Adikari Wisesa
INDONESIA

# WEBINAR MAINTENANCE SERIES

# PIPING VIBRATION INTEGRITY ASSESSMENT

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# Outline

First Session

- Introduction to Piping
- Piping Vibration Integrity Assessment (PVIA)
- PVIA Phase

Second Session

- Measurement Technique
- Case Study

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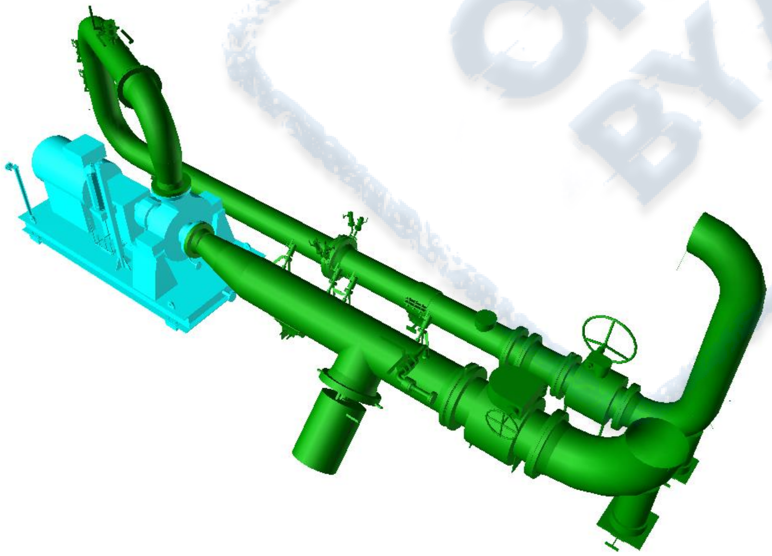
# First Session

# Introduction to Piping

- *Piping is a system of pipes used to convey fluids (liquid and gases) from one location to another. The engineering discipline of piping design studies the efficient transport of fluid.*
- *Piping systems are like arteries and veins. They carry the lifeblood of modern civilization.*



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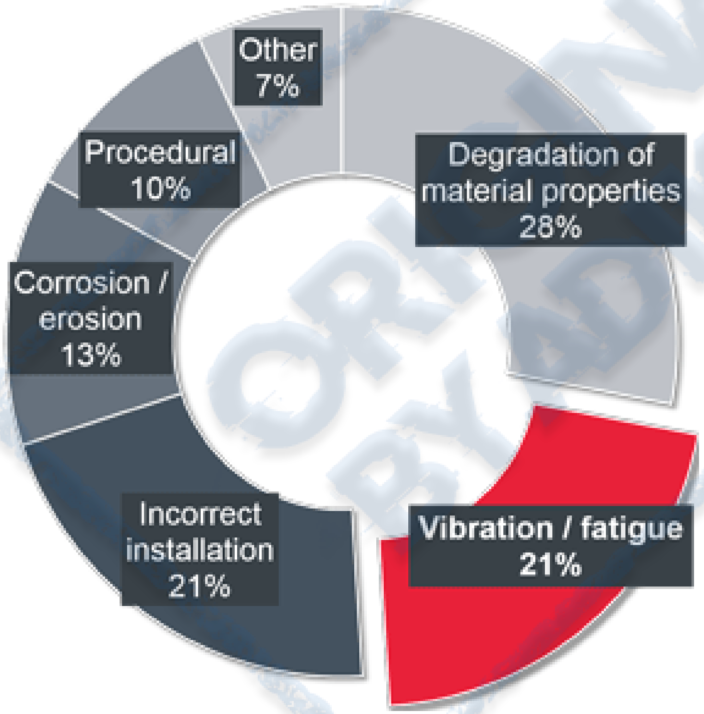
# Introduction to Piping Vibration Integrity Assessment (PVIA)

What is vibration on piping?

Why does it happen?

What the effect?

How to avoid?




Pipe vibrates not only from inside/fluid but also propagates from others

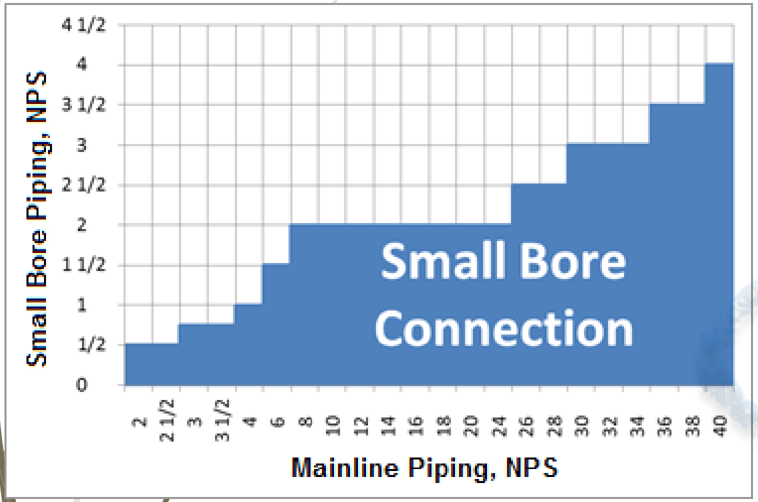
- Other pipe
- Near equipment
- Deck/Support

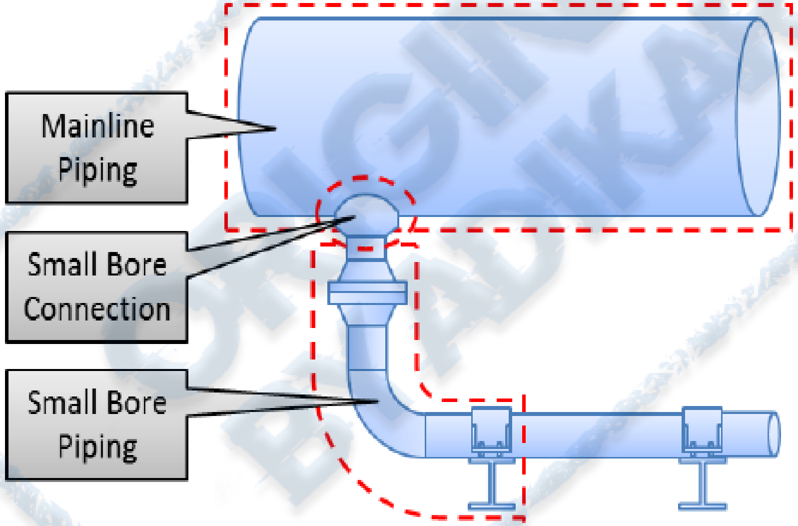
Can cause fatigue failure due to vibration

Avoid and mitigation?

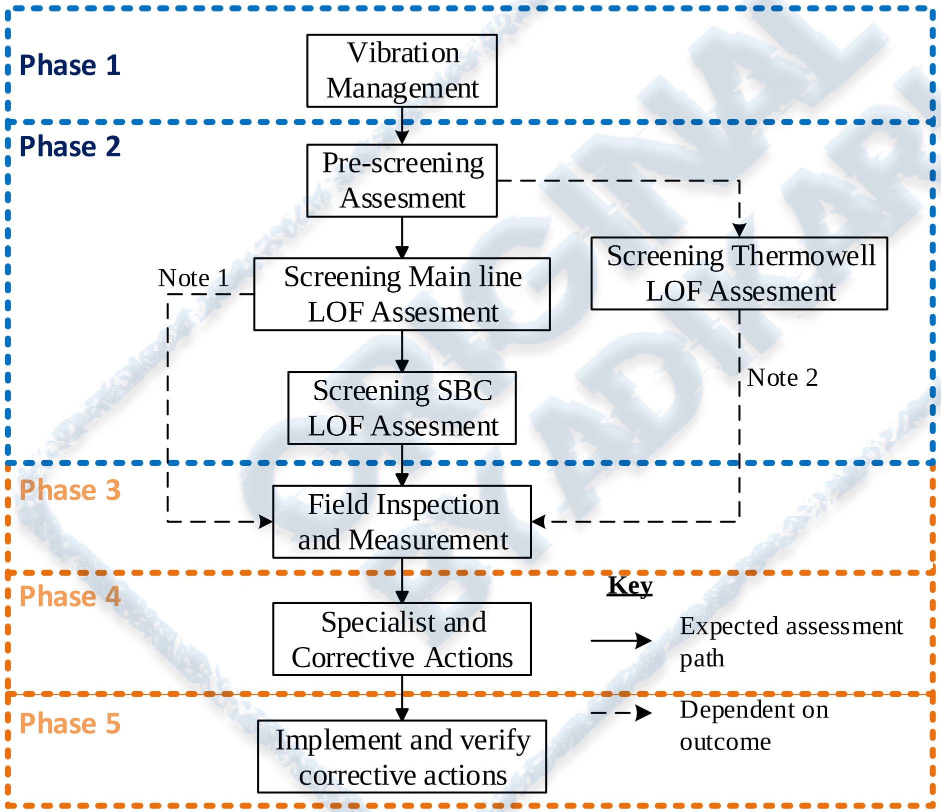
- Diminish the cause
- Change layout of pipe or support
- Vibration monitoring

# Introduction to Piping Vibration Integrity Assessment (PVIA)




# PVIA Phase




Note 1 If LOF score greater than 0.5
Note 2 If LOF score is 1.0

# Pre-Screening and Screening

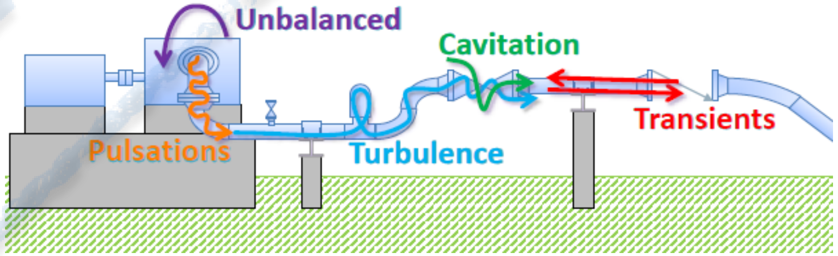
- Fluid Kinetic Energy
- Mechanical Excitation
- Pulsation
- High Frequency Acoustic
- Surge/Momentum
- Cavitation and Flashing

**Pre-Screening**

The goal is to identify potential LOF on the pipe

**Screening**

The goal is to quantitize the number of LOF on the pipe

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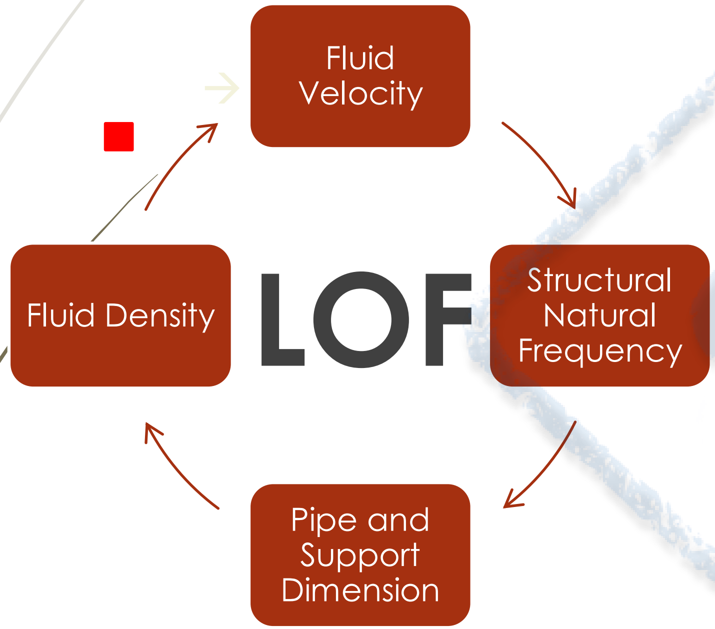
# Fluid Kinetic Energy

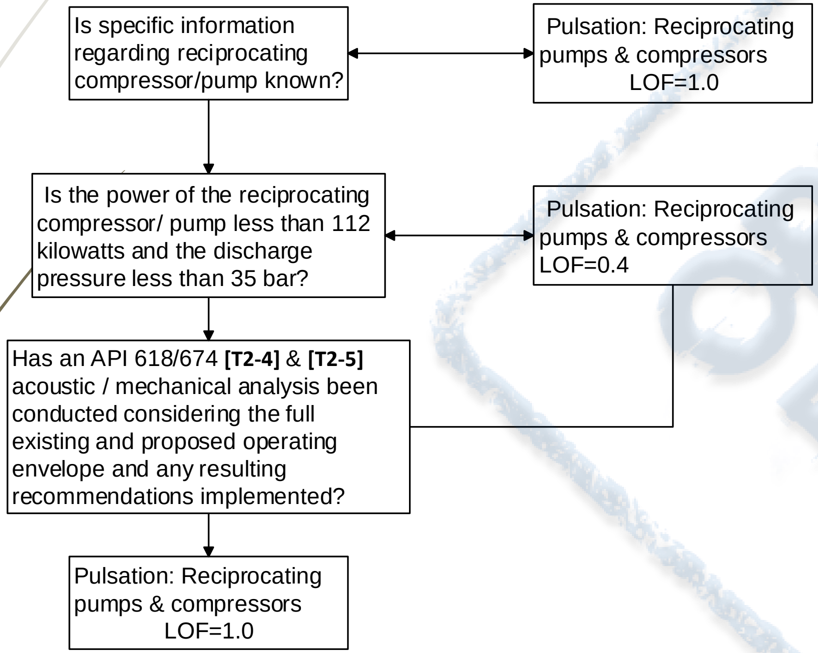



# Mechanical Excitation

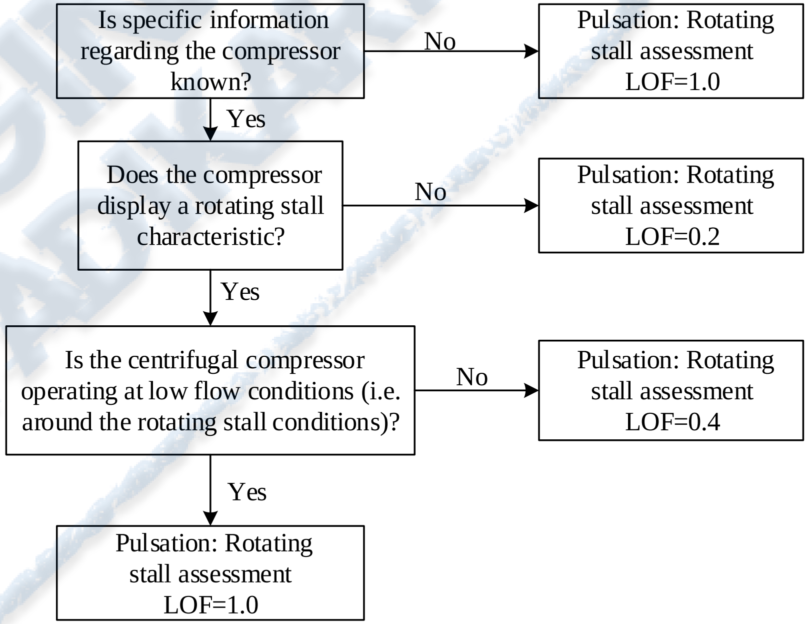
| Pipework connected or adjacent to | LOF |
|---|---|
| Reciprocating/Positive Displacement Compressor/Pump | 0.9 |
| Diesel Engine / Gas Engine | 0.8 |
| Screw Compressor/Pump | 0.6 |
| Centrifugal Pump | 0.4 |
| Electric Motor/Alternator (15kW or greater) | 0.4 |
| Electric Motor/Alternator (below 15kW) | 0.2 |
| Centrifugal Compressor | 0.2 |
| Gas Turbine | 0.2 |
| Fan | 0.2 |
| Other pipework with an LOF ≥ 0.5 | Equal to adjacent pipework LOF |

# Pulsation

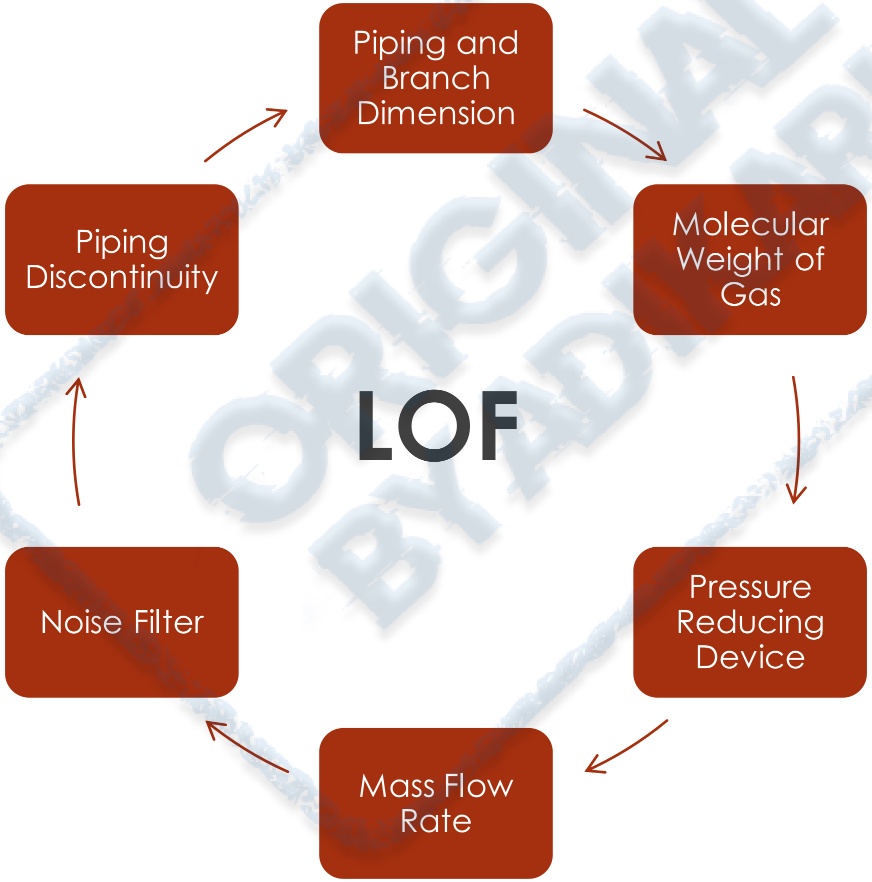
## Reciprocating Equipment




## Rotating Stall



# High Frequency Acoustic

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# Surge/Momentum

**Three Different Condition:**

- Dry Gas Valve Opening
- Liquid or Multiphase Valve Closure
- Liquid or Multiphase Valve Opening

**Properties**

- Fluid properties (density, bulk modulus, molecular weight, specific heat capacity)
- Speed of sound
- Pipe properties (dimension, Young Modulus)
- Working properties (pressure, pressure drop, valve closing time, valve opening time, valve type)

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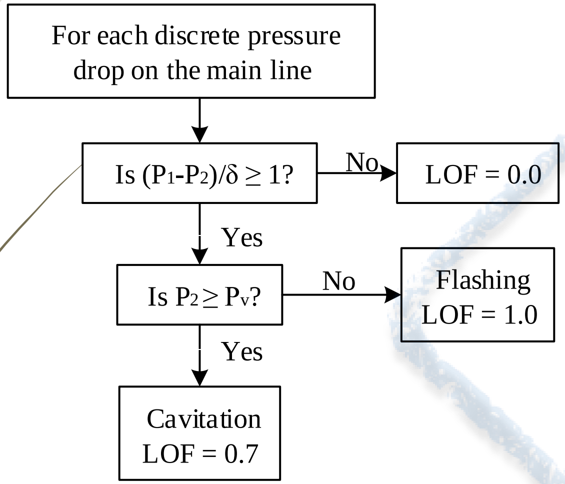
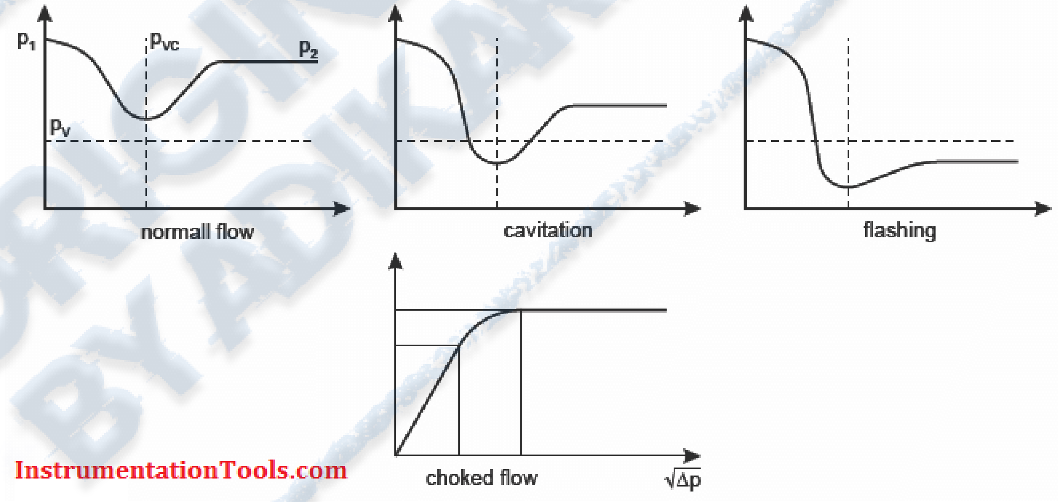
# Cavitation/Flashing

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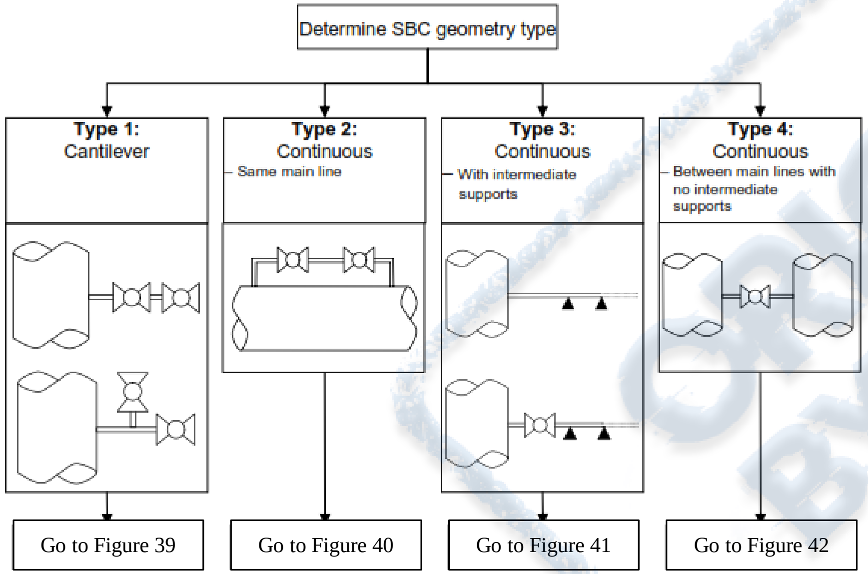
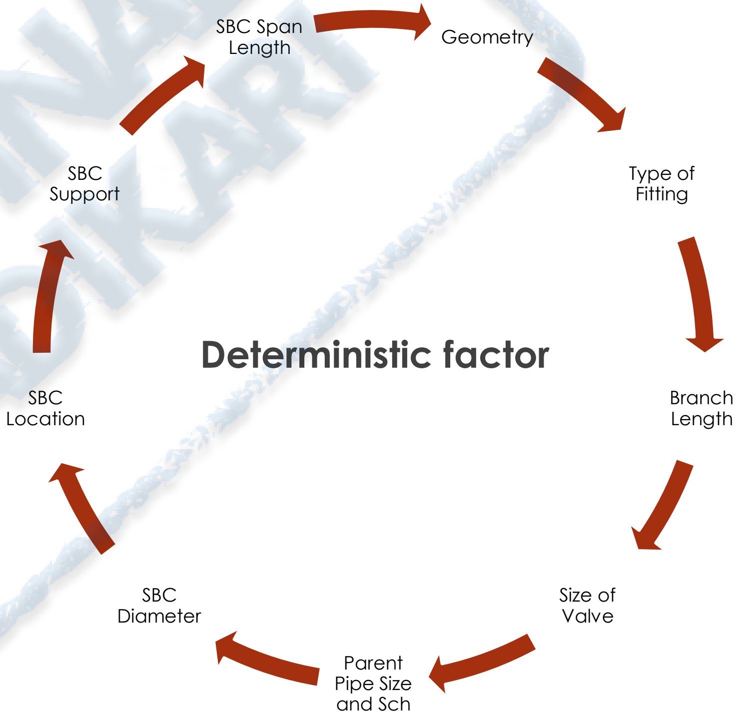
# SBC Screening

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# Second Session

# Measurement Techniques

### Direct Strain Measurement

**Direct assessment where fatigue failure is likely to happen**

Fatigue as consideration for piping where crack is likely will happen.

### Modal Analysis

**To know vibration mode shape**

Structural natural frequencies
Structural damping
Mode shape

### Dynamic Pressure

**Sensor capture fluid fluctutation**

Very important data to see directly the flow behaviour

### Vibration Measurement

**To know vibration characteristics**

By using vibration analyzer, the capture will be interpreted to see how the vibration occurs

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# Vibration Measurement

## Mainline Vibration

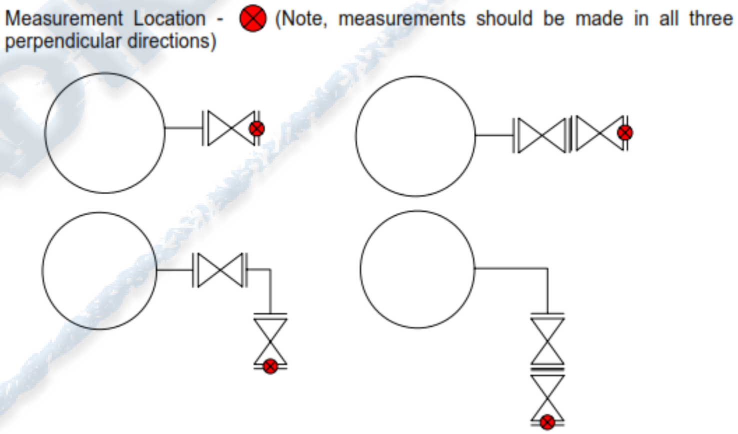
Triaxial Axis on the weakest point or suspect to generate high vibration

Common weak point on pipe :

- ½ pipe span (between support)
- Long pipe span with external load (valve, tee, etc)
- Adjacent to vibrating deck/support
- Close to vibrating equipment
- Complex geometry without adequate support
- Before/after control valve

## SBC Vibration

Triaxial Axis on the weakest point

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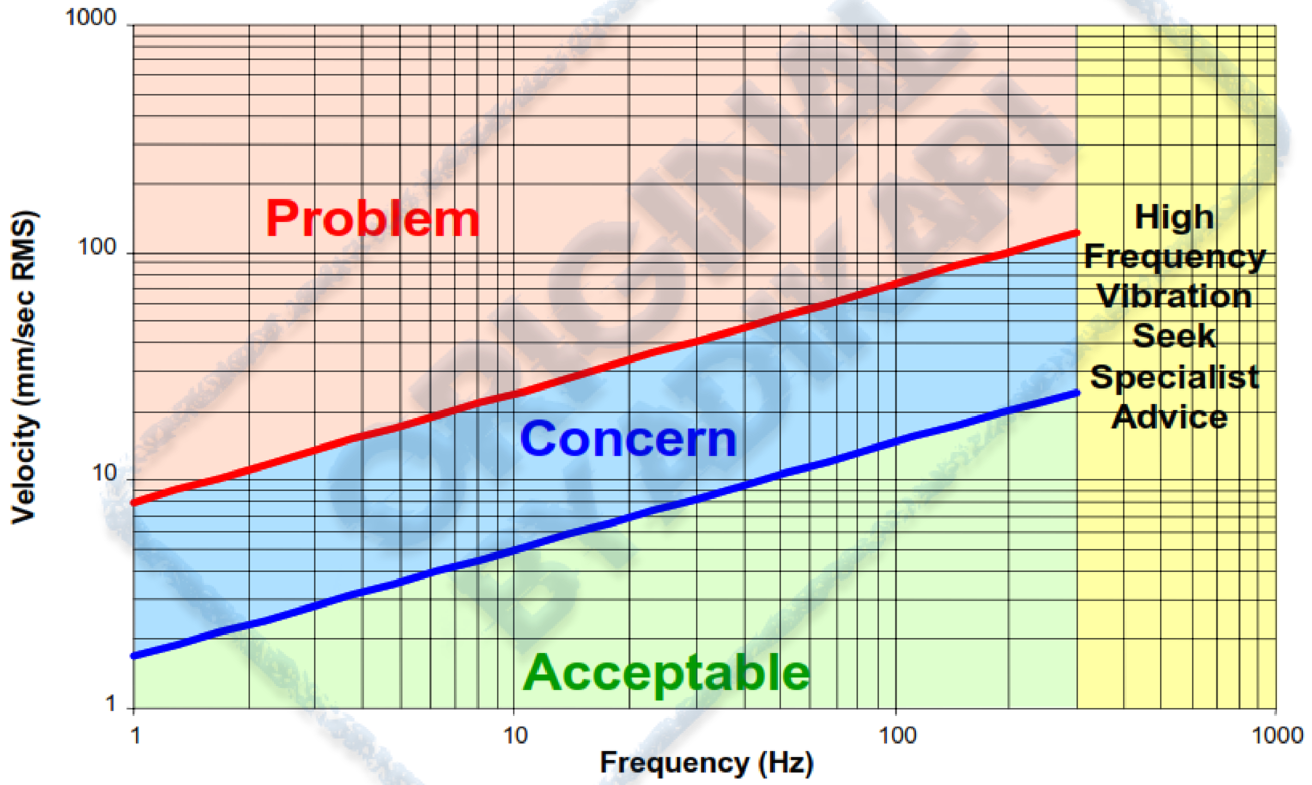
# Vibration Measurement



## Paya Pasir, Medan

# CASE STUDY

There was a gas metering station in Paya Pasir, Medan. After running day by day, week by week, month by month, a new symptom of noise started to emerge along with high vibration. In rural area, this noise propagated to other area. Client decided to find the root cause of the problem.

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# Overview and Scope of Work

- Overview

  Noise exceed 85 dB and vibration emerge.
- Scope of Work
  - Design evaluation of qualitative and quantitative assessment.
  - Visual inspection and vibration measurement.
  - Data acquisition by special techniques.

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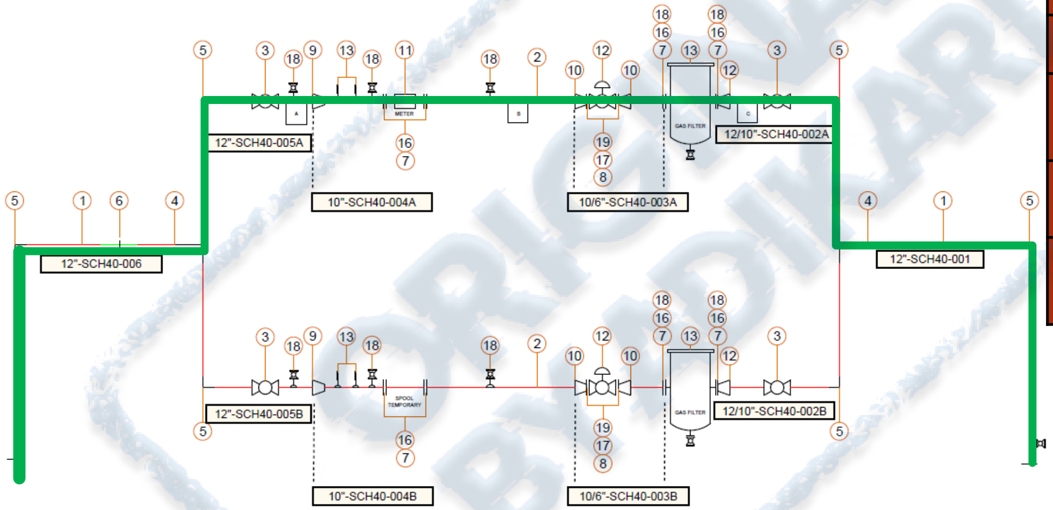
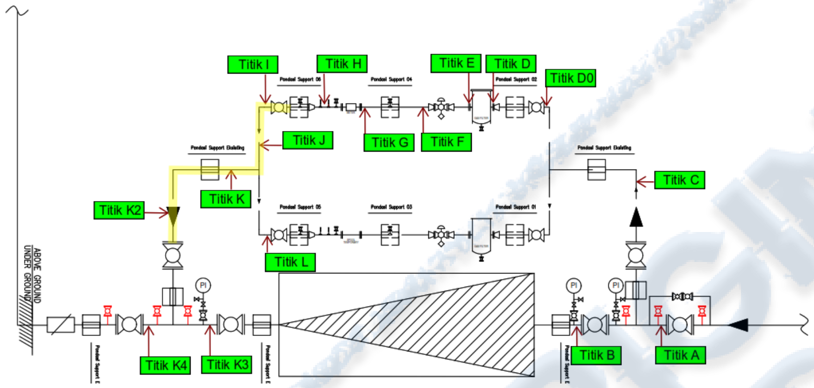
# Screening Assessment

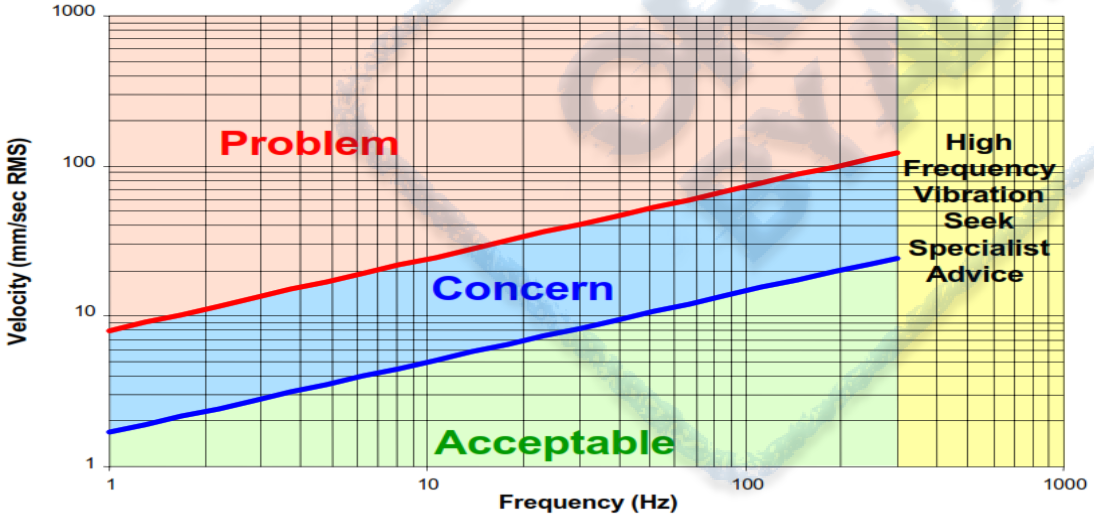



| Aspek | Line 1 | Line 2 | Line 3 | Line 4 | Line 5 | Line 6 |
|---|---|---|---|---|---|---|
| Energi Kinetik | Low | Low | Medium | Low | Low | Low |
| Choke Flow | Low | High | High | High | High | Low |
| Machinery | Low | Low | Low | Low | Low | Low |
| Kompresor/PD Pumps | Low | Low | Low | Low | Low | High |
| Kavitasi/Flashing | Low | Low | Low | Low | Low | Low |
| Surge/Momentum | Low | High | High | Low | Low | Low |

| Line Number | Line List |
|---|---|
| Line 1 | 12"-SCH40-001 |
| Line 2 | 12/10"-SCH40-002A |
| Line 3 | 10/6"-SCH40-003A |
| Line 4 | 10"-SCH40-004A |
| Line 5 | 12"-SCH40-005A |
| Line 6 | 12"-SCH40-006 |

# Basic Vibration Assessment




| Nama Pipa | Axial | | Vertikal | | Horizontal | | Kondisi |
|---|---|---|---|---|---|---|---|
| | Freq (Hz) | Amp mm/sec | Freq (Hz) | Amp mm/sec | Freq (Hz) | Amp mm/sec | |
| Titik I | 50 | 0.4625 | 125.01 | 0.3443 | 49.98 | 1.0134 | Minimum |
| | 50.17 | 9.3072 | 50.16 | 8.0831 | 351.11 | 0.6497 | Maksimum |
| Titik J | 49.95 | 0.9133 | 49.97 | 0.6451 | 49.97 | 0.6451 | Minimum |
| | 49.94 | 2.1962 | 374.62 | 1.9804 | 1798.38 | 2.0511 | Maksimum |
| Titik K | 49.98 | 3.8425 | 50 | 3.3676 | 50 | 1.0436 | Minimum |
| | 49.91 | 10.7729 | 49.93 | 6.8217 | 49.95 | 1.8534 | Maksimum |
| Titik L | 25.01 | 0.1655 | 25.01 | 0.2774 | 50.01 | 1.3158 | Minimum |
| | 49.74 | 1.7772 | 99.45 | 1.3246 | 49.75 | 3.4206 | Maksimum |
| Titik K2 | 49.93 | 0.7601 | 49.93 | 1.2219 | 49.94 | 2.2839 | Minimum |
| | 49.91 | 8.7317 | 49.94 | 5.0607 | 49.94 | 1.7133 | Maksimum |
| Titik K3 | 49.9 | 1.2503 | 49.92 | 0.3166 | 24.97 | 0.6715 | Minimum |
| | 49.92 | 2.1637 | 99.84 | 0.6208 | 49.95 | 0.4676 | Maksimum |
| Titik K4 | 50.02 | 0.5265 | 25.02 | 0.3554 | 25.01 | 0.5218 | Minimum |
| | 49.96 | 2.0632 | 49.96 | 0.8647 | 49.95 | 0.606 | Maksimum |

# Basic Vibration Assessment

- Gas Booster Compressor
  - Gas Supply to GTG 3x25 MW
  - 700 m from Paya Pasir Metering Station
  - Pin: 15.5 bar and Pout: 34 bar
  - 5 unit Booster Compressor
  - Driven by electric motor 280 kW with 1485 rpm.

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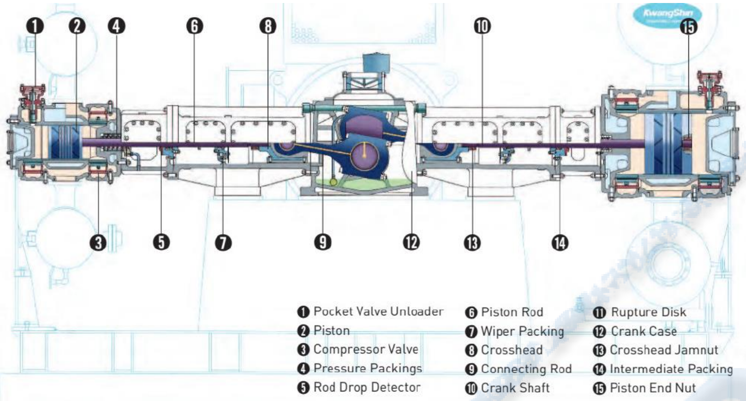
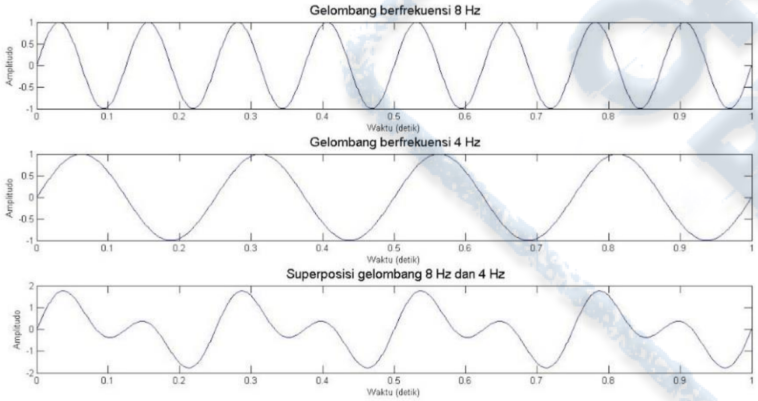
# Basic Vibration Assessment



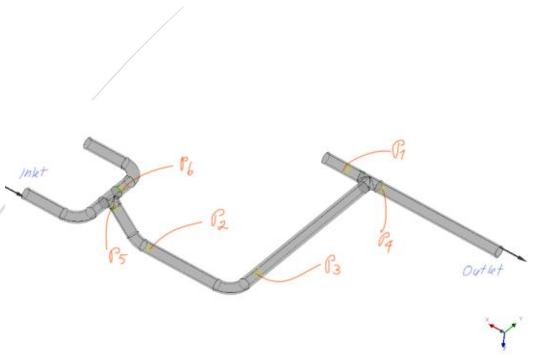

| Axial | | | Vertikal | | | Horizontal | | |
|---|---|---|---|---|---|---|---|---|
| PEAK NO. | FREQUENCY (Hz) | PEAK VALUE | PEAK NO. | FREQUENCY (Hz) | PEAK VALUE | PEAK NO. | FREQUENCY (Hz) | PEAK VALUE |
| 1 | 24.97 | 10.4615 | 1 | 24.95 | 4.8827 | 1 | 24.95 | 12.7153 |
| 2 | 49.94 | 7.73 | 2 | 49.91 | 3.5562 | 2 | 49.91 | 3.6263 |
| 3 | 74.92 | 6.4753 | 3 | 74.87 | 18.9253 | 3 | 74.86 | 5.5868 |
| 4 | 99.89 | 2.3789 | 4 | 99.82 | 2.5076 | 4 | 99.83 | 2.0514 |
| 5 | 124.87 | 2.2347 | 5 | 124.78 | 2.4512 | 5 | 124.78 | 4.1703 |

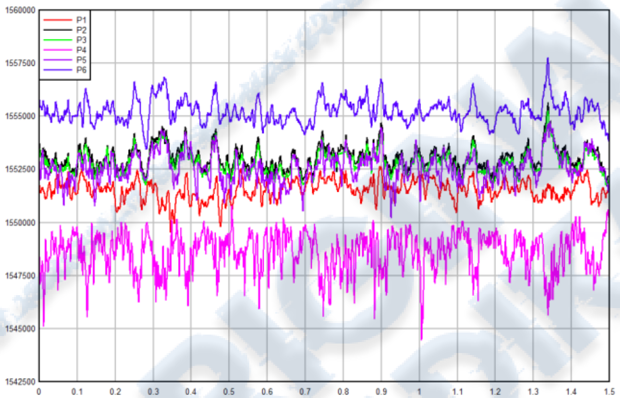
## Basic Vibration Measurement

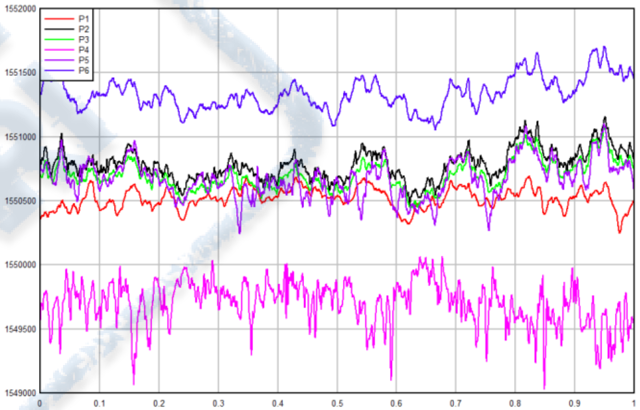
Electric motor operates at frequency 25 Hz (1485 RPM)

- Double acting reciprocating compressor cause the excitation source at 50 Hz.
- Harmonic frequency of driver running speed 25 Hz (25, 50, 75 Hz,..etc) propagates to Paya Pasir through fluid or pipeline.
- Compressor configuration cause excitation source propagates to Paya Pasir up and down depends on superposition.

# Computational Fluid Dynamics



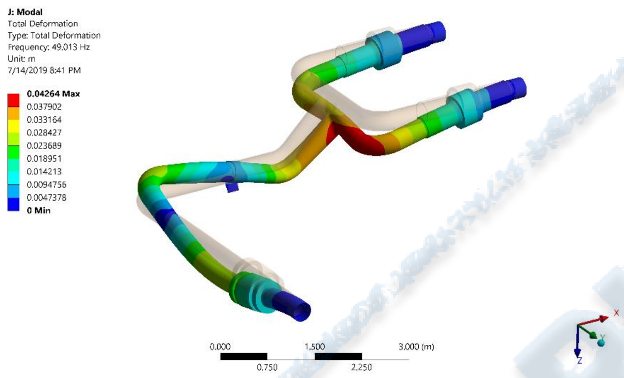



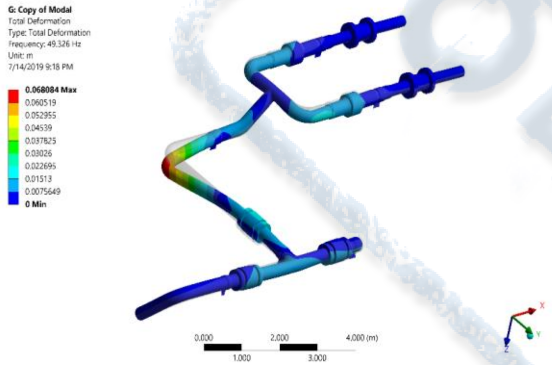




| | Model A (kiri) | | Model B (kanan) | |
|---|---|---|---|---|
| Titik | Max ΔP (frekuensi) | ΔP pd 50Hz | Max ΔP (frekuensi) | ΔP pd 50Hz |
| P1 | 170 Pa (<5 Hz) | 30 Pa | 90 Pa (8 Hz) | 3 Pa |
| P2 | 224 Pa (< 5 Hz) | 20 Pa | 45 Pa (< 5 Hz) | 5 Pa |
| P3 | 210 Pa (< 5 Hz) | 20 Pa | 90 Pa (< 5 Hz) | 5 Pa |
| P4 | 226 Pa (15 Hz) | 50 Pa | 85 Pa (< 5 Hz) | 25 Pa |
| P5 | 290 Pa (< 5 Hz) | 60 Pa | 99 Pa (< 5 Hz) | 10 Pa |
| P6 | 180 Pa (< 5 Hz) | 50 Pa | 99 Pa (< 5 Hz) | 5 Pa |

- Computational Fluid Dynamics Result
  - Pressure fluctuation inside the pipe happens.
  - Pictures above in terms of waveform that can interpret in FFT.
  - There are pressure fluctuation in 50 Hz.
  - Maximum pressure fluctuation in low frequency (<5 Hz).
  - Maximum pressure fluctuation at 290 Pa (operate at 1500 kPa).

# Modal Analysis




| Mode | Model A (atas) | Model B (bawah) |
|---|---|---|
| 1 | 29.05 | 13.75 |
| 2 | 41.69 | 18.98 |
| 3 | 44.08 | 23.90 |
| 4 | 49.01 | 28.45 |
| 5 | 59.76 | 29.30 |
| 6 | 63.10 | 31.80 |
| 7 | 85.14 | 33.15 |
| 8 | 113.40 | 34.99 |
| 9 | 122.58 | 36.00 |
| 10 | 125.74 | 49.33 |

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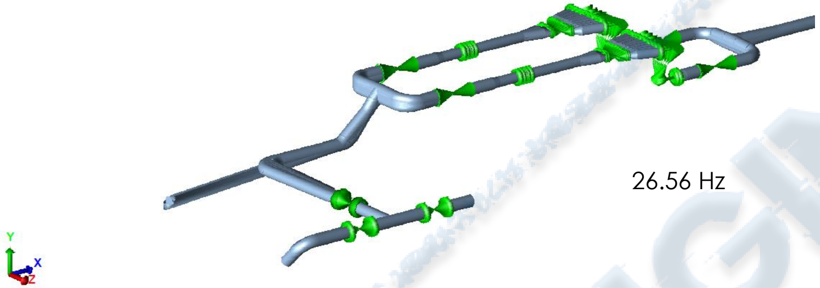
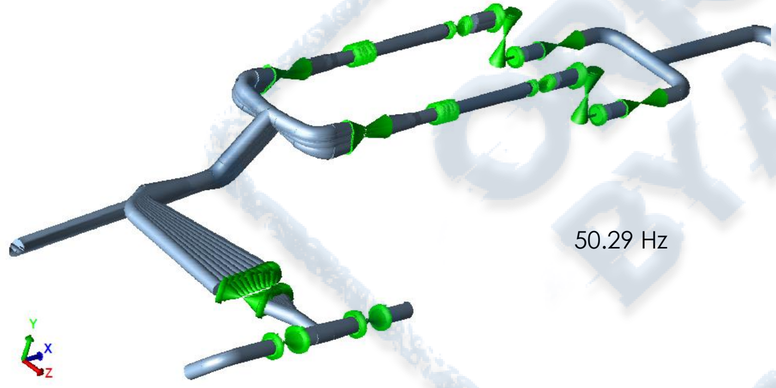
# Modal Analysis




| Mode | Frequency (Hz) |
|---|---|
| 1 | 3.169 |
| 2 | 15.246 |
| 3 | 20.314 |
| 4 | 20.803 |
| 5 | 26.56 |
| 6 | 27.91 |
| 7 | 29.83 |
| 8 | 30.21 |
| 9 | 35.56 |
| 10 | 36.18 |
| 11 | 36.24 |
| 12 | 36.24 |
| 13 | 38.51 |
| 14 | 39.25 |
| 15 | 40.53 |
| 16 | 42.13 |
| 17 | 43.52 |
| 18 | 48.86 |
| 19 | 50.29 |
| 20 | 52.91 |
| 21 | 57.6 |
| 22 | 59.647 |
| 23 | 60 |

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# Conclusion

- From assessment screening, potential excitation are kinetic energy, ch oke flow, compressor pulsation, surge/momentum.
- Vibration measurement in Paya Pasir shows maximum overall vibration level of 10.77 mm/sec at Point K (concern) with dominant frequency 5 0 Hz.
- Configuration of gas booster compressor cause wave superposition.
- CFD result shows pressure fluctuation with maximum 290 Pa (operation condition 1500 kPa). Low pressure fluctuation at 50 Hz.

➢ Vibration at Paya Pasir Metering Station caused by :
  - ➢ Excitation at 50 Hz. Excitation sources comes from pulsation of gas booster compressor.
  - ➢ Acoustic natural frequency and mechanical natural frequency at 50 Hz.

# Recommendation

- Add dampener to minimize pulsation effect. Sizing needed.
- Piping route modification to shift the mechanical natural frequency.
- Piping support modification to shift the mechanical natural frequency.

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# THANK YOU

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