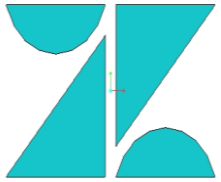


Z-Tech Design LLC, New Iberia LA, Zlatko Salihbegovic graduated Mechanical Engineer.

Gas lift valve-GLV bellow protection from high injection and dome pressure

Typical gas lift valve

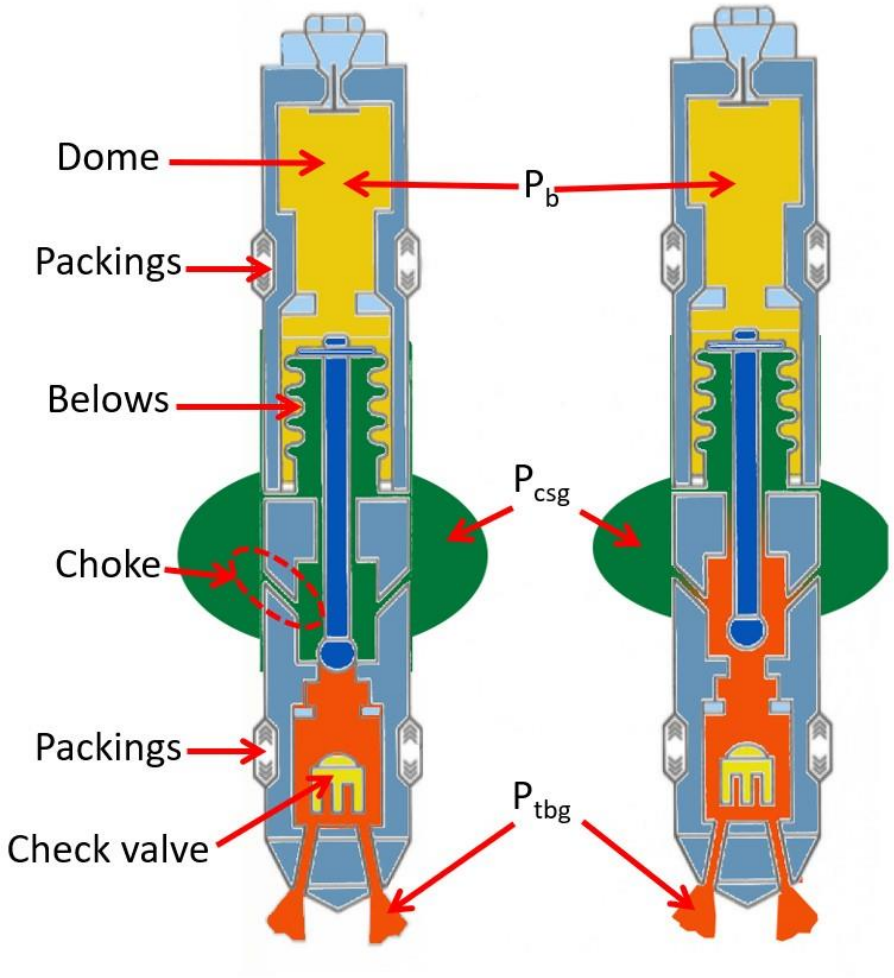
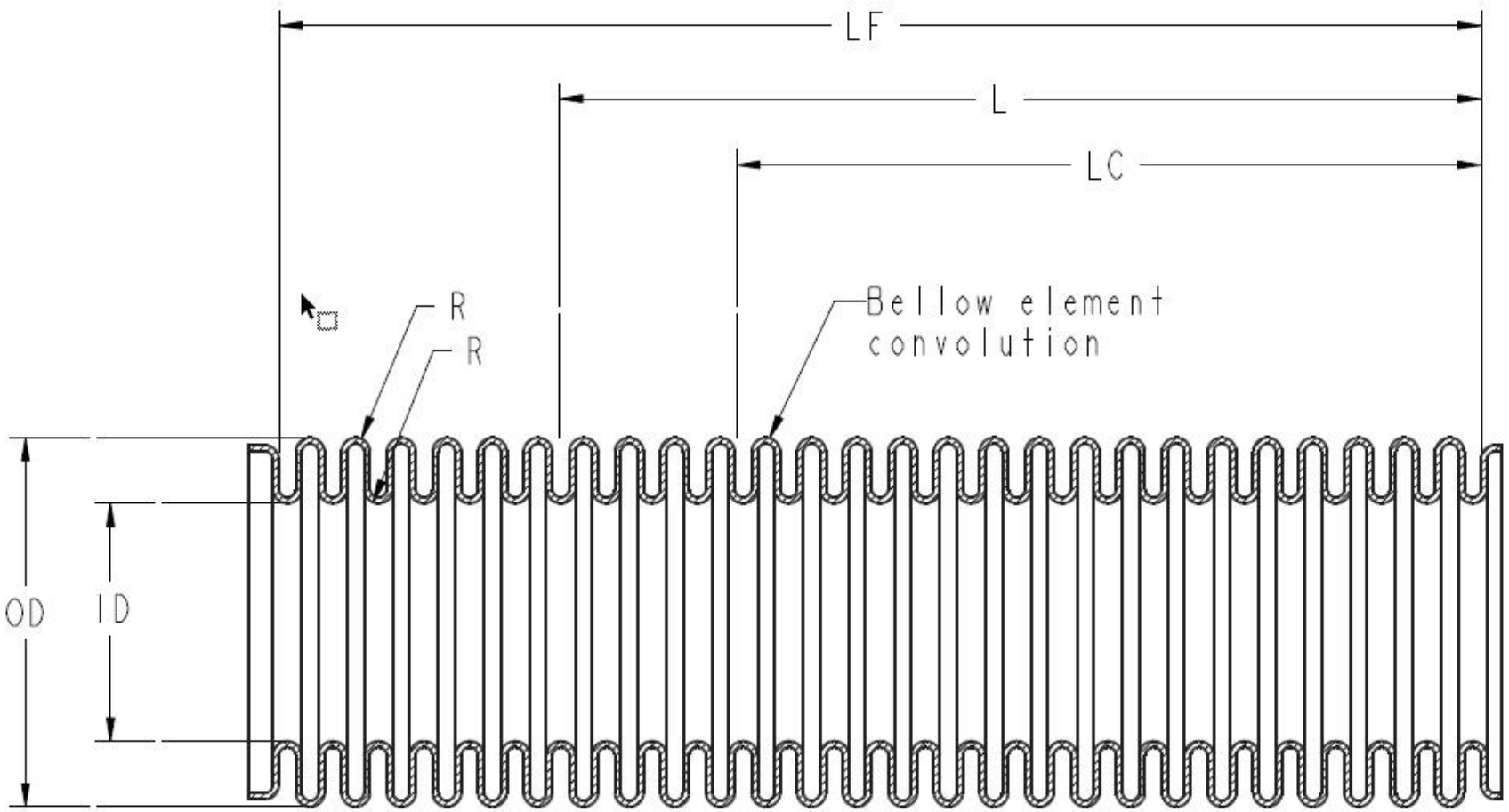


Figure 1

First step: Proper bellow crimping

- The purpose of bellow crimping is to increase overall mechanical toughness and increase external/internal pressure rating.
- Bellows used in gas lift valves are rated to approximately 200-250 PSI.
- In gas lift valves bellows are exposed up to 2000 PSI or even higher pressures.
- Bellow is delivered in free length LF, must be compressed to LC in order to produce as crimped length L.
- Determining optimal as crimped length L is lengthy process that includes EDM cutting for inspection, cycle testing etc. Bellow partially springs back during crimping, like spring. See Figure 2.

Bellow reference dimensions Fig. 2



Existing bellow crimping method

- Most manufacturers crimp bellows after soldering to mating parts.
- After crimping valve is aged, to “ stabilize” bellow which further deforms it. Ageing is usually performed with 1000 PSI dome pressure and 5000 PSI external pressure.
- This method completely deforms bellow convolutions during crimping because of built in mechanical stop and over-pressurizing. See figure 3 below:

Figure 3

Bellow crimping with Int/ext pressure patent # US 11,845,120 B2

- Bellow is crimped before soldering to mating parts in custom designed device.
- Int/ext. pressure applied following very specific sequences.
- Bellows is crimped-compressed to perfect Ω shape, see picture.
- Bellow plys-layers are pressure supported internally and don't separate.
- Maintaining Ω shape is essential for proper bellow functioning.
- Bellow crimping pressure exceeds valve working pressure, see Figure 4 below

Figure 4 below shows bellow crimped using Int/ext. pressure with perfect Ω shape.

Figure 4

Mechanical bellow crimping

- Bellows can be mechanically crimped, better than simple pressure crimping.
- However, plys-bellow layers are not supported internally, and this may result in ply separation.
- Result is much better but inferior to internal/external pressure crimping.
- Mechanically crimped bellow does not have perfect Ω shape see figure 5 below

Figure 5 below shows mechanically crimped bellow

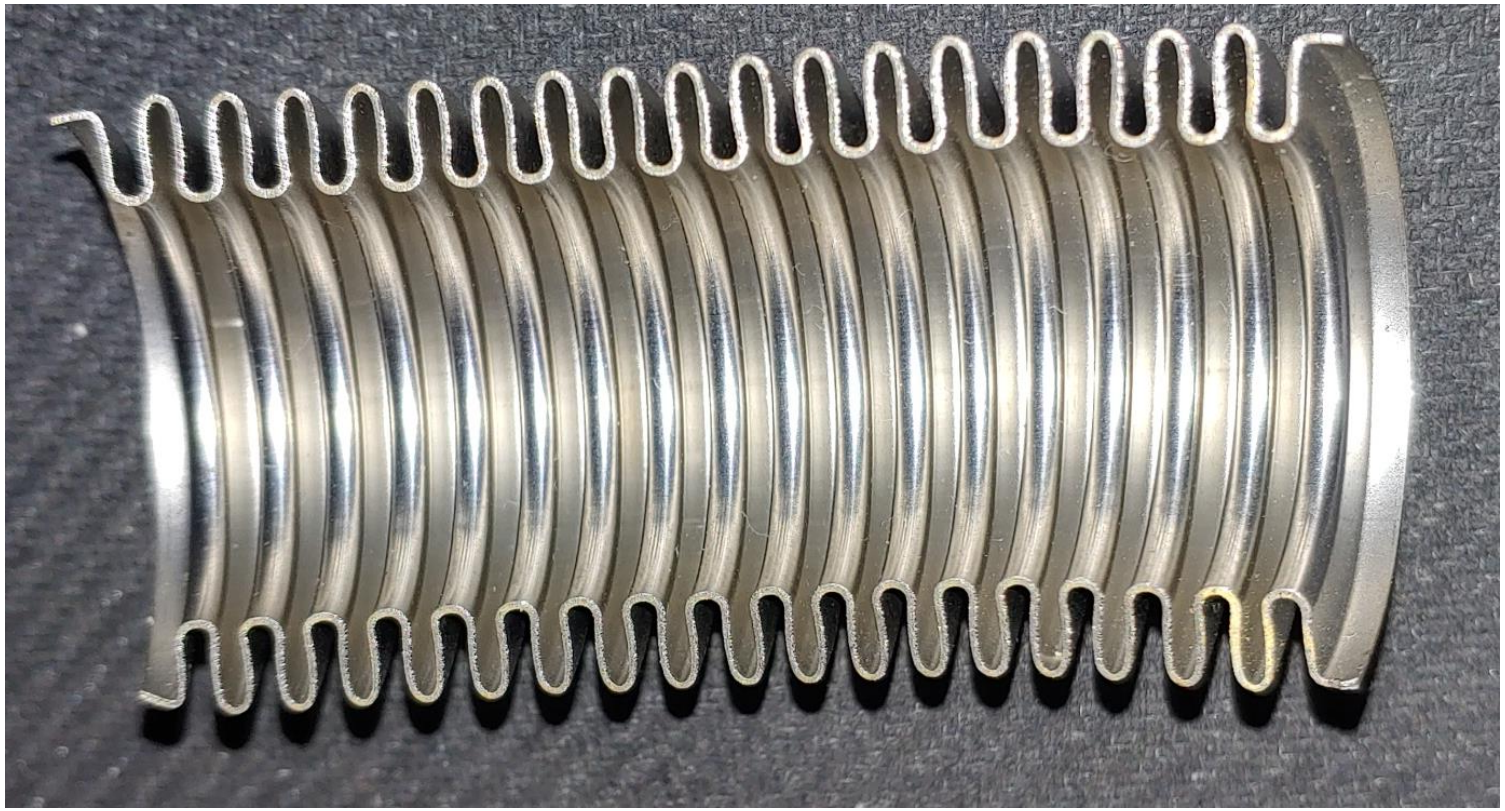


Figure 5

GLV bellow hydraulic protection from high injection pressure

Most GLV feature internal seal that traps " non compressible" silicone oil and protects bellow from high injection pressure. This is actually wrong assumption. See figure 7 below:

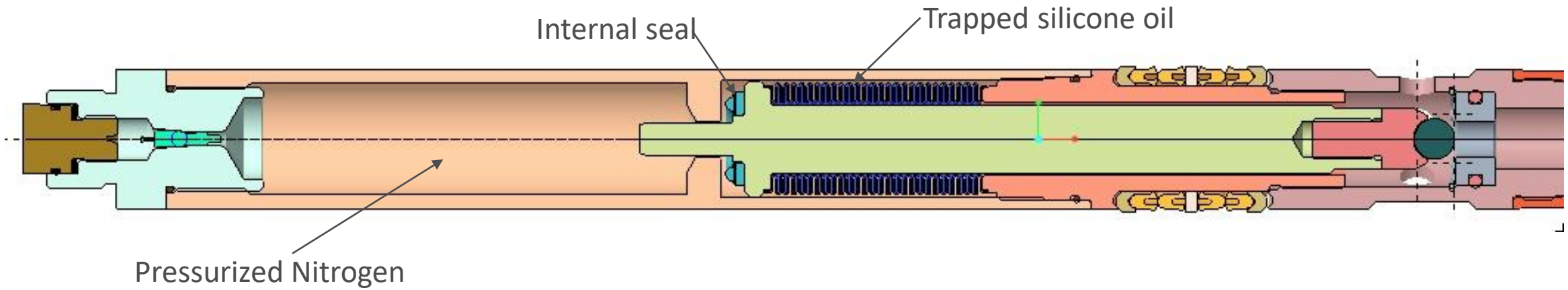


Figure 7

Permanent gas effect

- In GLV dome charged Nitrogen is in direct contact with silicone oil and dissolves/penetrates into oil.
- Nitrogen is permanent gas and never liquifies no matter how high pressure is.
- This creates mixture of silicone oil and Nitrogen bubbles rendering oil compressible.
- Complete theory of GLV “hydraulic bellow protection” is based on wrong assumption.
- Bad bellow crimping, wrong theory of hydraulic bellow protection, chatter, overtravel and over-pressurizing are main reasons for valve/bellow failures.
- Bellows mostly fail due to material fatigue

Solution for bellow protection

- First step is proper bellow crimping.
- Second is application of patent based “ *FORTRESS*™ ”-external stem seal”
- “ *FORTRESS*™ ”- seal is placed outside bellow and engages when valve is in fully open position. See figure 8 below showing valve in closed position.
- This prevents high injection pressure ever reaching bellow.

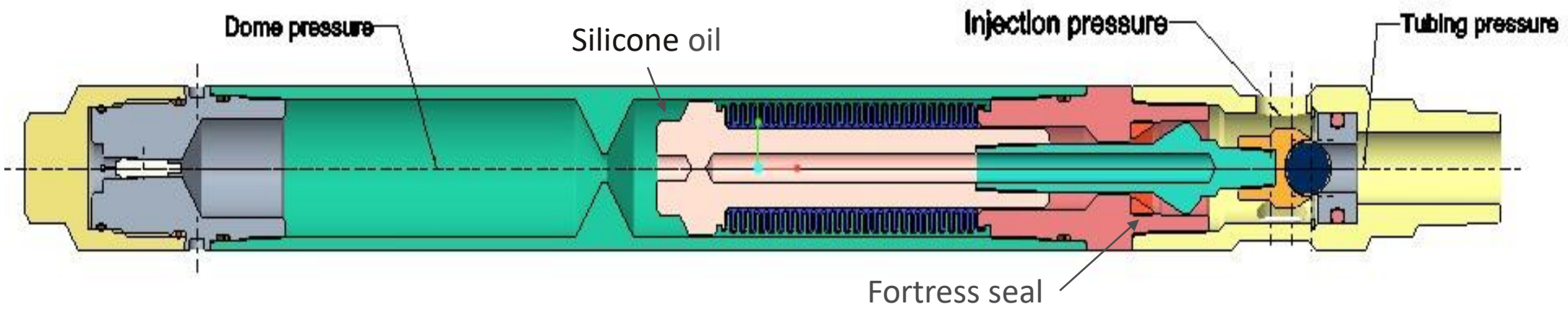


Figure 8

Solution for absolute bellow protection

- Conventional valve with external stem seal engaged and valve in fully open position. Path of injection pressure to bellow is closed. See figure 9 below.
- No impact on valve performance.
- Silicone oil is used only to prevent valve chatter

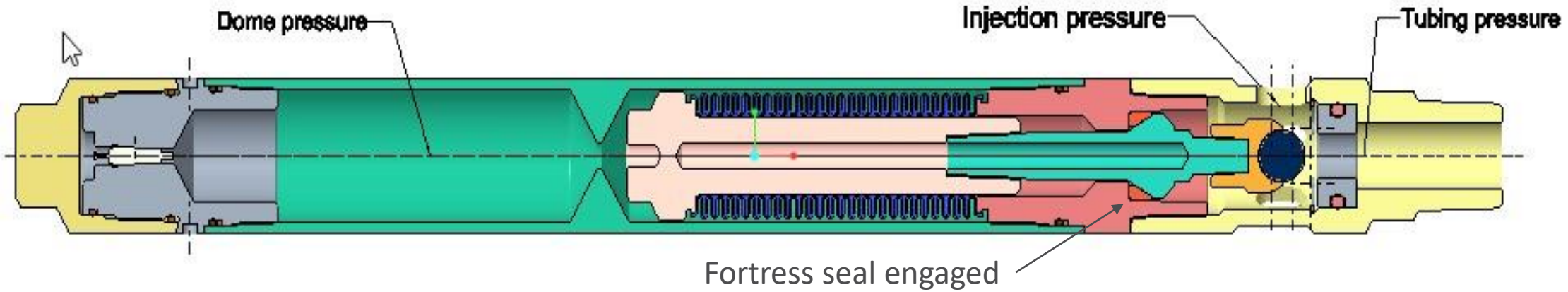


Figure 9

Dual fortress seal gas lift valve per patent # US 11,242,732B2

- This design features dome and stem fortress seal. Dome seal protects bellow from high dome pressure, stem seal protects bellow from high injection pressure and ageing pressure.
- Valve is using pre-crimped Inc 625/718 or Monel 400 bellow.
- Valve is using telescoping stem because two mechanical stops at a same time are impossible. Dome fortress seal is mechanical stop. See figure 11 below.

Dual fortress seal gas lift valve per patent # US 11,242,732B2

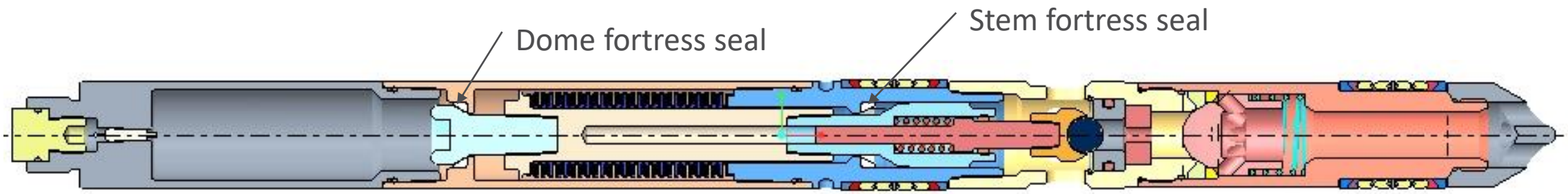


Figure 11

High pressure DEWB-dual edge welded bellow gas lift valve per my patent # US 11,686,185 B2

- Valve features sealed DEWB-dual edge welded bellows subassembly filled with non-compressible de-gassed silicone oil, see figure 12 below.
- Edge welded bellows do not require crimping. There are two types of EWB, for full compression to solid and for partial compression.
- Both bellows go to full compression either by dome or injection pressure, bellows are fully protected.
- Lower bellow surface area is larger than upper-dome bellow area for the area of orifice. This provides close to zero differential pressure across bellows for complete pressure range.
- Valve max dome pressure is 10KSI.

High pressure DEWB-dual edge welded bellow gas lift valve per my patent # US 11,686,185 B2

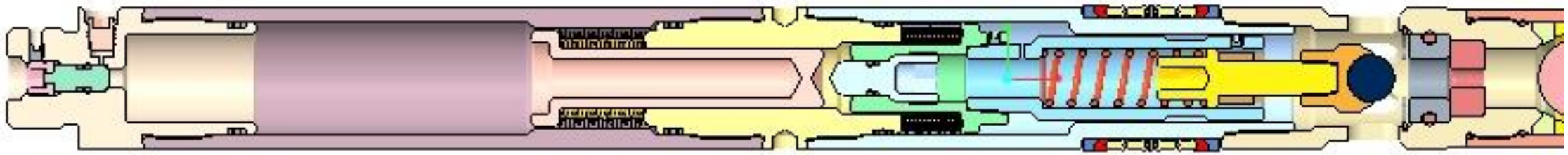


Figure 12

DEWB-Dual edge welded bellow assembly

- DEWB subassembly is sealed, filled with de-gassed silicone oil.
- Oil volume is minimized to minimize effect of thermal expansion, figure 13 below.

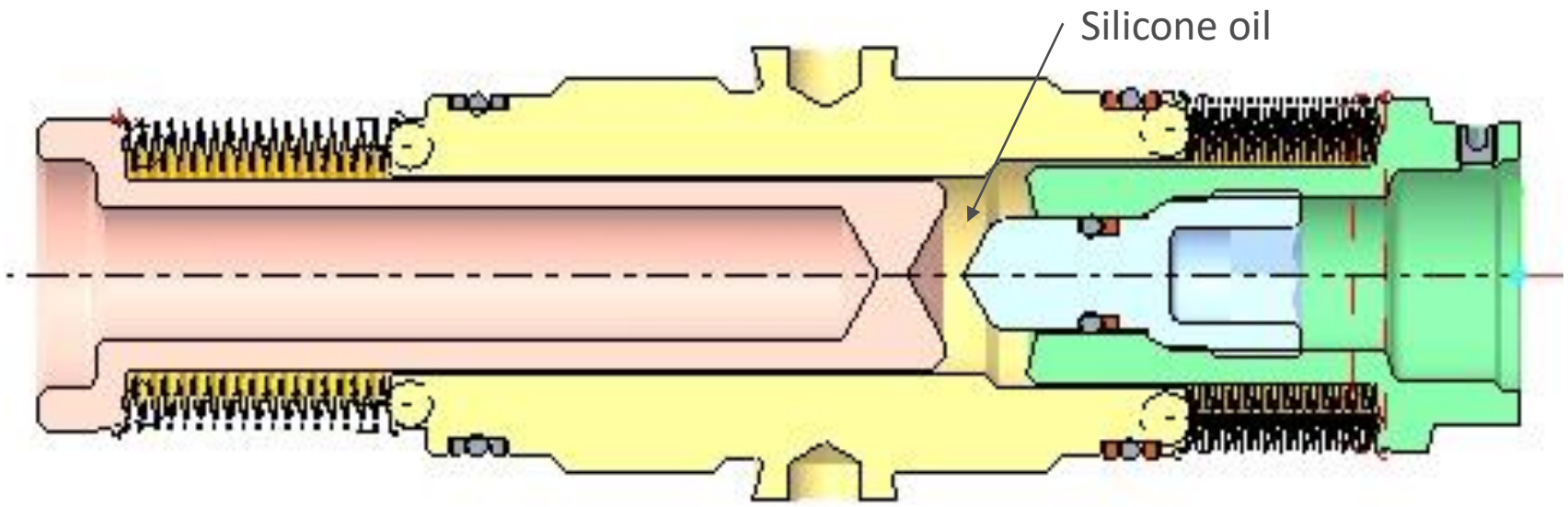


Figure 13

SEWB-single edge welded bellow valve with fortress seal

- Another design shows SEWB gas lift valve with external stem seal, see figure 14 below.
- Bellow goes to full solid state by design protecting bellow from high dome pressure.
- External stem seal protects bellow from high injection pressure

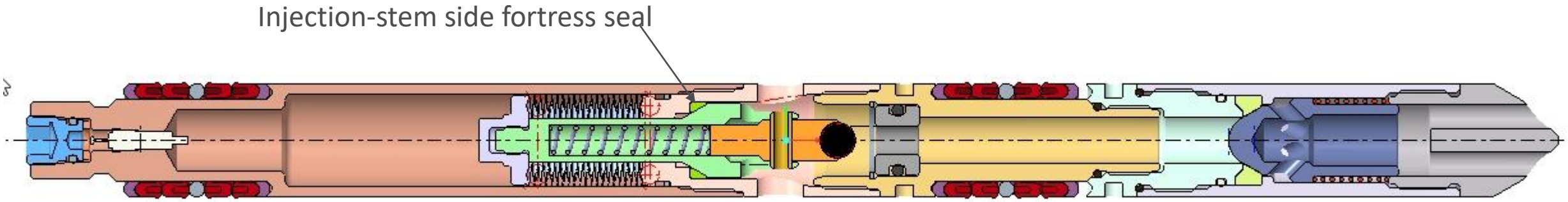
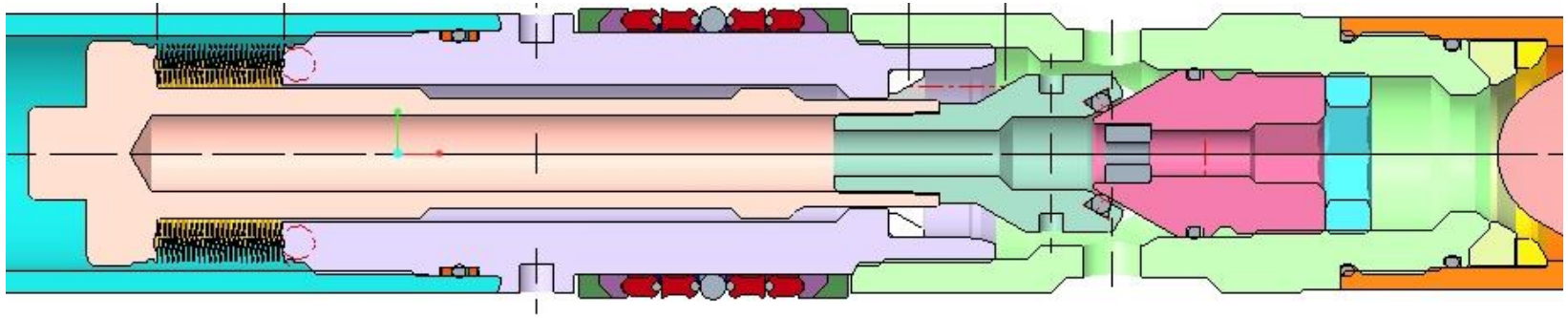


Figure 14

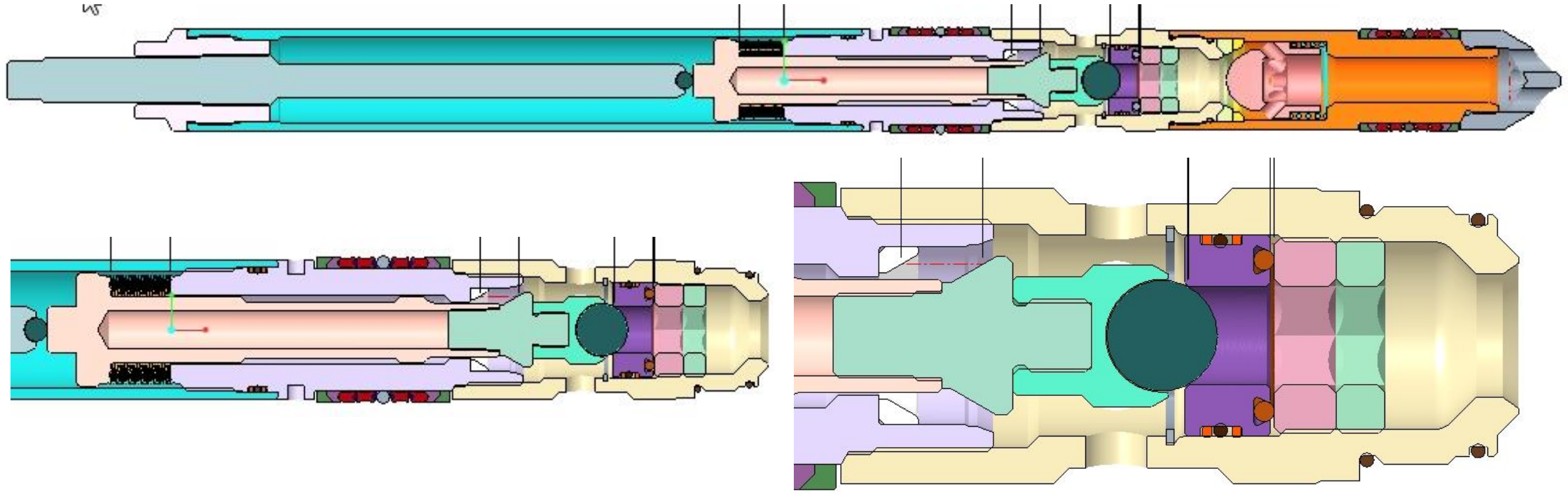
Introducing game changer-TSMS gas lift valve per my patent # US 11,643,910 B2

- TSMS-Two simultaneous mechanical stops chemical injection and gas lift valve.
- First mechanical stop fully compressed SEWB or DEWB bellow that fully protects bellow from high dome pressure.
- Second adjustable mechanical stop TC ball/orifice or conical sealing surface with compressible seal.



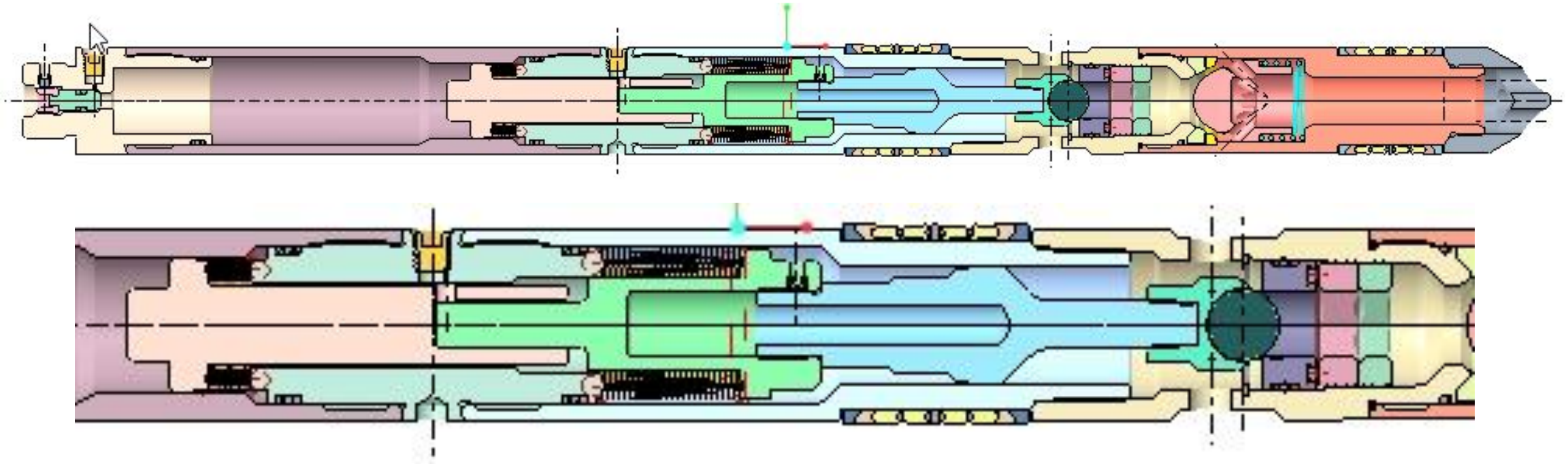
TSMS gas lift valve per my patent # US 11,643,910 B2

- Both valves CI and GLV feature external stem seal that protects bellow from high injection pressure.



TSMS dual edge welded bellow high pressure GLV

- Design based on my patents # U S11,643,910 B2 and # US 11,686,185 B2
- GLV features absolute bellow protection from high dome/injection pressure up to 10 KSI.



Acknowledgements, Thank You & Questions

1. Existing valve design work, why do we need changes?
2. Why is ageing process performed and is it necessary?
3. When is differential pressure against bellow at maximum?

- Author would like to thanks Z-Tech Design New Iberia LA, ELC Energy Services Houston TX, Alloy Precision Technology OH for pictures and drawings used for this presentation and Damien Leonard, increase wellproduction.com for picture 1.