A New Approach to The Differential Valve

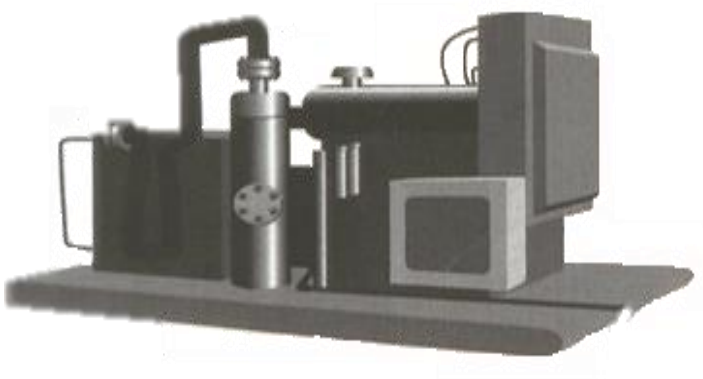
- Steve Long – Weatherford Gas Lift PLM

Introduction – Background Information

- First differential valves used widely in 1930's & 40's
- 1944 King Injection Pressure Operated Valve (IPO)
- New differential valve designs - 1990's & 2000's
- 2012 Weatherford development for Shell HPHT
- 2014 Weatherford New 1.5" Differential Valve
- 2016 Weatherford RH-2 XHP IPO Valve (5000 psi)

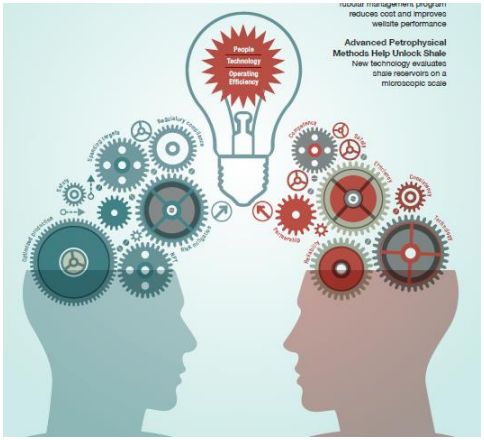
Why Bother with Differential Valves?

- **Can operate at varying injection gas pressures**
- **No Bellows**
- **Not temperature sensitive**
- **Good flow characteristics**
- **Simplicity in design and handling**

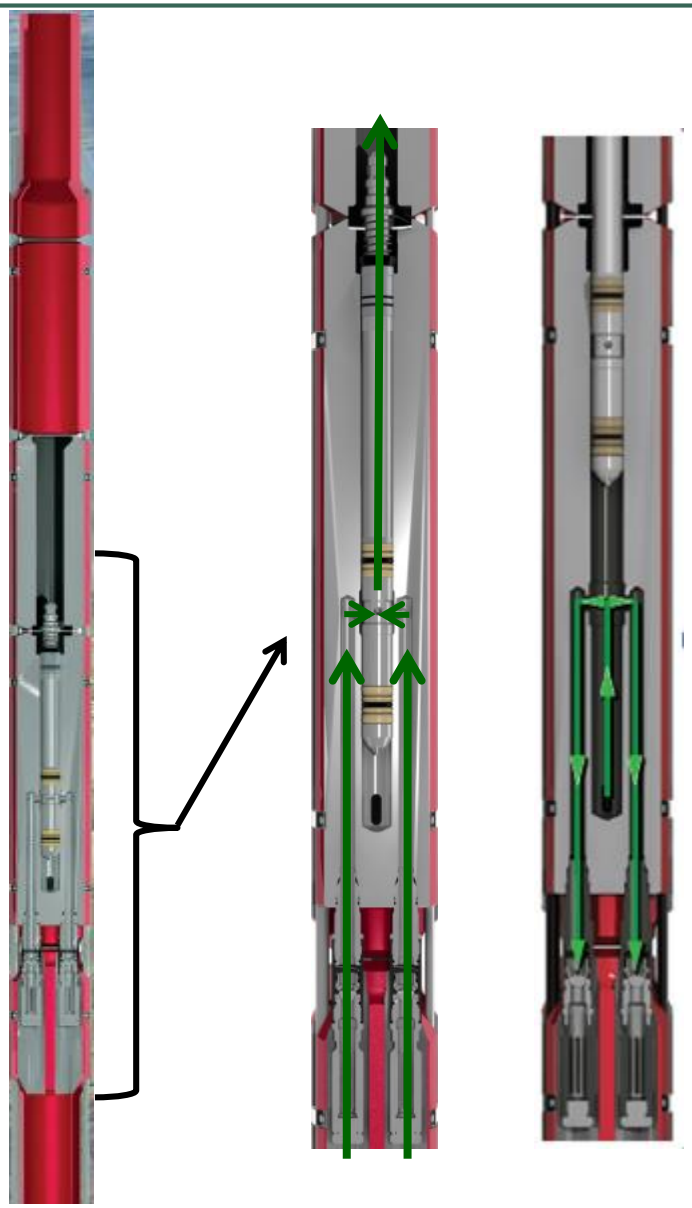


New Weatherford 1.5” Differential Valve

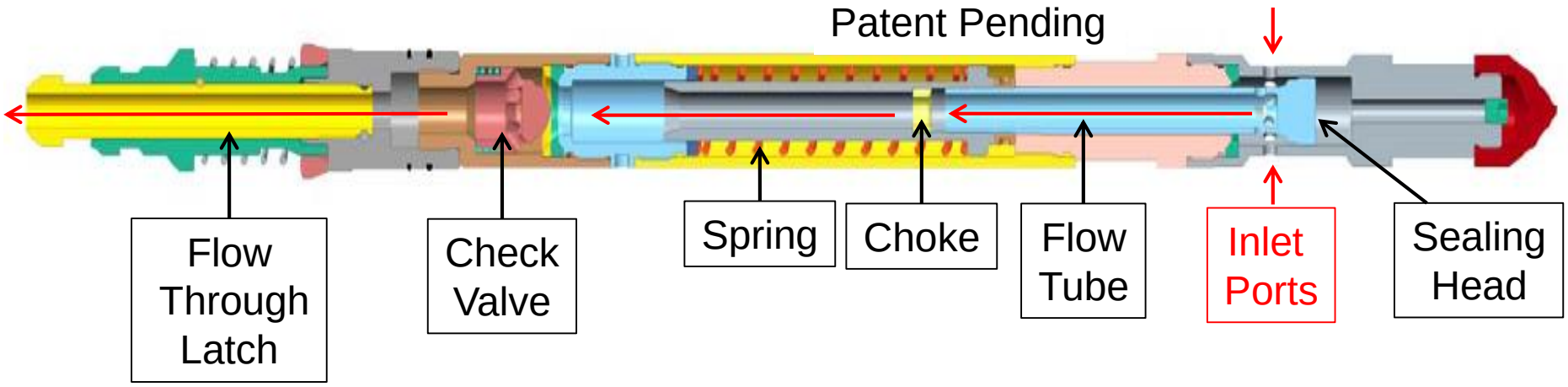
- **Complete redesign similar to a velocity type safety valve**
- **Positive results from flow testing**
- **Closes on predetermined differential pressure**
- **Reopens at lower differential pressure than original closing differential**
- **Considerations**
  - **Specific unloading and kick-off procedures**
  - **Surveillance and planning**



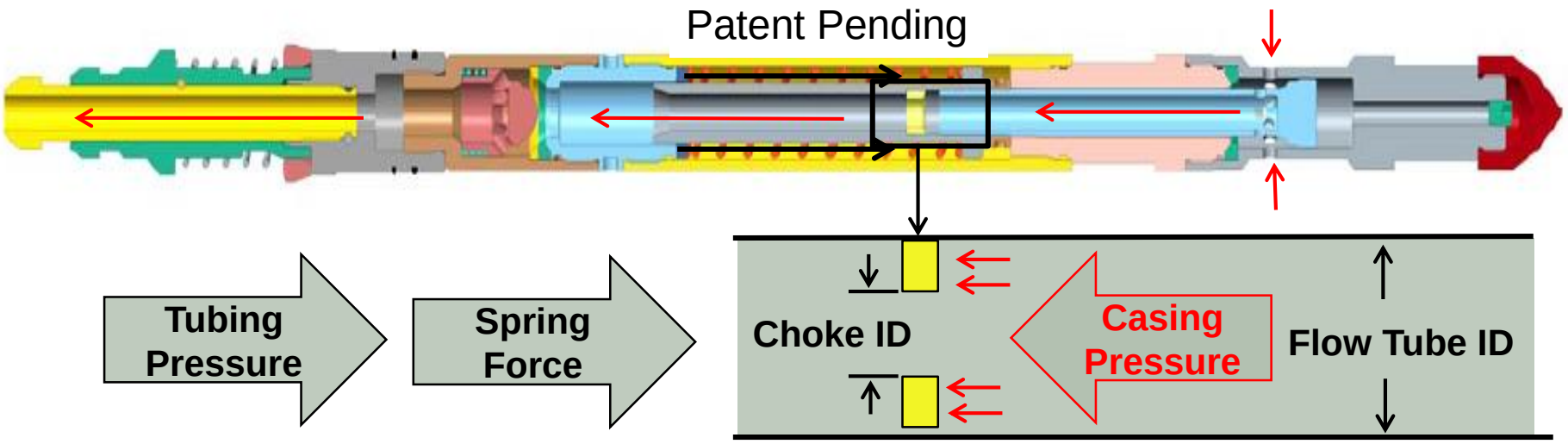
New 1.5” Differential Valve Flow Path



New 1.5” Differential Valve



New 1.5” Differential Valve Mechanics – Open Position



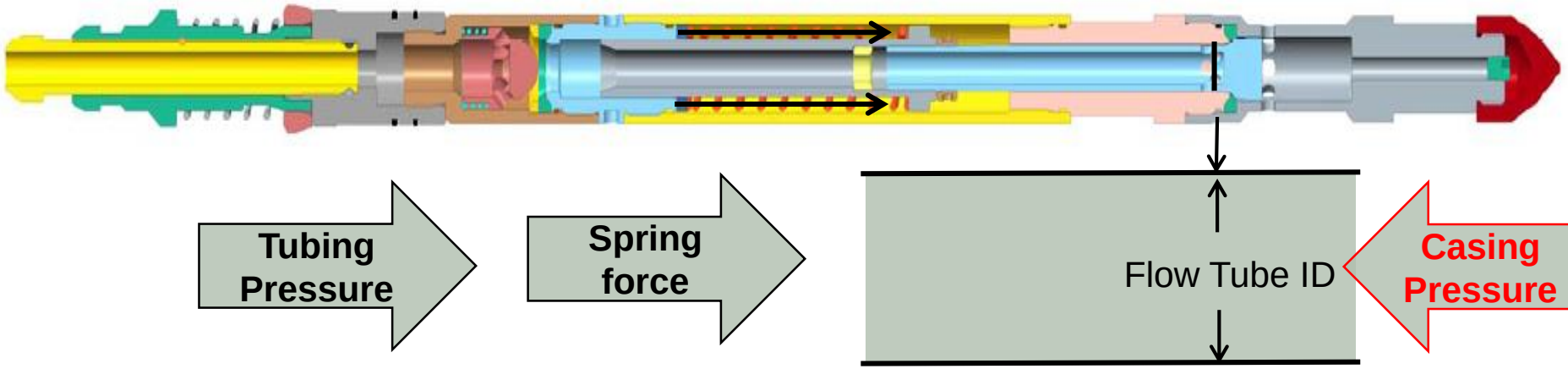
$$\text{Differential Closing Pressure} = \left[\frac{\text{Spring Force}}{\text{ID Area of flow-tube – ID area of choke}}\right] \left[\text{Friction Factor}\right]$$

Where:

$$\text{Differential Closing Pressure} = \text{Casing Pressure – Tubing Pressure}$$

New 1.5” Differential Valve Mechanics – Closed Position

Patent Pending



$$\text{Differential Reopening Pressure} = \left[\frac{\text{Spring Force}}{\text{ID Area of flow-tube}} \right]$$

Where:

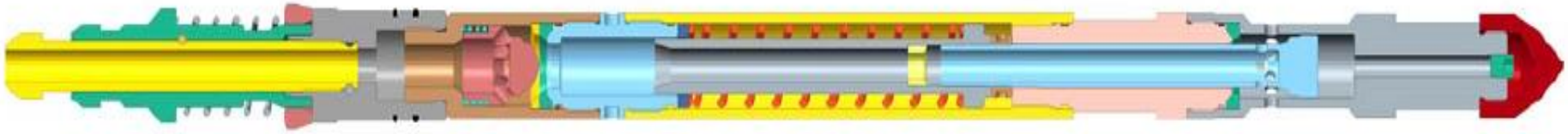
$$\text{Differential Reopening Pressure} = \text{Casing Pressure} - \text{*Tubing Pressure}$$

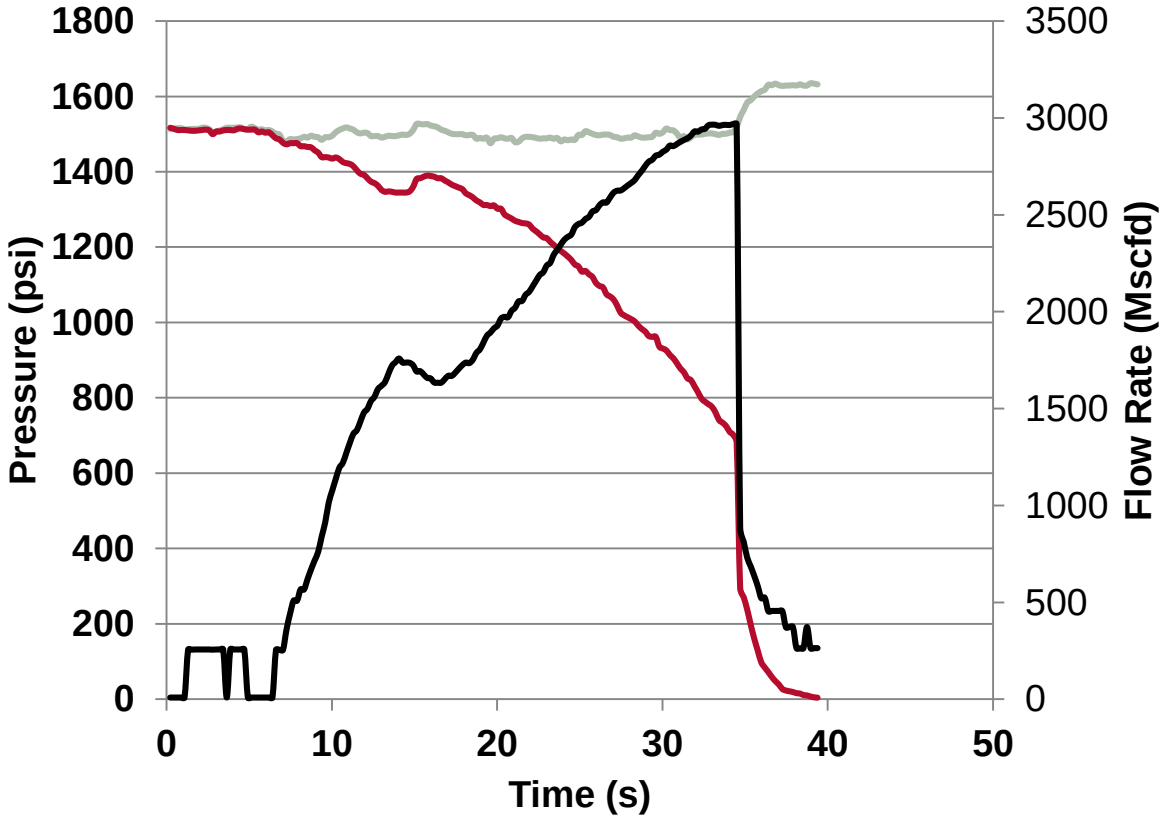
Note: If check is spring loaded check valve and the sealing head with a positive seal is used, then trapped pressure inside the flow-tube instead of tubing pressure applies

Weatherford Gas Lift Valve Test Skid at R&D Lab

New 1.5” Differential Valve – Test #57 Close

Patent Pending

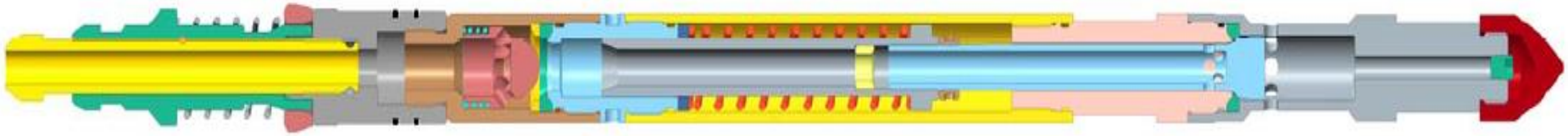


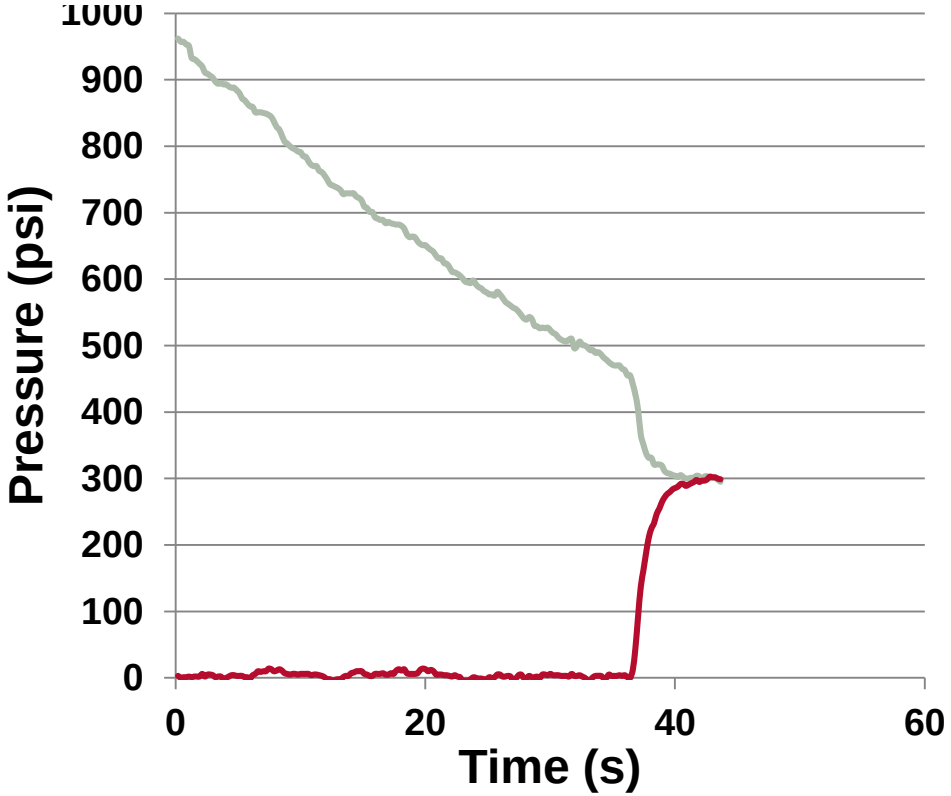


- **.313” Choke**
- **~1520 upstream/casing**
- **Closed at 680 psi downstream**
- **840 psi differential closing pressure**
- **2.9 MMSCF/Day at close**

New 1.5” Differential Valve – Test #57 Reopen

Patent Pending





- .313” Choke
- 450 psi Reopen

Example Well Data

Tubing Size	**5.5”**
Mid Perforations	**10,000’**
Static BHP	**5000 psi**
Completion Fluid Gradient	**.500 psi/ft**
Productivity Index	**5**
Water Cut	**50%**
Water Specific Gravity	**1.07**
Formation GOR	**200:1**
Wellhead Back Pressure	**200 psi**
Injection Pressure	**1500 to 2000 psi**
Injection Gas Specific Gravity	**.70**
Injection Gas Volume Requirement	**3 to 5 MMSCF/Day**
Production Rates**	***10,000 BFPD with 1500 psi injection pressure**
	***12,000 BFPD with 2000 psi injection pressure**

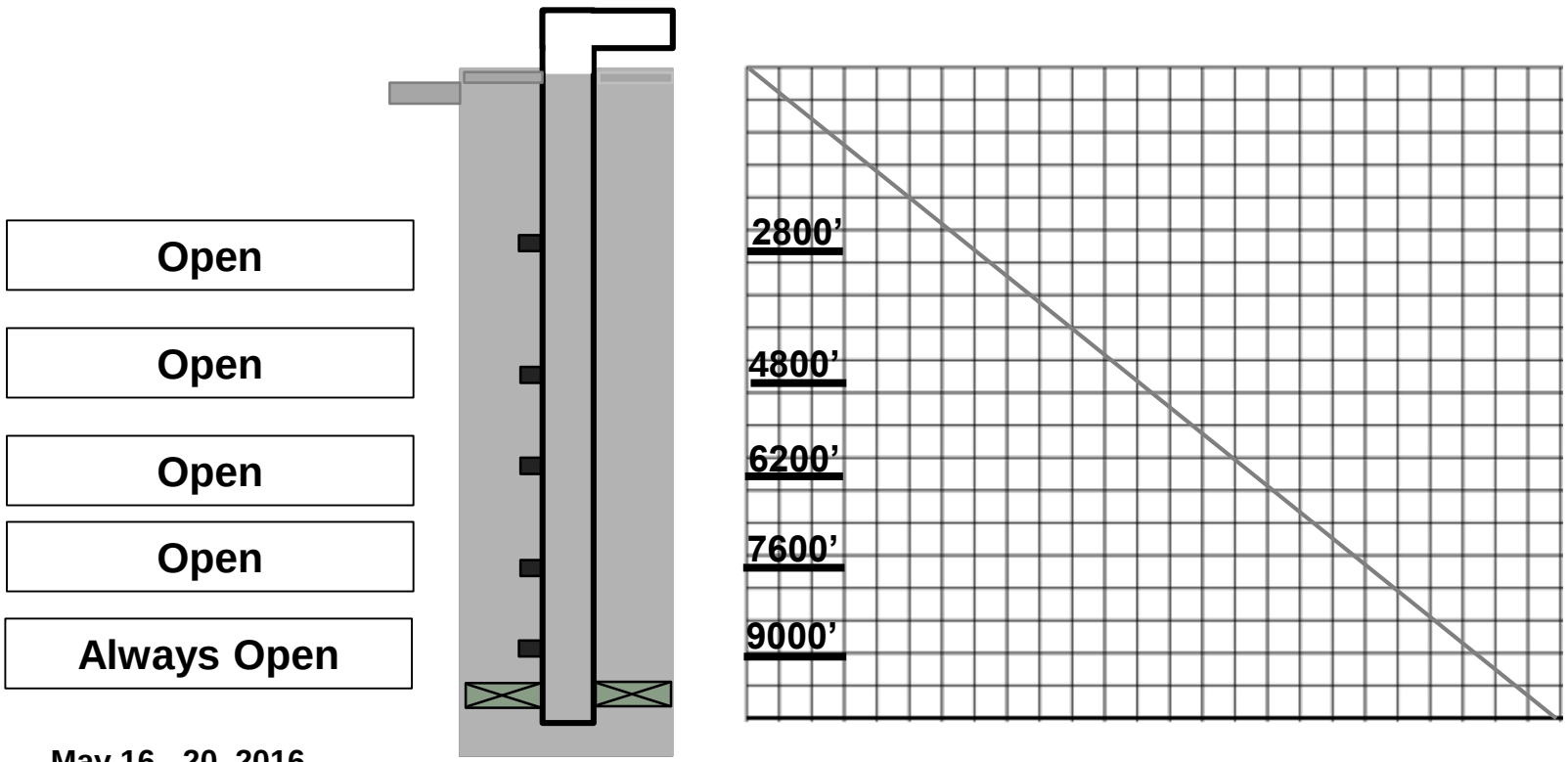
Example Well Differential Valve Design

True Vertical Depth (feet)	Valve Type	Choke Size (inches)	Differential Close (psi)	Differential Reopen (psi)
2800’	Differential	16/64”	1050	650
4800’	Differential	20/64”	750	450
6200’	Differential	22/64”	750	400
7600’	Differential	24/64”	750	400
9000’	Orifice	24/64”	NA	

*The above spacing is based on minimum of 1500 psi injection pressure and maximum 2000 psi

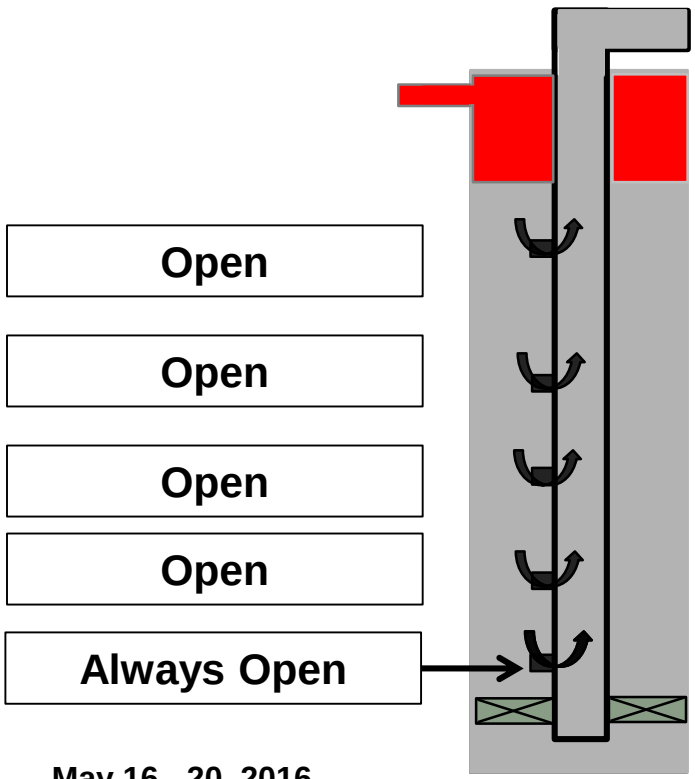
Stage 1 – New 1.5” Differential Gas Lift Valve Unloading

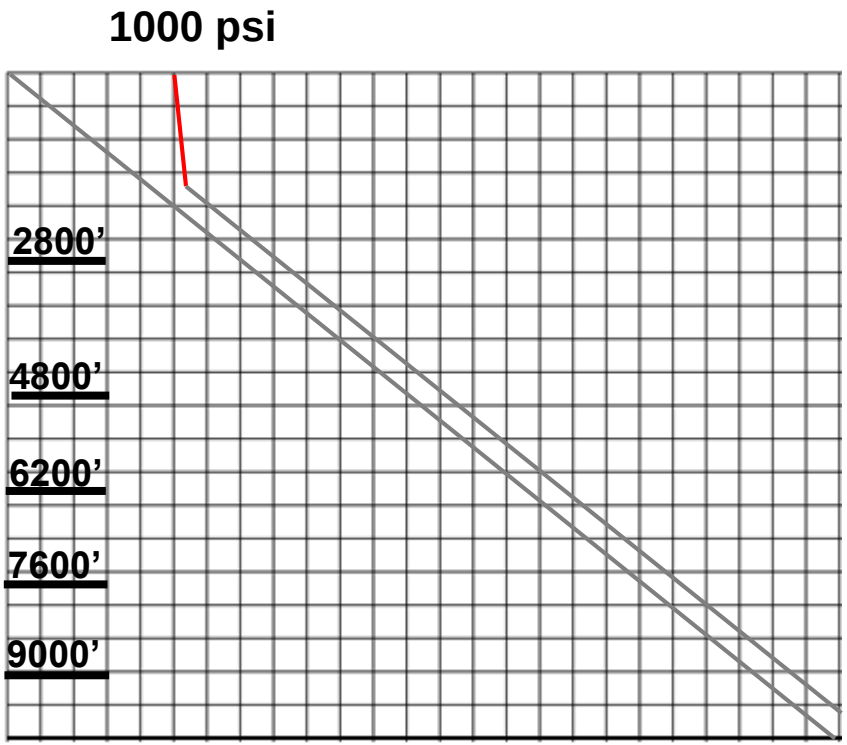
- Well is loaded with completion fluid.
- All differential valves are open
- The orifice valve remains open at all times



Stage 2 – New 1.5” Differential Gas Lift Valve Unloading

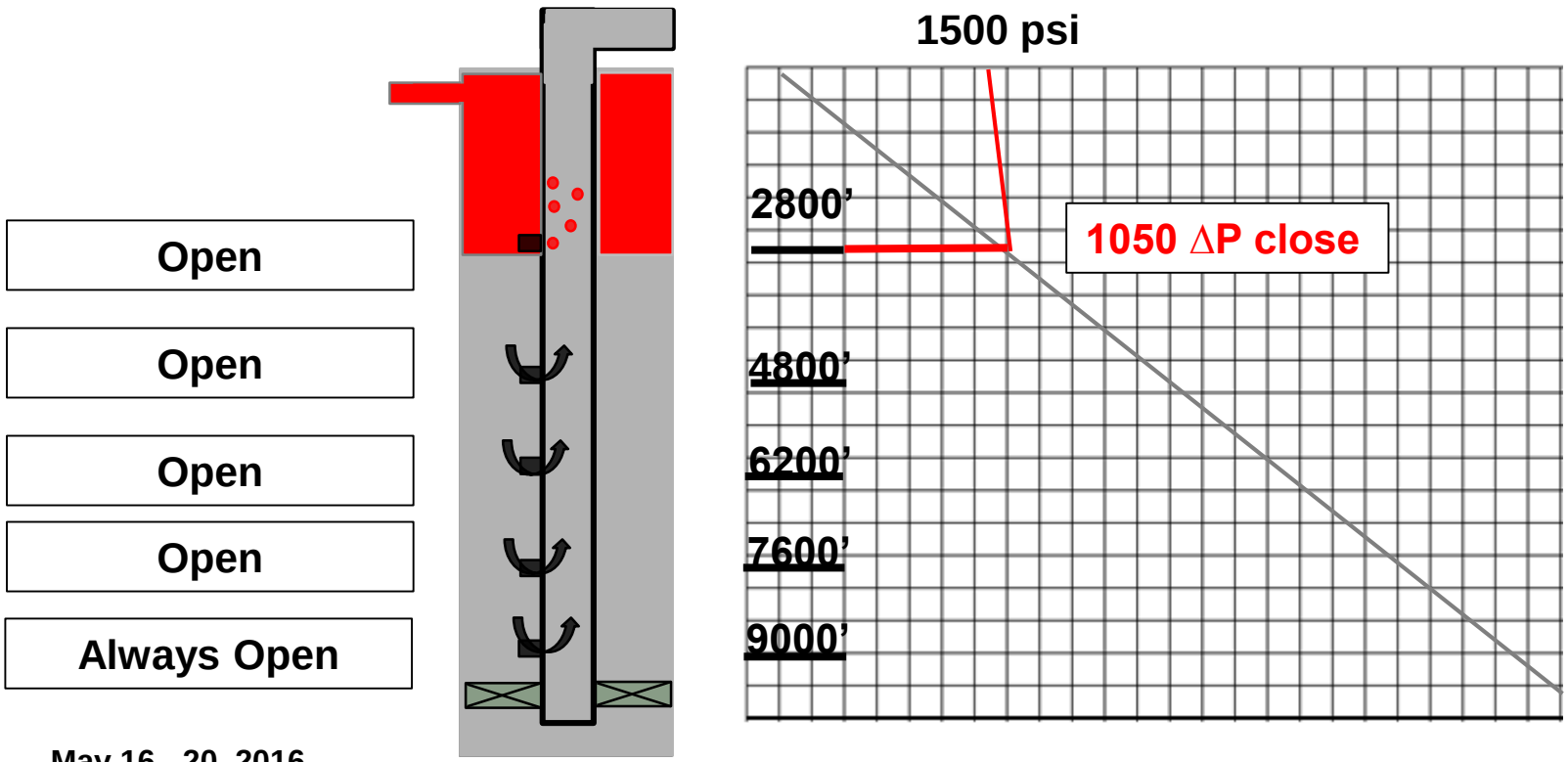
- **Injection gas is started to unload well**
- **Differential valves open**





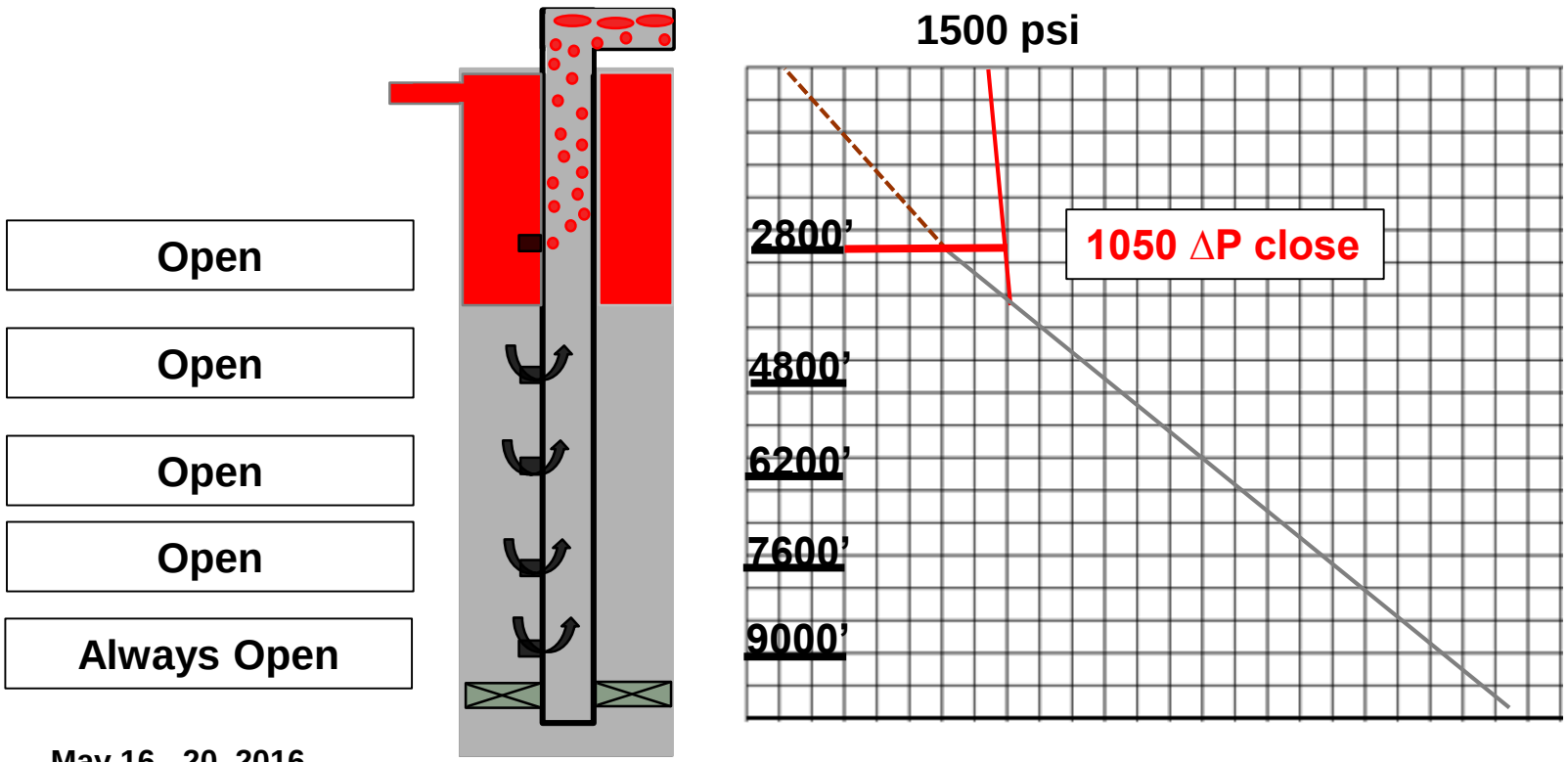
Stage 3 – New 1.5” Differential Gas Lift Valve Unloading

- **Injection gas enters top differential valve at 2800’**



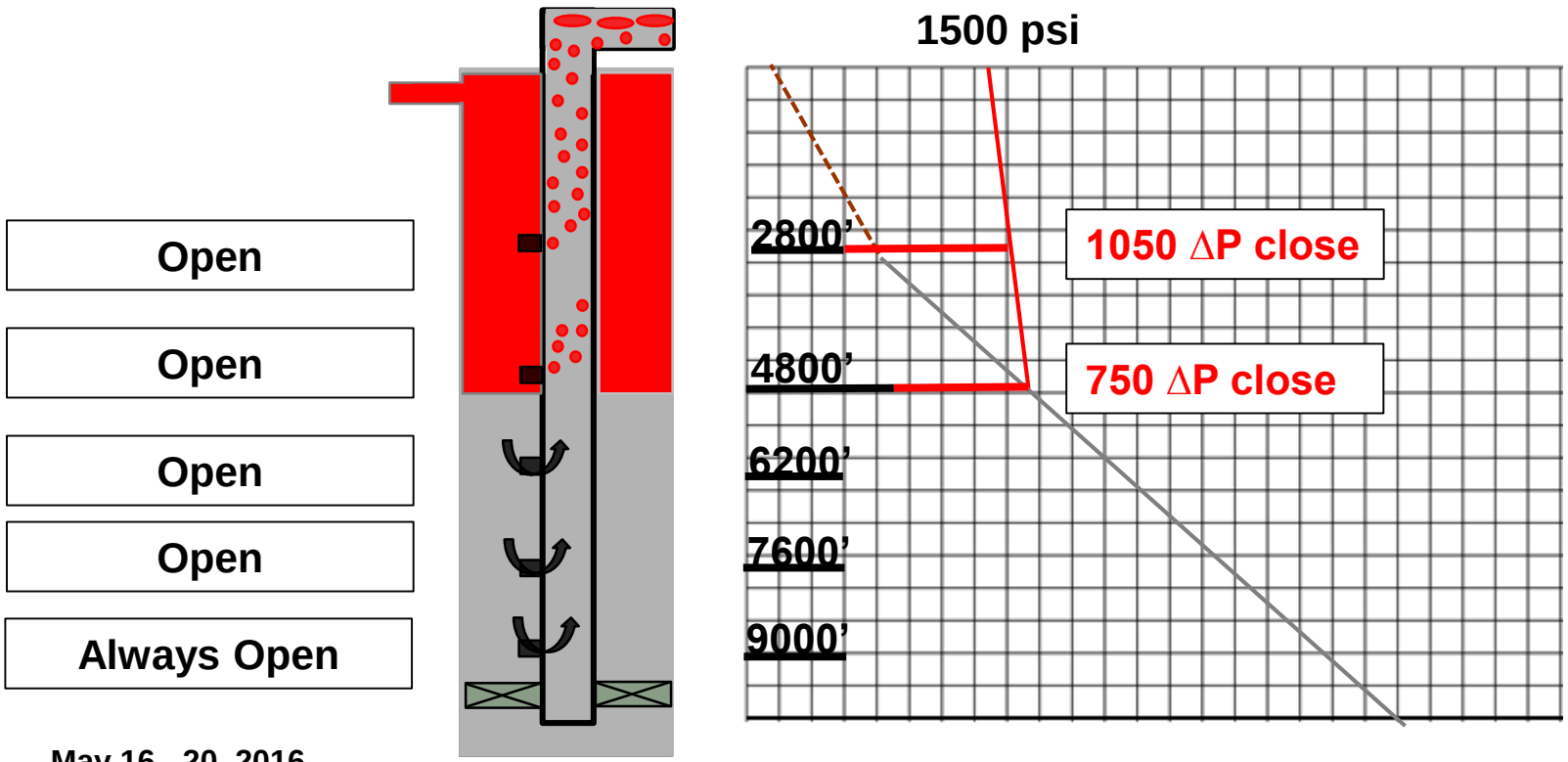
Stage 4 – New 1.5” Differential Gas Lift Valve Unloading

- **Fluid level in casing continues to drop as gas is injected in top differential valve at 2800’**



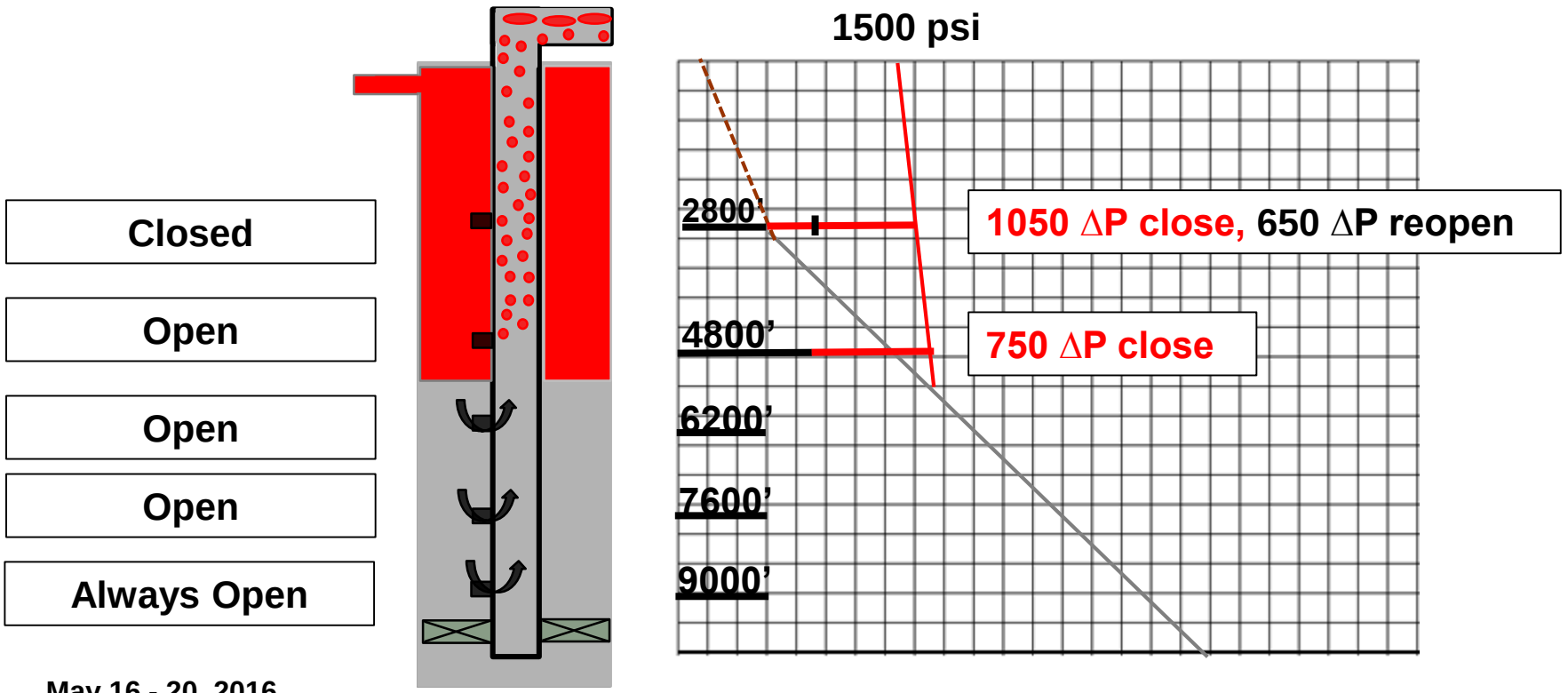
Stage 5 – New 1.5” Differential Gas Lift Valve Unloading

- Injection gas enters 2nd differential valve at 4800’
- Top and 2nd differential valves will be injecting gas simultaneously
- Sufficient injection gas volume will have to be maintained



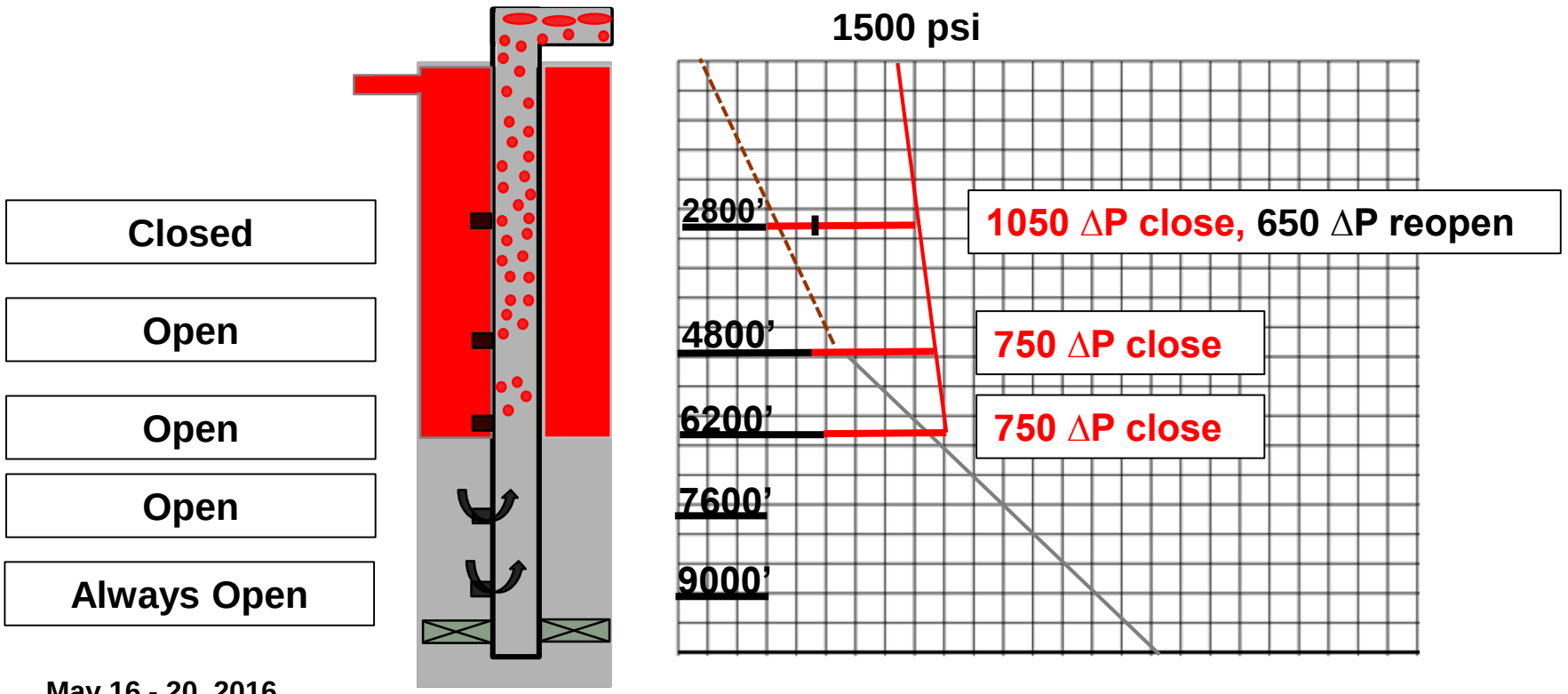
Stage 6 – New 1.5” Differential Gas Lift Valve Unloading

- Differential valve at 2800’ closes
- Injection point is at 4800’ as unloading continues



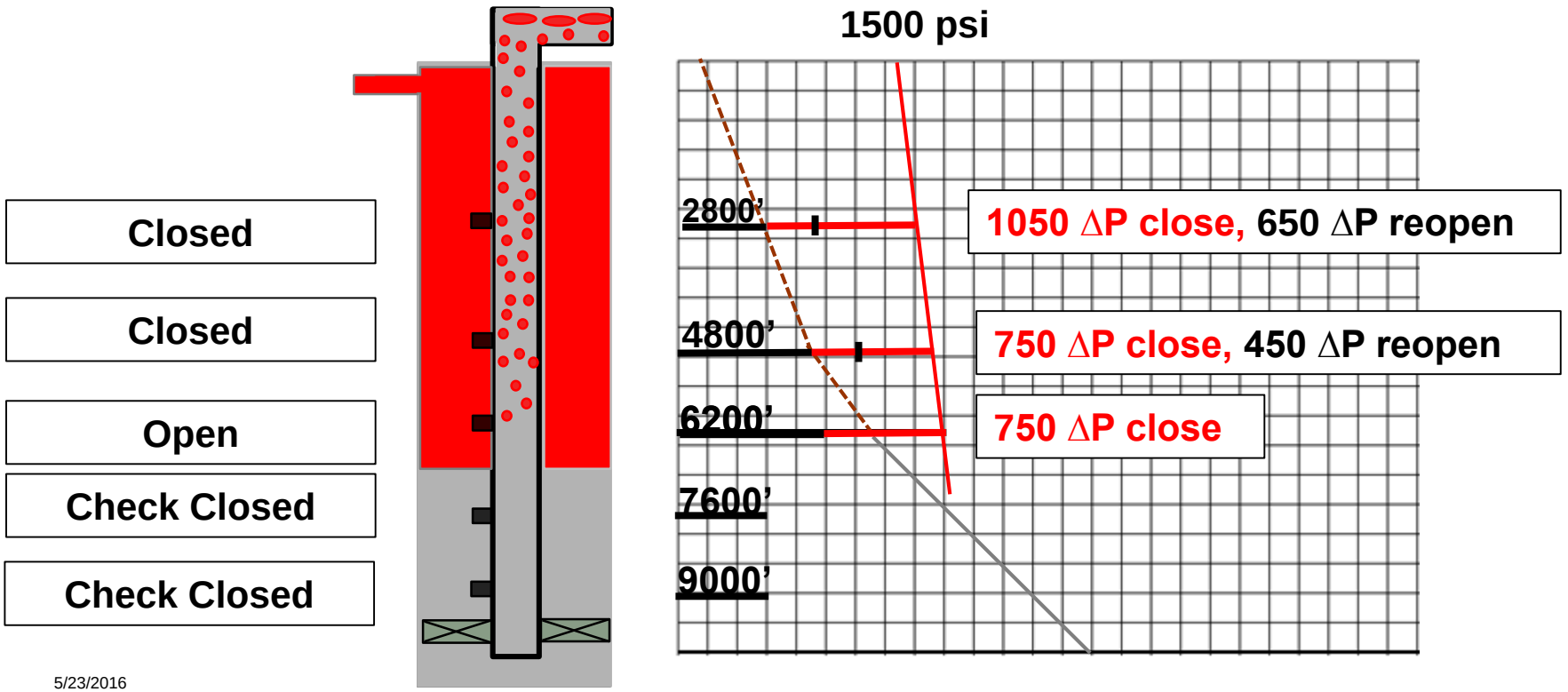
Stage 7 – New 1.5” Differential Gas Lift Valve Unloading

- Injection gas enters 3rd differential valve at 6200’
- 2nd and the 3rd differential valves will be injecting gas simultaneously
- Sufficient injection gas volume will have to be maintained



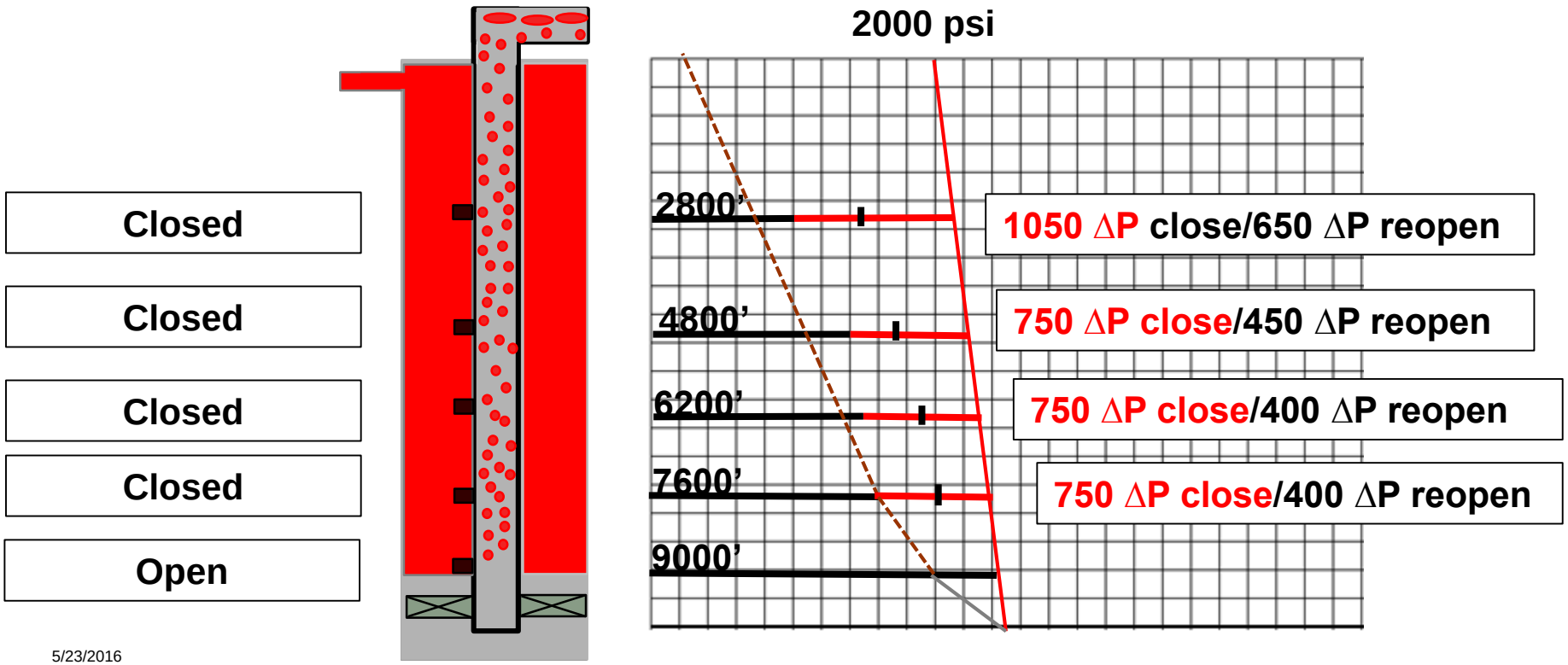
Stage 8 – New 1.5” Differential Gas Lift Valve Unloading

- The differential valve at 4800’ closes
- The injection point stabilizes at 6200’
- Production rate of ~10,000 BFPD



Stage 9 – Unloading Complete for 2000 psi Injection Pressure

- The differential valve at 7600’ closes
- Injection point stabilizes at 9000’
- Production rate is ~12,000 BFPD



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