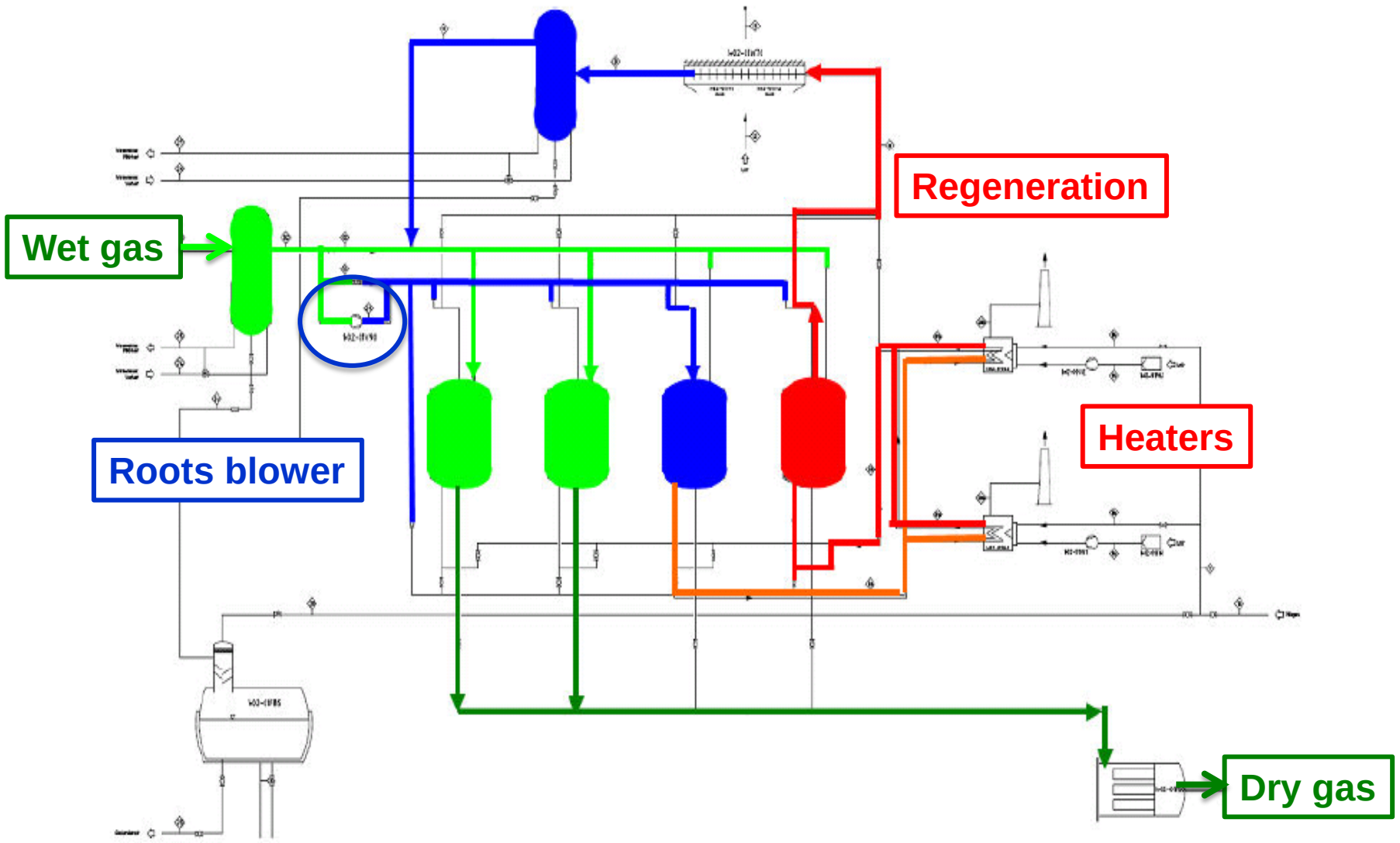
- Large new UGS infrastructure (2011, Central Europe, $2*10^9$ m^3 storage capacity)
- To ensure sufficient buffer capacity upon high demand, and for gas trading purposes
- Storage in depleted natural gas caverns
- Challenging application, requiring high availability of rotating equipment



Drying of the gas

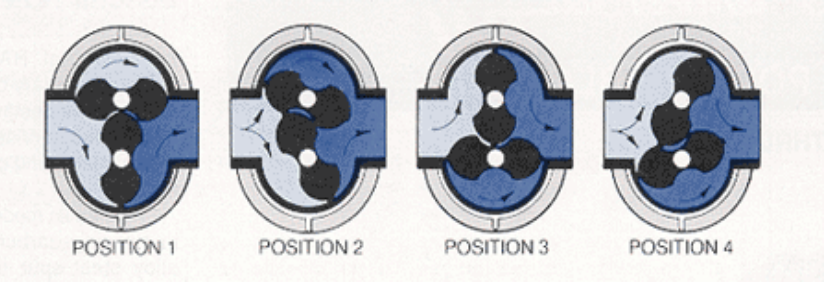
- Stored gas contains excess liquid; before injection the gas must be dried
- Adsorbing technology using silica gel grains is adopted
- Requires regeneration, using recirculation loop with heaters and separators
- Roots blower is used to compensate for the additional pressure loss

System overview



Roots Blower

- Newly installed positive displacement machine
- ‘2D equivalent’ of screw compressor
- Low pressure ratio
- Variable speed
- Unsteady flow → gas pulsations

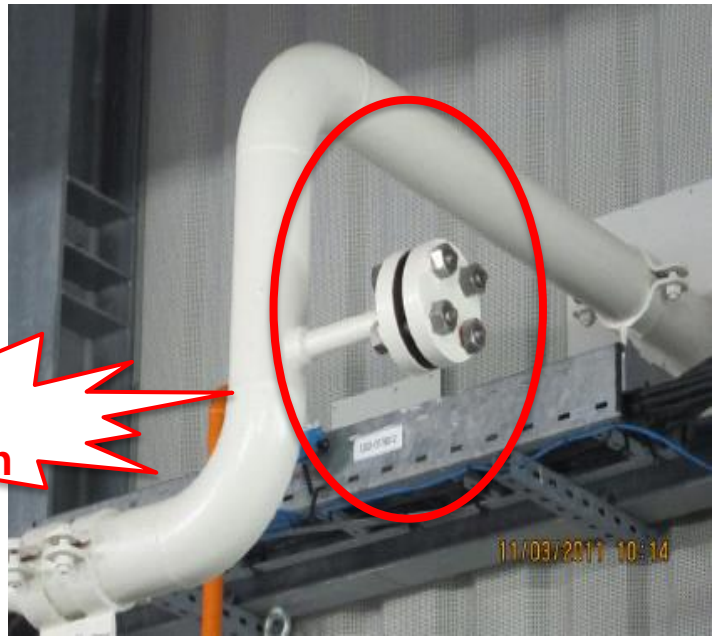


High vibrations on the piping

- Preliminary scan at site visit: vibration levels and spectral signature
- Unallowable levels (>> guideline from European Forum for Reciprocating Compressors)
- Evident relation with blower speed
- Side branches, liable to fatigue failure

Part	Horizontal compressors [mm/s RMS]		
	Key zones		
	A/B	B/C	C/D
Foundation	2.00	3.00	4.5
Frame (top)	5.33	8.00	
Cylinder (lateral)	8.67	13.0	
Cylinder (rod)	10.67	16.0	
Dampers	12.67	19.0	28.5
Piping	12.67	19.0	28.5

Urgent correction



Preliminary conclusions

- Design philosophy did not consider ***pulsating service***
  - Design is a copy of similar adsorber systems *without root blower*
  - No pulsation dampers
  - No restriction orifice plates
  - No ‘dynamic’ supporting layout
  - No alarm from roots blower vendor

- Temporary work-around; pressure loss for regeneration is compensated by downstream turbo-compressors

Proposed RCA and solution strategy

- Detailed pulsation and vibration measurements
- Numerical modelling and comparison with measurements
- Evaluation of the solutions with simulation models:
  - Solutions based on overall design for service with ‘positive displacement machinery’
    - Pulsation dampers
    - Orifice plates
  - Numerical acoustic optimization
  - Numerical mechanical optimization

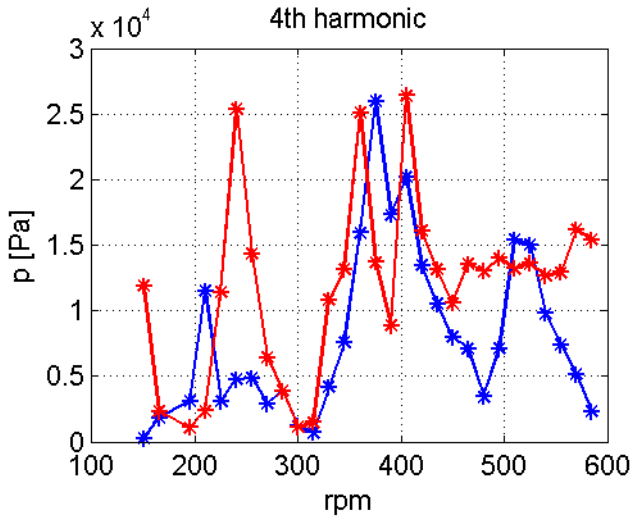
Field survey

- Systematic scan over process conditions
- Low (33 bar) and high (55 bar) pressure
- Full speed range: 150-690 rpm
- Simultaneous recording of pulsations & vibrations

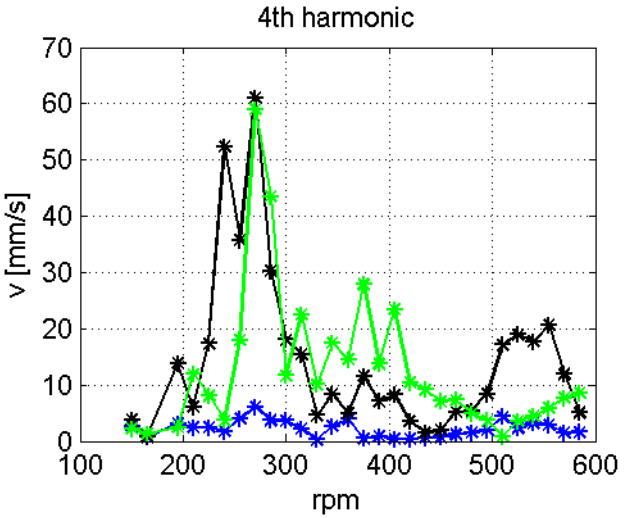
Field survey

- Unacceptable pulsation levels
  - Strong resonances, 2* limits in API 618
- Unacceptable vibration levels
  - Strong resonances, up to 60 mm/s RMS, dominated by 4th and 8th order
  - Tripping of the roots blower
- Effect of the *mechanical resonances* appears most prominent

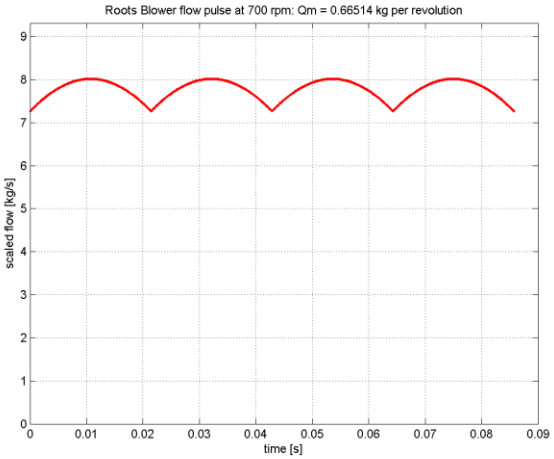
Pulsations, **suction** and **discharge** side



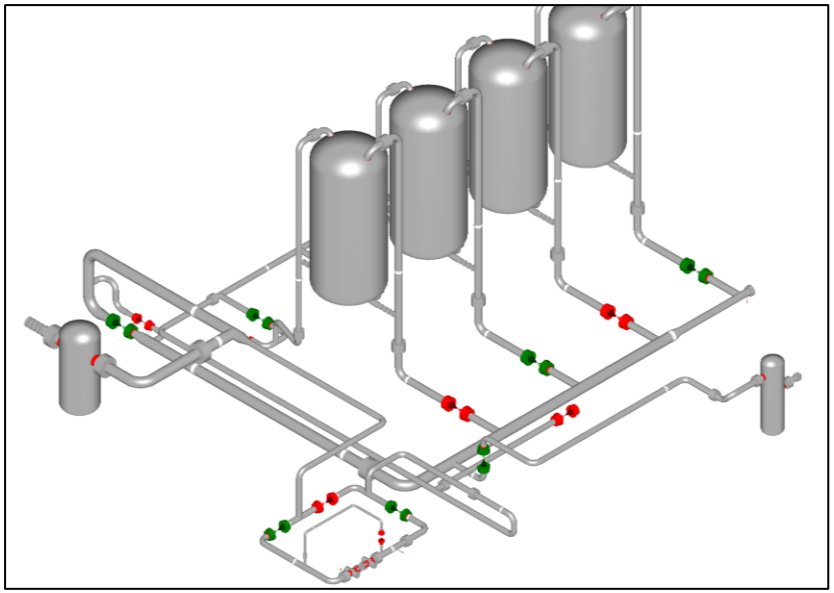
Vibrations at suction side, 3 directions

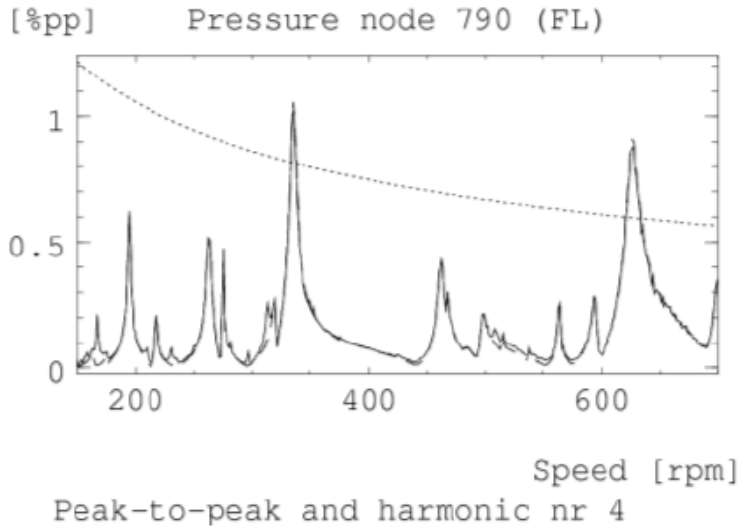


Pulsation analysis



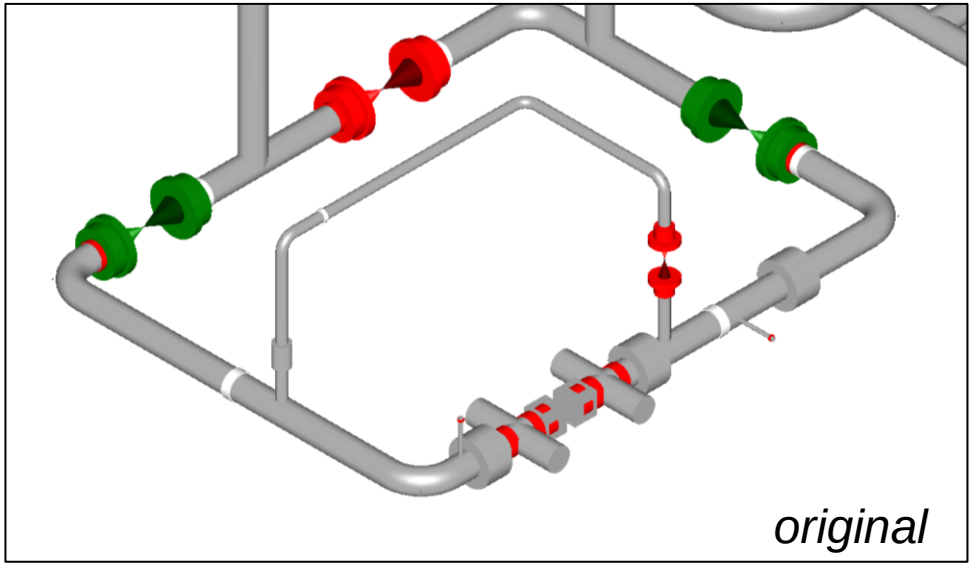
- Analysis with 1D pulsation model
- Generic model for blower pulses
- Matched with the measured pulsation levels
- Calculation of all configurations, full speed range
- Global trends in the simulations are comparable with the measured trends

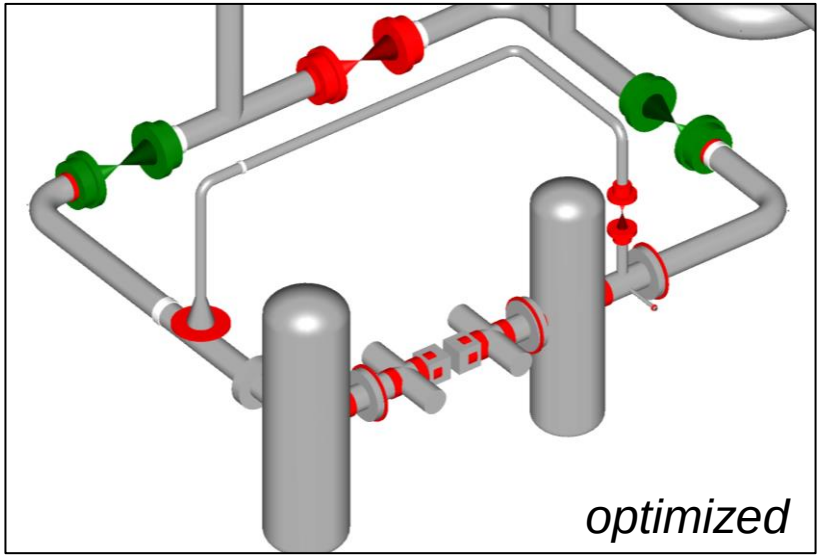




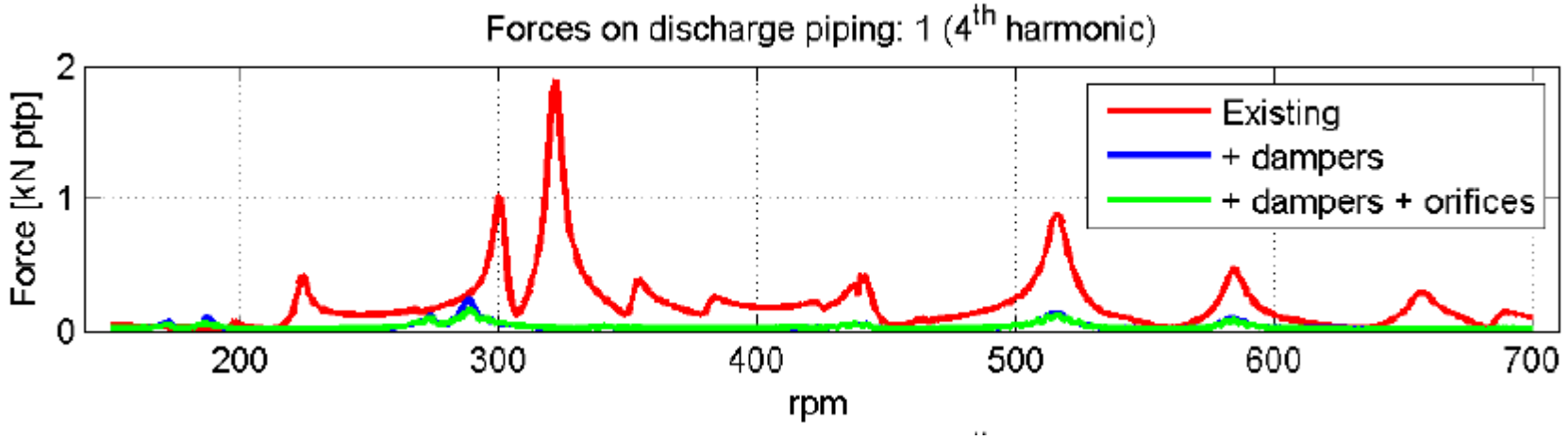
Numerical optimization steps

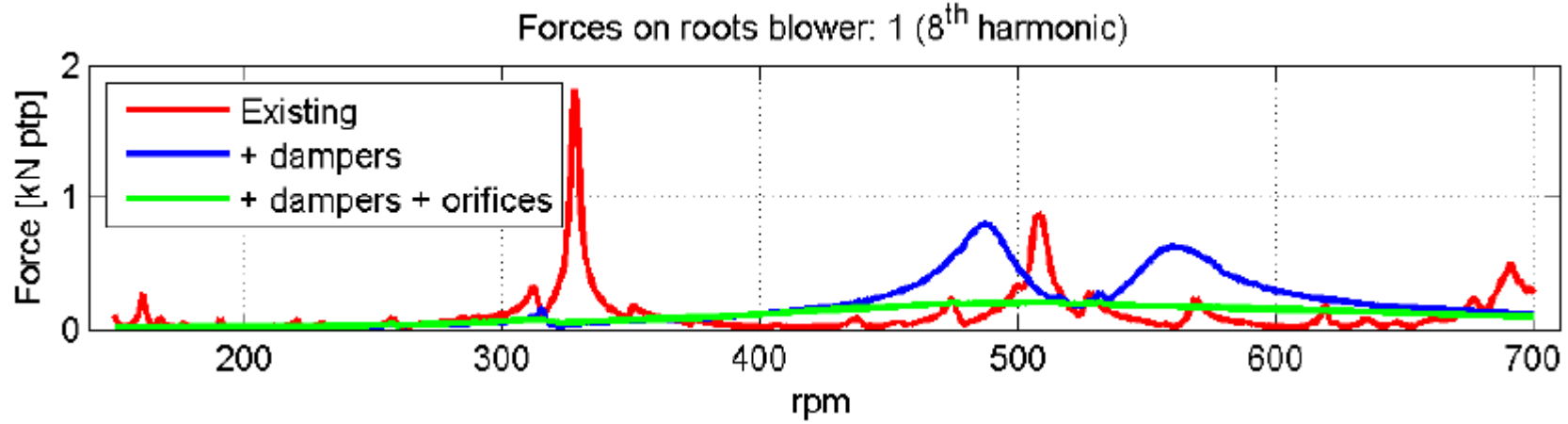
- Pulsation dampers at inlet and outlet
- Restriction orifice plates
  - Significant suppression of acoustic resonances
  - Marginal negative effect on pulsation source strength, due to increased Δp over blower
- Evaluate impact on pulsations and shaking forces





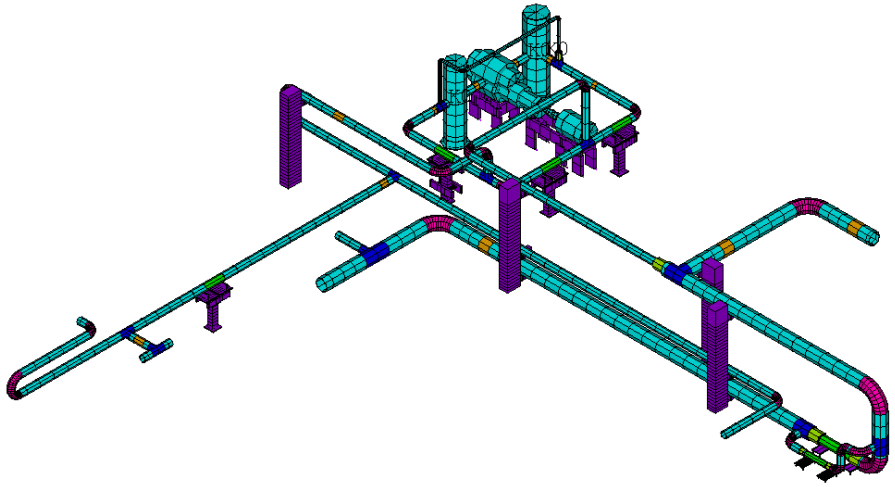
Simulation results

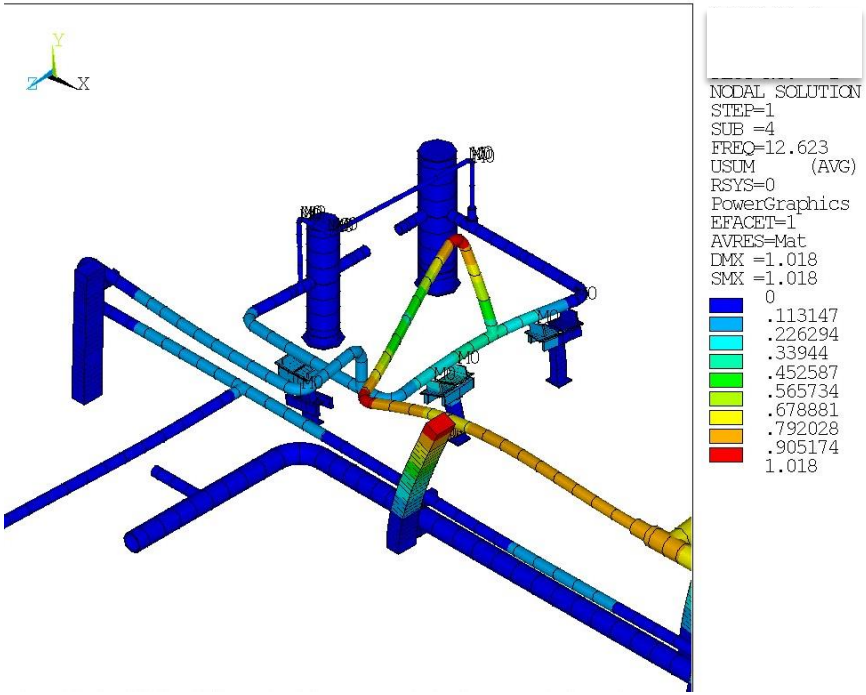




Mechanical response analysis

- FEM model used for analysis (beam-type)
- Pulsation-induced shaking forces are applied to model
- Calculation of worst-case conditions
- Used to optimize supporting layout

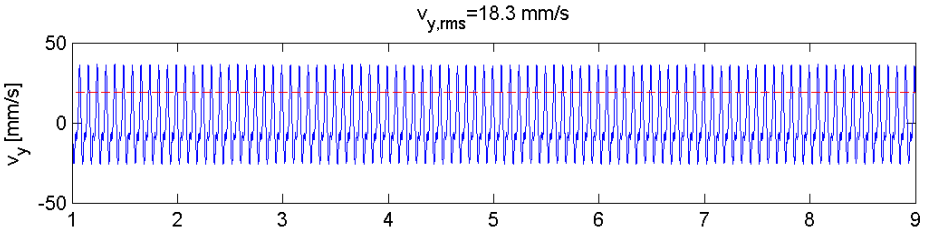


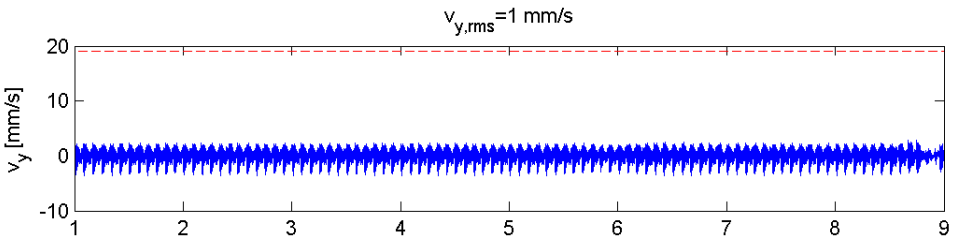


Supporting layout

measurement on pipe shoe

measurement on support beam

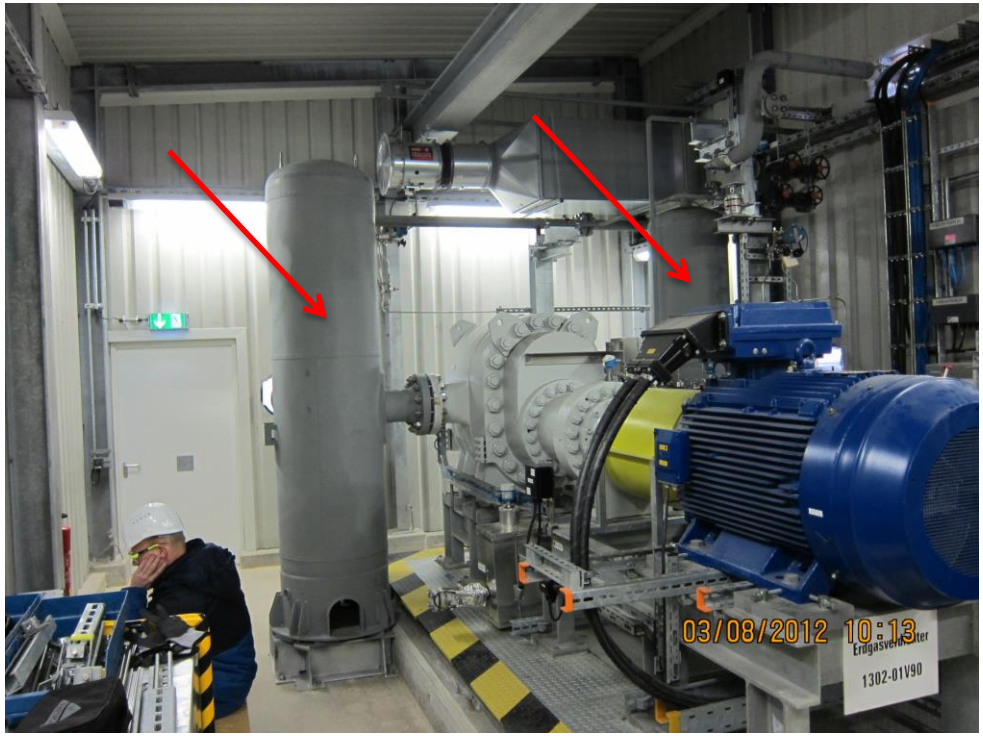


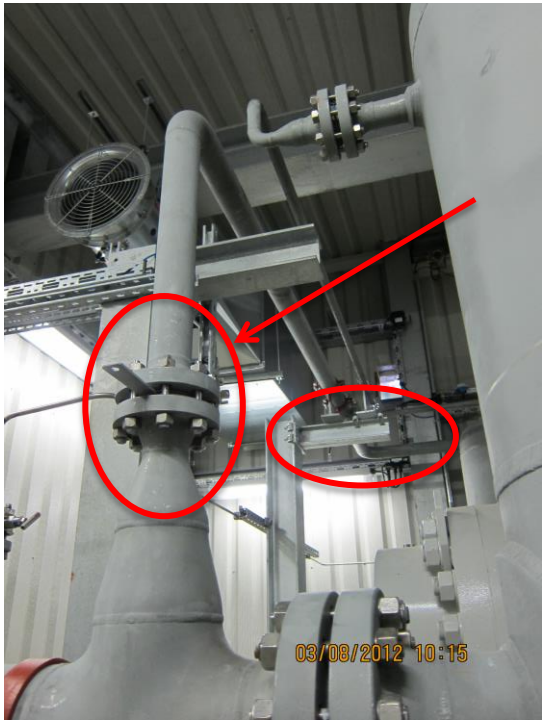


→ Support is loose, shall be improved

Implementation on site

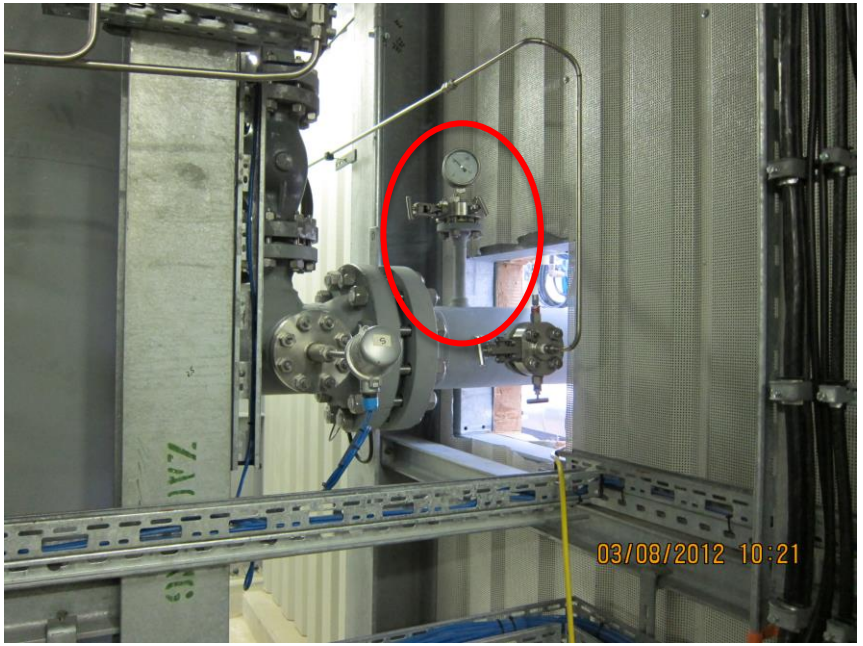
- Pulsation dampers were designed and constructed within short time frame, (< 4 months)
- Orifice plates, bypass line modification and improved supporting





Verification of vibration levels

- Significant reduction on piping and roots blower
- No tripping of the roots blower
- Maximum vibration level is 20 mm/s
- Based on numerical analysis; no integrity issues
- At small bore side branches (on new pulsation dampers) some issues remain

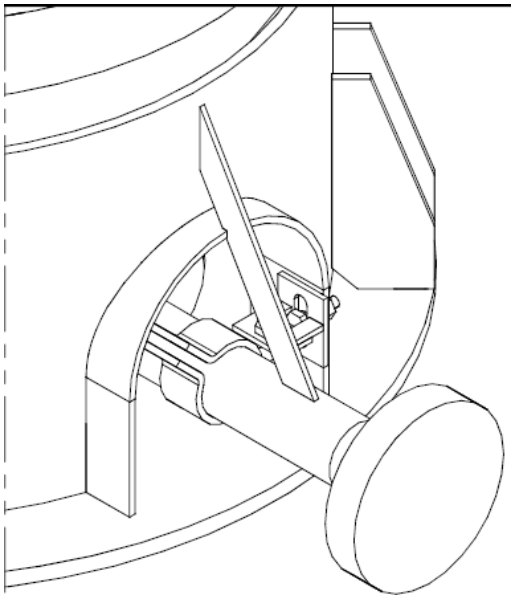


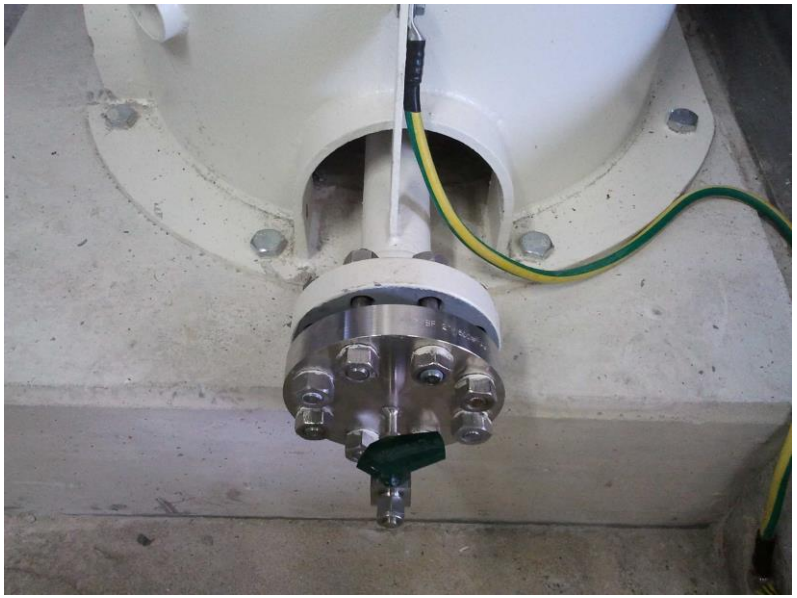
Bracing of small branches not adequate

- Bracing must be stiff, compared to the branch
- In two directions
- Reduce length and/or overhung mass

Final layout

- Final verification on site
- Successful commissioning of gas drying facility, including the roots blower system
- Adequate performance over full scope of operation





Lessons learned

- Roots blowers are pulsation machines!
- A careful design can resolve the pulsation and vibration issues
- However, prevention is better than cure
- Reduction of pulsations by means of dampers and orifice plates is an effective control strategy
- To improve existing mechanical layout is challenging
- Not trivial to ensure adequate bracing
- Combination of measurements and numerical analysis powerful tool to identify and mitigate pulsations and vibrations