Flow Line Safety Restraint System (FSR)

An engineered and proven system to reduce the danger zone around flow line failures

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Agenda

- Why do you need a flow line safety restraint (FSR) system?
- What is a FSR System and how does it work?
- How do you quantify the FSR system?
- Restraint system design considerations
- Short Video

The Dangers of Flow Line Ruptures

- Pumping highly-pressurized or energized fluids inherently creates greater potential for safety incidents on site.
- In its worst case, flow line disengagements may possibly lead to damaged equipment, and injuries or death to personnel.

Simulated frac testing

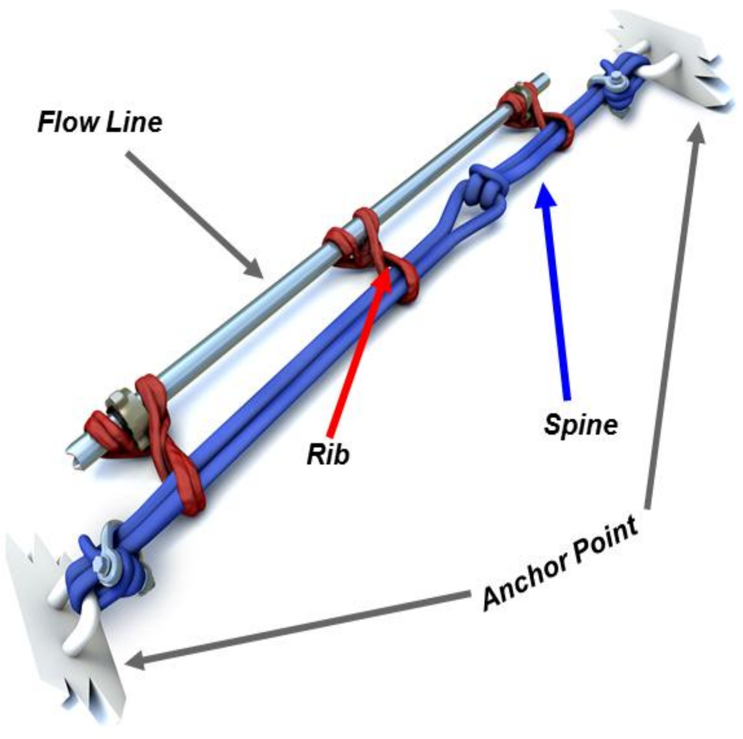
Pipe constrained within acceptable area

FSR Primary Components

- The FSR System utilizes interlocking synthetic loops strung the length of the flow line, attached to critical points of the flow line through smaller loops.

- This assembly is then anchored to a substantial structural tie-down.

- FSR Primary Component Parts:
  - *Spines – Main restraint member running the length of the flow line*
  - *Ribs – Transverse members attaching the spine to the flow line at critical locations*

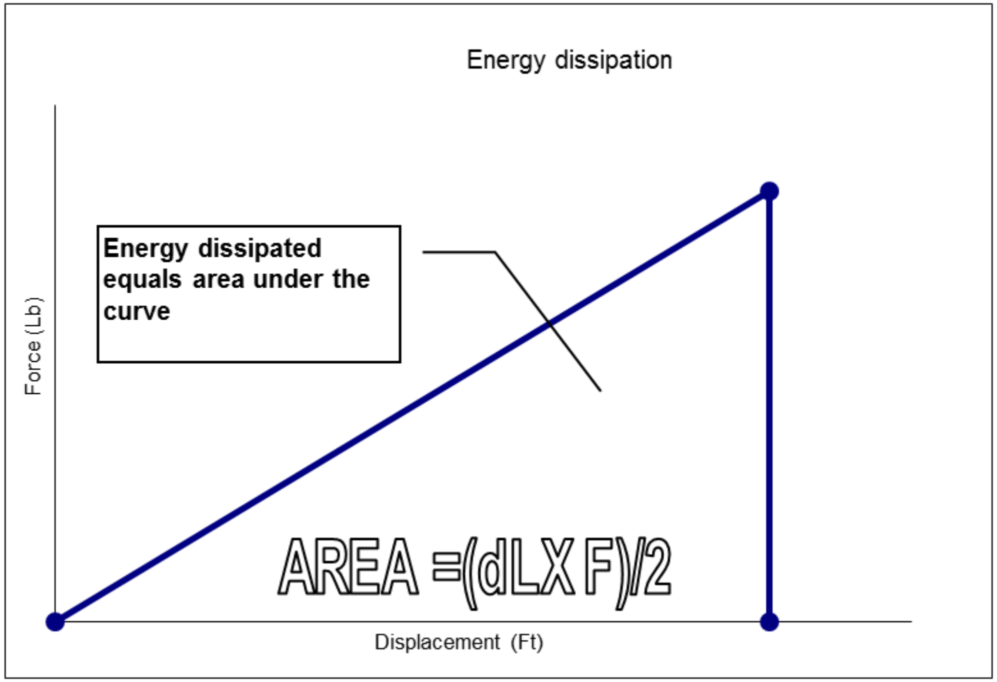


How Does a Restraint System Work?

- During rupture of piping, the discharging fluid will create a reaction force on the failed component. The value of this force is a function of fluid velocity and fluid mass.
- The continuous discharge of fluid can cause the component to accelerate and gain additional energy.
- The purpose of the restraint system is to capture the ejecting components and dissipate their accumulated energy by converting to thermal energy.
- This is accomplished by the physical elongation of the primary restraint (spine) and the gradual dissipation of the energy.

How to Determine Maximum Energy Dissipation?

- Maximum energy dissipation is a function of breaking strength of the material, and maximum elongation at failure.
- The longer the restraint, the more energy it can dissipate.



Calculation Methods to Qualify Restraint
Reaction Force based on Mass Flow Rate

- Mass flow rate calculation is common approach
- Based on determining reaction force that would occur due to discharging high pressure fluid
- Use load multiplier of 1.5 to account for shock loading
- Assumes infinite reservoir of fluid
- Only defines the maximum load that would be imparted to the restraint system

<u>Weakness</u>

- Does not take into account the dynamic capabilities of the restraint system

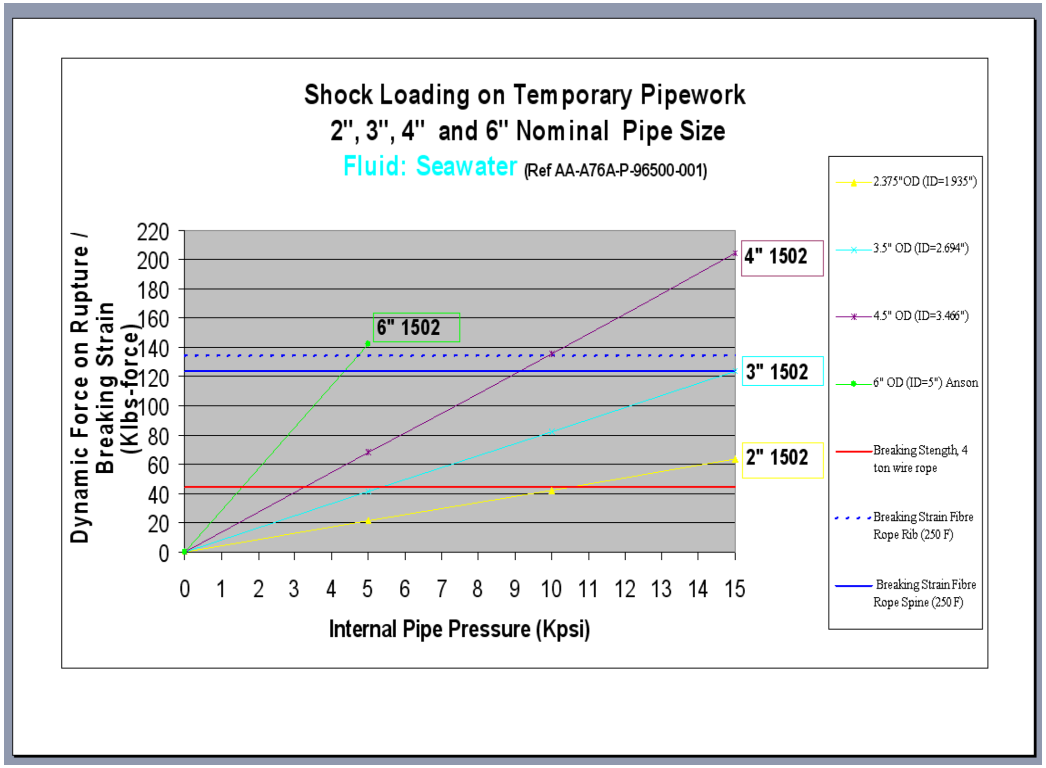
diameter of pipe (in)	d	1.935
length of pipe (ft)	L	5280
inlet pressure (lb/in^2)	p_1	15000
outlet pressure (lb/in^2)	p_2	14.7
nitrogen density @ 68 deg F (lb/ft^3)	$\rho_{nitrogen}$	0.0727
friction factor (dimensionless)	f	0.0175
resistance coefficient, entrance	$K_{entrance}$	0.5
resistance coefficient, exit	K_{exit}	1
speed of sound in nitrogen (m/s)	$v_{sound\text{-}nitrogen}$	353
gravitational acceleration (ft/s^2)	g	32.2
ratio of specific heats	k	1.4
absolute temperature at exit point, deg R	T_2	520
specific volume of nitrogen (ft^3/lb)	$V_{nitrogen}$	13.7551582
cross-sectional flow area of pipe (in^2)	A	2.94062071
cross-sectional flow area of pipe (ft^2)	A	0.02042098
Pressure difference (lb/in^2)	ΔP	14985.3
resistance coefficient, pipe	K_{pipe}	573.023256
resistance coefficient, total	K_{total}	574.523256
mass flow rate (lb/s)	m_2	1.92
velocity (ft/s)	v	1292.12
speed of sound in nitrogen (ft/s)	$v_{sound\text{-}nitrogen}$	1132
fluid mach number at exit point of pipe	M_2	1.14
SUMMARY REPORT		
mass flow rate at exit point of pipe (lb/s)	m_2	1.92
fluid mach number at exit point of pipe	M_2	1.14
gravitational acceleration	g_c	32.2
ratio of specific heats	k	1.4
gas constant	R	55.2
absolute temperature at exit point of pipe	T_2	520
absolute pressure at exit point of pipe	P_2	14.7
cross-sectional flow area of pipe (in^2)	A	2.94062071
steady state force value	F	44143.4071

Calculation Methods
Shell Method

- Developed by Shell
- Qualifies suitability of restraint solely on breaking strength of material and fluid pressure
- Widely accepted
- Shell method is more conservative than Mass method. Due to this, we use this approach

<u>Weakness</u>

- Does not take into account the dynamic capabilities of the restraint system



Calculation Methods
Energy Method

- This method calculates the stored energy that is released during a failure
- Has the potential to offer the most realistic predictions
- Allows for direct comparison against performance offered by each restraint system
- Current calculation method is complex
- Is very accurate for small fluid volumes, but overstates the impact from larger fluid volumes
- We are currently refining this calculation method

Calculation Methods
Summary

- There are multiple calculation methods for qualifying a restraint system for a particular application
- The variables are complex. Different scenarios may generate different loading on the restraint system
- The best restraint system will offer the largest design margin to account for “unknowns”

Design Considerations
Assembly Method

- Assembly techniques are critical to ensure the restraint will dissipate energy as intended

Critical Features:

- Must minimize slack in the assembly
- Steps must be taken to maximize the length of the main line
- The anchor point must have a load rating equivalent to the minimum breaking strength of the restraint
- Personnel training regiments

Weir FSR Spine and Rib Method

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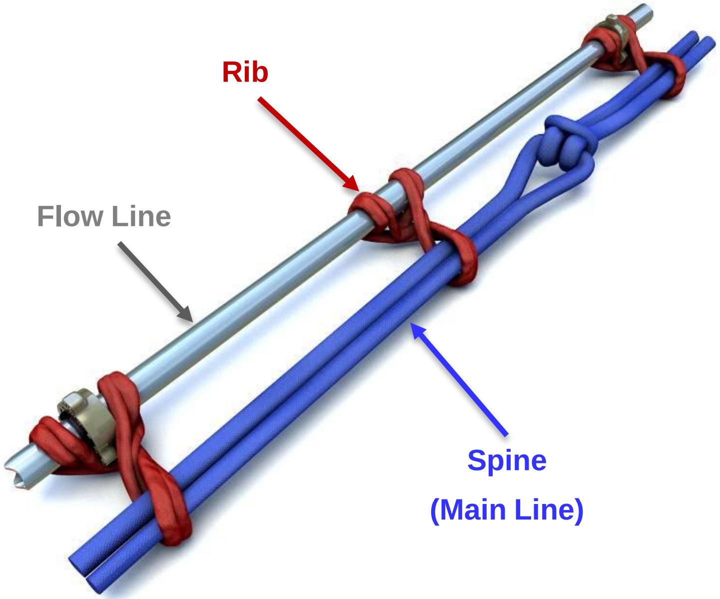
Design Considerations

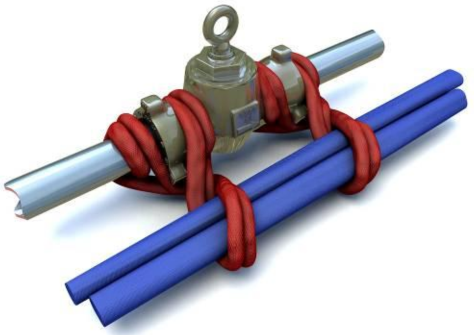
Weir SPM Assembly Method

- This patented design is based on one principle – No matter where the failure occurs, all the released energy will be transmitted into the main load bearing line

- This is accomplished by using ribs at periodic intervals to connect the pipeline and the load bearing line

- The design ensures that the transmittal of failure forces to the main line will be distributed across multiple ribs
  - *This prevents the shorter ribs from experiencing failure*





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Assembly Methods
Half-hitch Method

- This method was developed because of our existing patent
- This method uses a single mainline that is periodically half-hitched around piping to ensure engagement
- This approach does not allow failure loads to be dissipated along the entire length of the restraint
  - *Rather it reduces the load transferred behind each half-hitch*
- The amount of energy dispersed by this method is a fraction of the spine and rib method

Half-hitch Method

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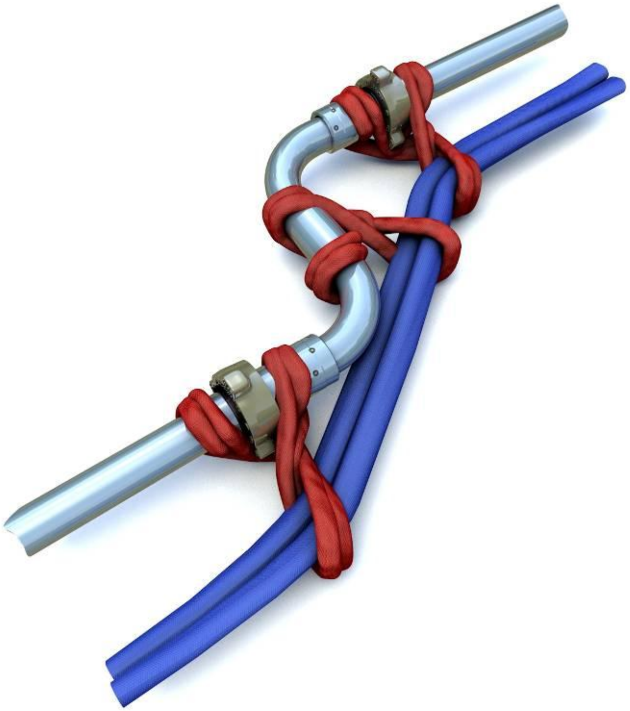
Design Considerations
Material Selection

- Dynamic Capability of the Restraint System:
  - *Breaking Strength*
  - *Elongation at Break*
  - *Strength Reducing Characteristics*

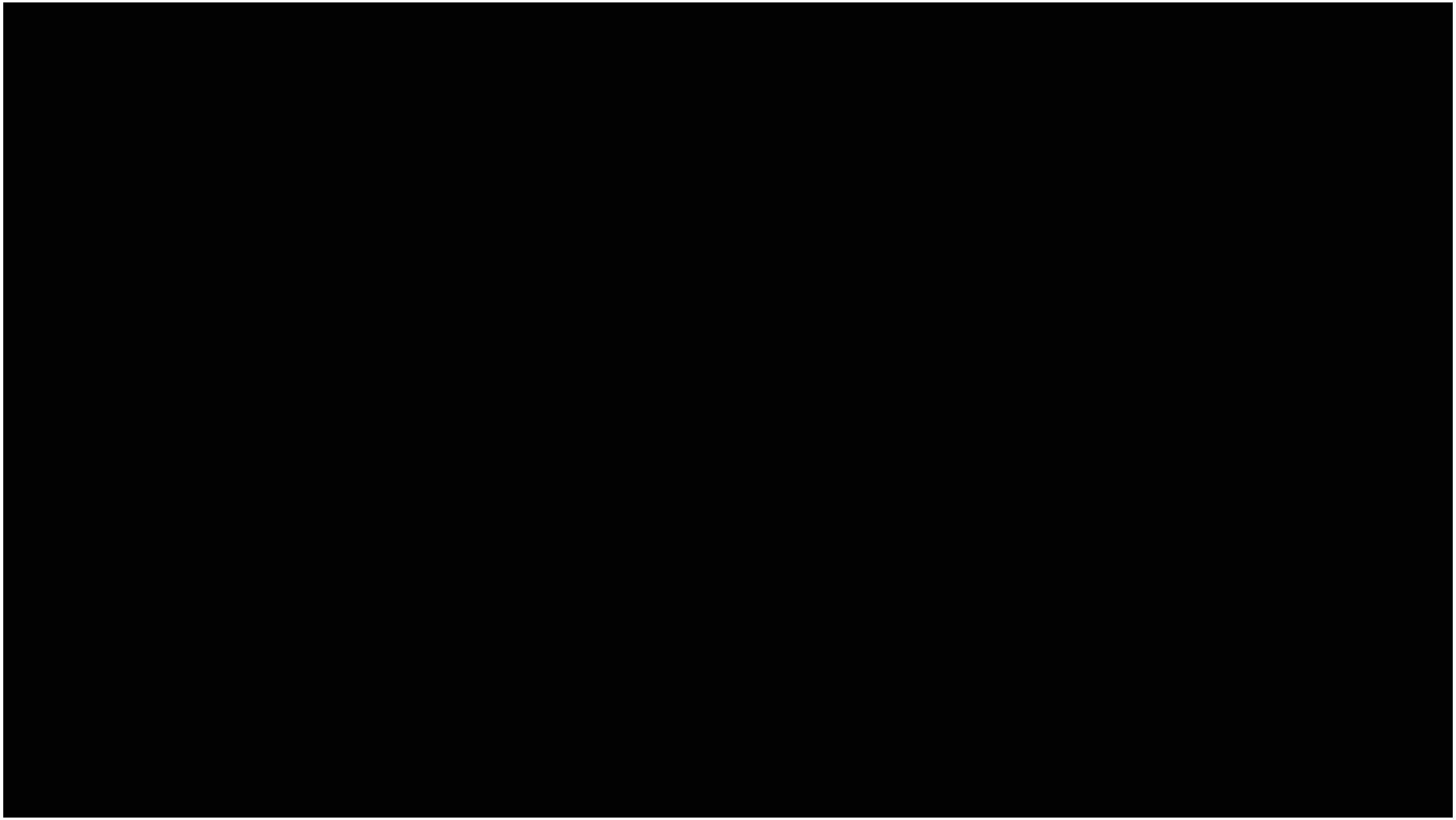
- Environmental Considerations:
  - *Abrasion Resistance*
  - *Chemical Resistance*
  - *Functional Temperature Range*
  - *UV Resistance*

- Practical Considerations:
  - *Weight and Diameter*
  - *Ease of Inspection*
  - *Material Availability*
  - *Cost*



Conclusion

Remember, flow line safety restraints are not a cure-all. Energized fluid is always extremely dangerous. The safety restraints will only **<u>ASSIST</u>** in containing flow line components if a breach in the line occurs. We liken the safety restraints to seat belts. They should help greatly reduce the potential of field personnel getting killed or injured; however, there is never any guarantee of absolute safety.



Questions?

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