# Acoustic Fatigue – Turbulence Induced Fatigue Failure of Relief System Piping

Ed Zamejc
BP
Spring 2006 API Refining Meeting
May 3, 2005

# In Salah Gas Flare Header Rupture


PV-111

# ISO 23251/API RP521

- No specific guidance on velocity limitations other than in backpressure calculations
- No guidance on acoustic fatigue or vibration induced fatigue
- Do we need more guidance and if so what?

# NORSOK

- P-001 Process Systems, Rev. 4, October 1999
- “In general, all flare lines shall be designed to keep the $\rho V^2 < 200\ 000$ kg/m-s$^2$ criteria”
- “Where the $\rho V^2$ criteria will not be met, additional calculations will be required to document that the selected pipe size is still acceptable. This involves evaluating piping stress levels, supporting, noise etc.”
- “Selection of piping specification must consider the effect of acoustic fatigue”

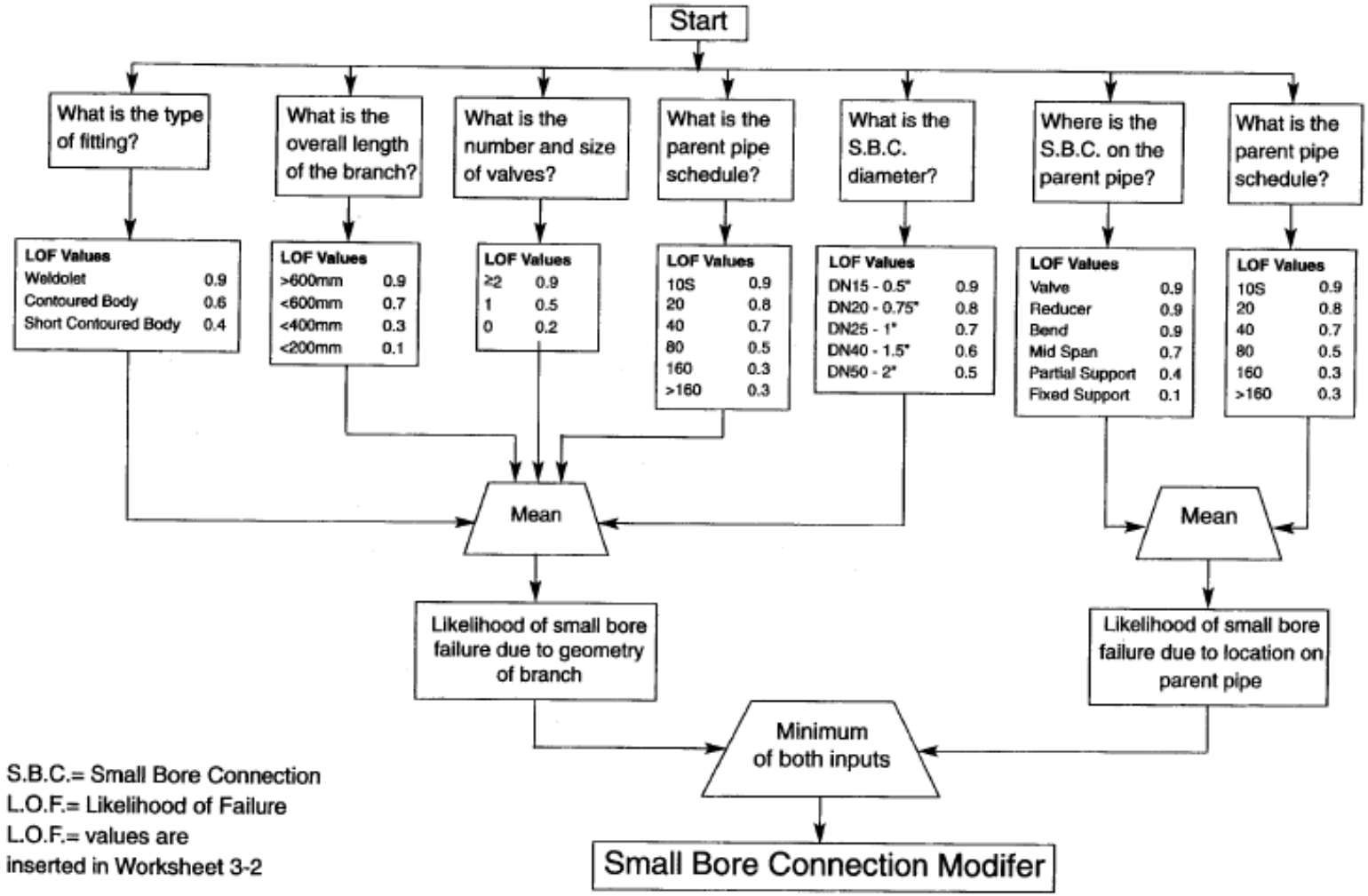
# Harris Shock and Vibration Handbook, Chapter 29 **VIBRATION OF STRUCTURES INDUCED BY FLUID FLOW** by R. D. Blevins

- Oscillatory flow (reciprocating pumps, flow through valves and obstructions) in pipes can cause vibration
- If pressure and velocity in the pipe oscillate, then fluid force on the bend will oscillate, causing pipe vibration
- Problem most prevalent in unsupported pipe bends adjacent to pumps and valves.
- Two solutions:
  - (1) support pipe bends and changes in area so that fluid forces are reacted to ground and
  - (2) reduce fluid oscillations in pipe by avoiding large pressure drops through valves and installation of oscillation-absorbing devices on pump inlet and discharge.

# MTD 99/100

- “Guidelines for Avoidance of Vibration Induced Fatigue in Process Pipework” ISBN 1 870553 37 3, 1999.
- Use of thinner wall pipe (flexible) causes higher stress concentrations at small bore connections
- Higher velocities causing greater turbulence
- Guidelines are for “steady state” plant operation
- Piping excitation mechanisms:
  - High frequency acoustic excitation
  - Flow induced turbulence @ low frequency (< 100 Hz)
  - Mechanical (reciprocating compressors loads)
  - Pulsation (fluid flow from recip. compressors)
- Guidance to determine “Likelihood Of Failure” (LOF) and design solutions

# MTD 99/100 (Example Flowchart)



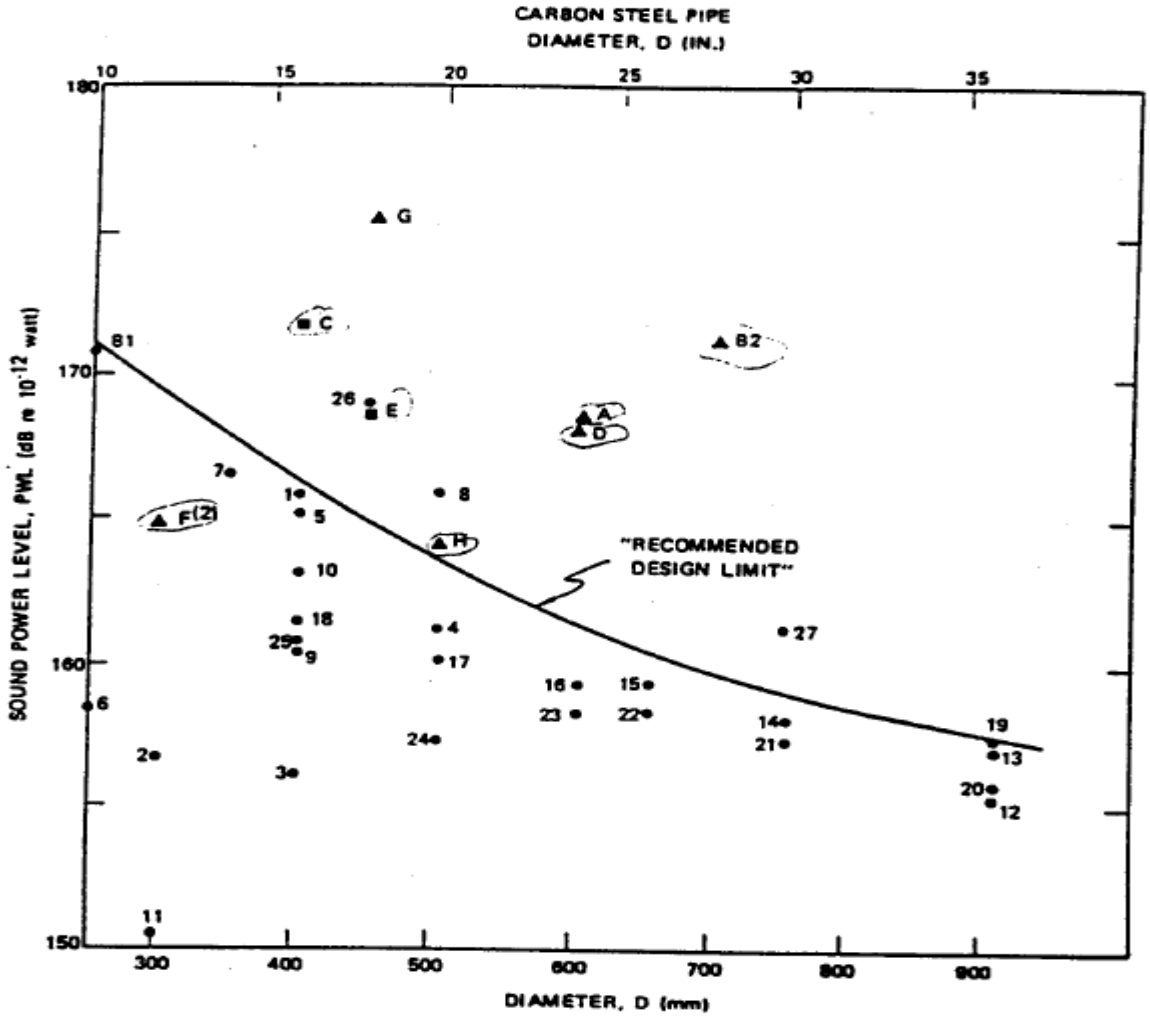
# CONCAWE 85/52

- Acoustic Fatigue of Pipes - Carruci & Mueller (ASME)
- Very rapid failure (seconds)
- Large diameter piping (>10”), asymmetric piping, small bore connections downstream of choke points
- Determine sound pressure level at choke point:

$$L_{W-DV} = 10 \log \left[ (W^2) \left( \frac{\Delta P}{P1} \right)^{3.6} \left( \frac{T}{M_w} \right)^{1.2} \right] + 45$$

where :

| | |
|---|---|
| W | = flow rate of the gas, lbs/hr |
| $\Delta P$ | = $P_1 - P_2$ = pressure drop, psi |
| P1 | = upstream pressure, psia |
| P2 | = downstream pressure, psia |
| T | = temperature of flowing gas, °R |
| $M_w$ | = molecular weight of flowing gas |




Notes: (1) Legend ▲ Acoustically Induced Failures (Data From Table 1)
■ Severe Vibrations, But No Failures (Data From Table 1)
● No Abnormal Experience (Data From Table 2)

(2) Point f Failure Attributed To Severe Weld Undercutting At A Small Connection. No Abnormal Experience After Quality Welds Achieved.

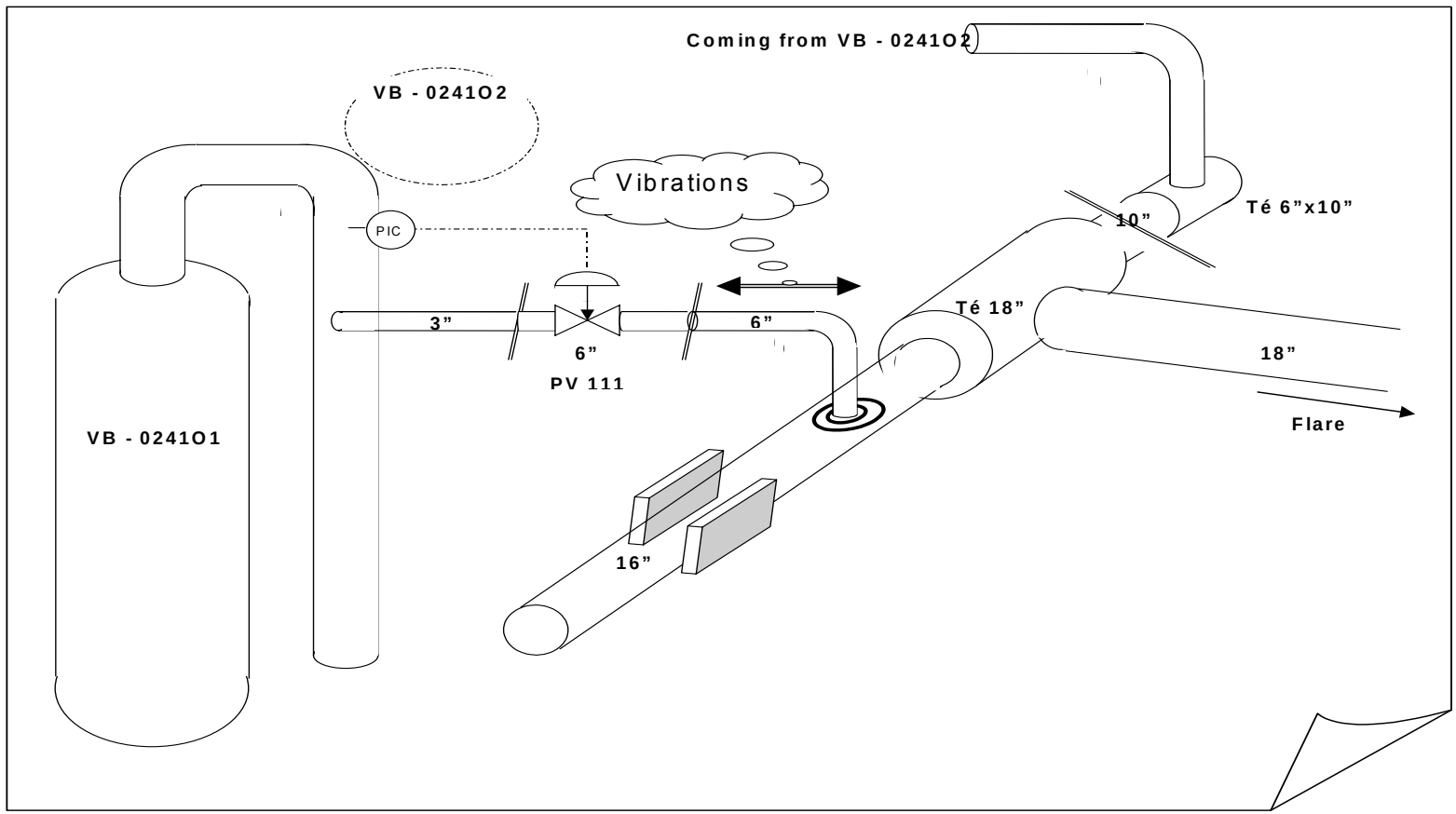
(3) All Data Points Are 8.0 mm (0.313") Or Less Wall Thickness, Except For Points 8 And 18 Which Are 9.5 mm (0.375") Wall Thickness, And 27 Which Is 11.9 mm (0.469") Wall Thickness.

**Fig. 3. SAFE DESIGN LIMIT BASED ON EXPERIENCE OF ACOUSTICALLY INDUCED PIPING VIBRATIONS**

Sound < 157 dB appears okay

# In Salah Gas Incident

Line failed due to turbulence induced fatigue (not acoustic) @ header tie-in **– need to perform proper piping analysis and provide adequate supports!**



# Turbulence Induced Vibration Failure

- In Salah Gas Incident
- Longer time to occur than acoustic vibration failure (minutes or hours)
- Visible motion of piping often observed
- Consider when velocities >0.5 to 0.8 Mach
- Potential failure with low frequency vibration (1-15 Hz) where high stress (e.g. > 3000 lbf)
- No weldolets
- Mitigate by bracing, wrapping pipe, thicker wall pipe,…

# Path Forward

- Propose to add guidance on acoustic and turbulence induced fatigue potential of relief system and blowdown piping systems
- Guidance based on references provided, any others?
- What do other companies do?