

New Multi-chamber Valve Saves Time, Improves Safety on Midcontinent Unconventional Well

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Abstract

The paper presents the early field application of a new multi-chamber frac valve, placed between the frac head and lubricator, to improve the efficiency and safety of plug and perforate completions. On two Midcontinent wells, the valve enabled continuous frac operations and wireline transitions in 8 to 15 minutes (subsequent well transitions were performed in 3 to 5 minutes) while reducing personnel safety exposure and eliminating certain operational risks including cutting the wireline.

The new system was developed to make it faster, easier and safer for crews to deploy perforating and frac plug assemblies during multi-stage frac completions. The system is comprised of two hydraulically actuated flapper valves that are enclosed in a cabinet, which also contains a computer that controls valve operation. A quick-connect latch on top of the upper valve enables easy connection of the wireline lubricator. During each stage of the completion, the multi-chamber valve equalizes pressure between the surface/lubricator and the well and enables wireline conveyed tools, balls and collets to pass easily between the surface and the well without pressuring down and re-pressurizing the flow iron.

The paper describes an early application of the multi-chamber valve on two multi-stage wells in the Midcontinent region. On this job, the valve was not equipped with the quick-connect latch for attaching the lubricator. As configured for these wells, two conventional valves could be removed from the frac stack, and the new system provided a dual barrier above the frac head. Only two hydraulic lines were required for valve actuation. No backside pump was needed to equalize pressure in the lubricator. During the completion process, the system's valves were remotely operated from a control cabin, eliminating the risk of severing the wireline through human error. Remote control reduced the need for crew members to work at height in the red zone. Two swaps were performed at each stage in 8 to 15 minutes each, compared to 40-60 minutes per swap using common practices. On two 25-stage wells, the new valve saved at least 25 hours of operating time. In addition, the valve enabled a quick response to close in the well after a wireline failure, enabling the immediate resumption of well control.

The paper also provides a brief operational summary of the system using the multi-chamber valve coupled with the quick-connect latch on a three-well pad in Wyoming, during which

wireline swaps were performed in an average of three minutes each.

Plug and Perf Preferred over Sleeve Method

The plug and perforate (PnP) technique is the most prevalent completion method in North America's shale and tight oil plays. The method provides the ability to pinpoint fracture locations with perforating guns; adjust stage spacing during the completion; achieve zonal isolation between stages; and complete a hundred or more stages in a horizontal well.

In contrast, the ball-and-sleeve completion method uses predetermined stage spacing, does not provide perforation tunnels to initiate fractures, and ball drop sleeve actuation limits the total stage count to around 40 stages. The ball-and-sleeve method's main advantage is providing the ability to conduct continuous pumping operations that are uninterrupted by time-consuming wireline perforating runs. Three to four days of continuous pumping are possible with this method.

Inefficiencies of PnP Completions

On a typical PnP horizontal well completion (Table 1), deploying wireline equipment for plug setting and perforating takes about twice the time required for pumping the frac treatment at each stage. The PnP process also typically involves personnel working at height in the red zone close to the frac tree.

Surface operations during a traditional PnP completion (Figure 1) require up to an hour to run the wireline tools through the lubricator into the well prior to perforating and up to another hour to retrieve the spent guns, drop the ball and seal the well for pumping.

Traditional wireline tool deployment (Table 1) involves three steps. First, the working valve on the frac tree is shut manually by a person working in the red zone, and the wireline operator picks up the gun assembly and suspends it over the frac head and the red zone operator. Next, the operator in the red zone installs the wireline lubricator. The frac iron is then pressure tested, and if the test is successful, the working valve is opened and the wireline tools can be lowered into the well. This process can take 30-45 minutes. If the pressure test is unsuccessful, more time is needed to find and repair leaks in the iron.

Pulling the wireline tools after perforating can be equally

time-consuming. During the traditional process, the operator in the red zone closes the working valve manually, releases the lubricator, and bleeds off pressure. (At this step, closing the valve on the wireline can cut the wireline, resulting in a costly fishing job and at least a day of non-productive time.) If a ball is needed, the red zone operator drops it onto the swab valve and then installs the frac head cap. The frac iron is then pressure tested, and if the test is successful, the red zone operator opens the swab valve manually to let the ball descend down the wellbore and seat onto the frac plug so pressure pumping can begin. This post-wireline process typically takes 30-45 minutes per stage.

Design Goals of New Multi-Chamber Valve System

The new multi-chamber valve was designed and developed by experienced field operators and engineers working to make the PnP wireline deployment and retrieval process safer and more efficient. The design goals for the new system were to enable remote control of pressure equalization between the well and the lubricator (no manual valve operation); remove operators from the red zone (quick connection of lubricator); make it impossible to cut the wireline during surface operations; reduce the need for repeated frac iron pressure tests; and introduce other features to improve reliability, safety and efficiency.

New Valve System

The new valve system includes an assembly containing two hydraulically actuated flapper valves placed on top of the frac head; a quick-connect latch for attaching the wireline lubricator; and a control center that powers the valves and enables remote operation of the system.

Three-Chambered Valve

The valve has three chambers, separated by the flapper valves, which enable pressure to be equalized between the lubricator and the well without operating the frac tree's working valve and while maintaining pressure on the stack and frac iron. The system's flapper valves, actuators, bypass valves, hydraulic lines, and control computer are enclosed in a cabinet and connected to the control center by only two hydraulic hoses (Figure 2). The onboard computer enables the system to be remotely controlled to equalize pressure in the chambers, operate the flapper valves, and open and close the quick-connect latch for the lubricator. The valve system is instrumented to provide pressure readings for each of the three chambers to verify proper operation and detect leaks.

The valve system's two flapper valves provide two 15,000 psi barriers to control well pressure. The flapper valves operate in one direction and seal against wellbore pressure from below. An o-ring provides a low-pressure seal, and above 500 psi the flapper has a metal-to-metal seal. The flapper valves are designed so they cannot be opened unless pressure is equalized above and below the valve within 5 psi, so accidental pressure releases are prevented. The flapper valves also are designed so they cannot damage or sever the wireline passing through the chambers in the event they are closed on the wireline.

Automated Quick-Connect Latch

The lubricator quick-connect latch (Figure 2) is fully automated and operated from the control center. At 22-in in height, the latch is one-third the size of traditional latches. Attaching the lubricator does not require an operator in a man-lift in the red zone and saves time by eliminating stabbing and winging of the lubricator. The new multi-chamber valve provides a double barrier, so a night cap is not required for well control. The iris-style latch secures the lubricator with 360° contact, instead of with discrete hold points. The latch has redundant safety features including the ability to test seals, and a lock that eliminates accidental detaching through human error or through loss of hydraulic pressure. An internal drain prevents fluid from spilling to the ground when the lubricator is de-pressured and detached.

Valve Control Center

The portable control center (Figure 3) can be used to remotely control up to four multi-chamber valves and quick-connect latches. The control center includes an office space for operators, an electric generator, hydraulic power unit, an air compressor and space to transport three valve systems with latches. It can operate on its own generator, rig power or solar power as required. Each valve is operated using a laptop in the control center using a simple screen interface (Figure 4).

Valve Operations Sequence

Sequential operation of the multi-chamber valve is illustrated in Figures 5 and 6. The flapper valves isolate the upper chamber, the load lock chamber, and the lower chamber. When the lubricator is attached to the latch, the lubricator and upper chamber are at atmospheric pressure, and the two lower chambers are at well pressure. Then the upper chamber and lubricator are filled to equalize pressure to match well pressure. At this point, the two flapper valves are opened and the wireline can be run with the plug and guns. After perforating, the guns are retrieved and both flapper valves are closed. The lubricator and upper zone are bled down to atmospheric pressure, the lubricator is removed, and a ball can be dropped to rest atop the upper flapper. The ball is conveyed by lowering pressure in the load lock chamber to permit opening the upper flapper. The ball remains in an atmospheric environment until ready to be introduced to the wellbore, thereby eliminating premature deterioration of dissolvable balls. After the ball has entered the load lock, the upper flapper is closed to equalize the load lock to well pressure. Then the lower flapper can be opened to release the ball into the well. Table 2 compares the time required to perform wireline deployment retrieval and ball drop procedures using traditional methods and the new valve/latch system. Because the valve always maintains well pressure, pressure on the frac stack and iron, pressure does not have to be reduced, and pressure tests do not have to be carried out. Swaps can be performed in four minutes or less with the new system compared to 30-45 minutes with conventional methods.

Initial Field Operation

Chaparral Energy, an independent operator in the STACK and adjacent plays, wanted to improve the efficiency of its PnP completions, particularly during swap operations. On earlier projects, the process of attaching the lubricator, opening the working valve to gain access to the well, and beginning to run the wireline took 40-60 minutes. The wireline retrieval and ball drop process took a similar amount of time. Personnel were working in the red zone to open and close the working valve, and a backside pump was needed to equalize the pressure between the well and the lubricator. Chaparral decided to use the new multi-chamber valve on a two-well pad in Canadian county, Oklahoma, to increase the efficiency of the wireline process and shorten swap time between stages. (Figure 7).

Two multi-chamber valves and a control center were mobilized to the location in October 2018. At the time, the quick-connect latch was not yet available, so the lubricator would have to be attached to the valve by conventional means.

The two wells on the pad had been drilled to approximately 9,000 ft TVD, and each had a 4,850 ft lateral. Twenty-five stages were planned for each well.

Because the new valve system calls for changes in wellsite procedures, a pre-job meeting was held to inform the 20 members of the wireline and frac crews to review operation of the valve and its impact on each step of the PnP process. In addition, some on-the-job instruction with the wireline crew would be needed during the first few stages of the operation.

At the pad site, the valve control center was placed 150 ft from the wellheads. No backside pump was required to equalize lubricator pressure. While no red zone work was required to open and close the multi-chamber valve, an operator in a man-lift was needed to guide the lubricator attachment. This red zone operation is eliminated with use of the quick-connect latch.

During PnP operations, wireline swaps were performed in 8 to 15 minutes each, improving efficiency enough to pump two additional or 50% more stages per day compared to the operator's previous completions. The operator experienced significantly fewer frac iron leaks because of the reduced cyclical pressure loading. No pressure tests were required.

The valve provided an additional benefit for Chaparral that was unrelated to swap operations. At one point when the wireline was being run out of the well, the gun assembly became stuck downhole and the cable separated from the rope socket. The wireline "spaghettied" out of control from the top of the frac stack and landed so that it obstructed the accumulator and master valve. If the multi-chamber valve had not been in place, well control could have been lost because it would have been impossible to quickly reach the master valve to close it. In this case, valve operators in the control center were able to contain well pressure immediately by closing the flapper valves remotely, preventing any frac fluid from escaping the wellbore.

Subsequent Operations

Since its initial application, the multi-chamber valve system with quick-connect latch has been used during several PnP completions in Oklahoma and Wyoming's Powder River Basin. (Figure 8).

The new multi-chamber valve was used by an operator in Wyoming on a three-well pad being completed with a zipper-frac operation. Previously, the operator had been using a conventional frac stack comprised of a hydraulic latch, goat head, flow cross and four large-bore frac valves. On prior completions, problems with the latch operation and conventional frac valves resulted in unplanned downtime. The operator sought a different solution to improve safety and reduce non-productive time.

In sub-freezing temperatures, the new multi-chamber valve and latch system helped achieve three-minute swap times and enabled the operator to complete 102 stages in an average of 15 stages per day, with a maximum of 17 stages completed in one day.

Conclusions

- The plug and perforate (PnP) completion method, while preferred by shale play operators, has inherent inefficiencies and safety risks associated with running tools and wireline in and out of the well at each stage of the fracturing process.
- A newly developed multi-chamber valve takes a novel approach to deploying wireline tethered tools for PnP completions, introducing automation, as well as a new flapper valve and quick-connect latch, to eliminate certain operational risks, improve safety and save time.
- The design objectives for the new system were to enable remote control of pressure equalization between the well and the lubricator; remove operators from the red zone; prevent the wireline from being severed during swap operations; and reduce the need for frac iron pressure tests.
- The three-chambered valve enables equalization of pressure between the lubricator and the well and running of wireline tools, balls and collets into the wellbore, and is operated by remote control without personnel working in the red zone.
- By using the new multi-chamber valve, operators conducting PnP completions can achieve continuous pumping operations similar to those during ball and sleeve completion methods.
- On its initial application on a two-well pad in Oklahoma, the new valve without a quick-connect latch enabled the operator to perform wireline swaps in 8-15 minutes each compared to previous performance of 40-60 minutes per swap, and enabled fracturing of two additional stages per day.
- On a subsequent application in Wyoming, the multi-chamber valve and latch combination enabled wireline swaps on 102 stages on three wells in an average of three minutes each, completing an average of 15 stages per day.

Acknowledgments

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Nomenclature

PnP = *Plug and Perforate*

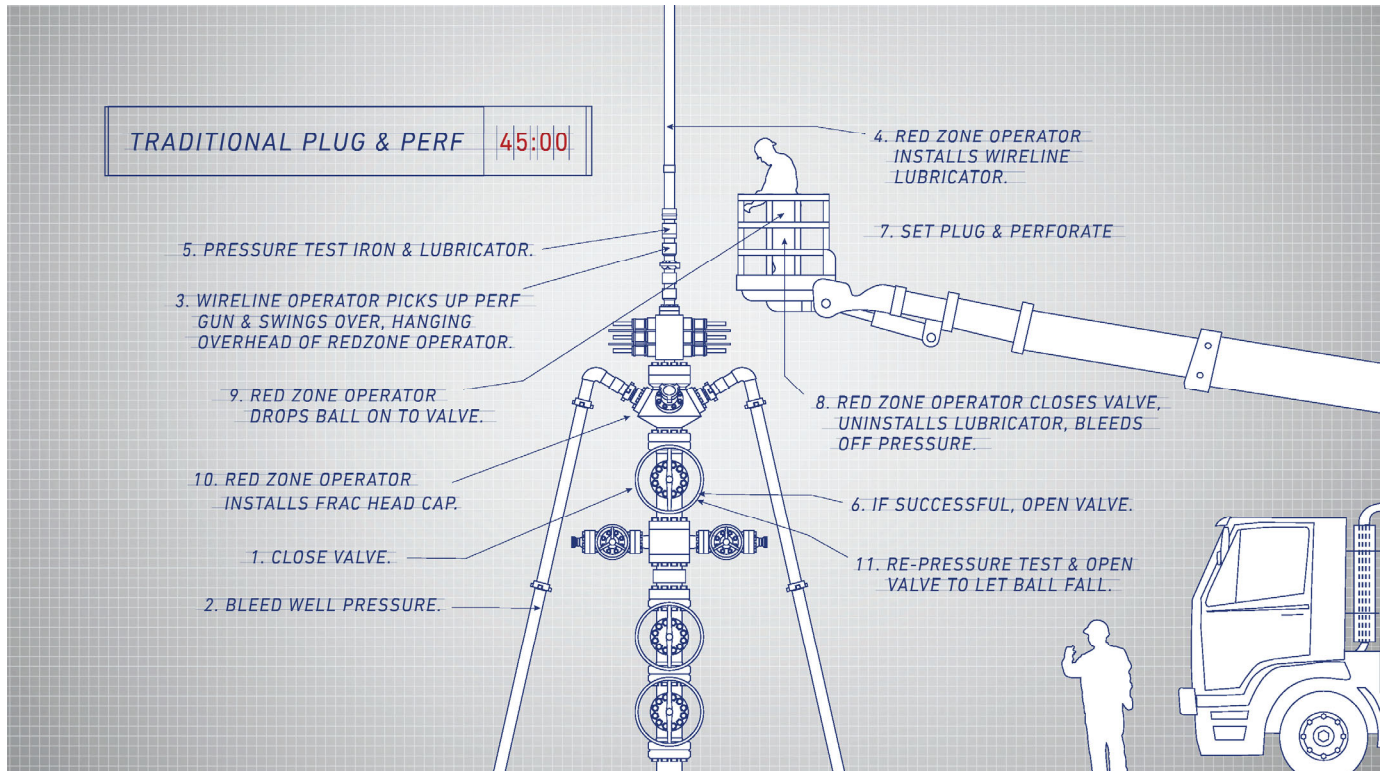


Figure 1. Traditional Plug and Perf Operations Are Unsafe, Complex and Inefficient

Table 1. Steps Required for Traditional Wireline Tool Deployment

Summary of Traditional Plug & Perf Operations		
Process	Steps	Time in Minutes
Initial Wireline Process (30-45 Minutes)	<ul style="list-style-type: none"> Frac Completes 	
	<ul style="list-style-type: none"> Working valve is shut and well pressure is bled Wireline operator picks up perf gun and swings over; tools are hanging over head of red zone operator 	5
	<ul style="list-style-type: none"> Red zone operator installs wireline lubricator 	10
	<ul style="list-style-type: none"> Pressure test iron and lubricator If successful, open working valve 	15 - 30
Post Wireline Process (30-45 Minutes)	<ul style="list-style-type: none"> Red zone operator closes working valve, uninstalls lubricator and bleeds off pressure Wireline can be cut during this process, causing in excess of \$300k in unplanned costs and 24 hours of non-productive time (NPT) 	20
	<ul style="list-style-type: none"> Red zone operator drops ball on to swab valve 	
	<ul style="list-style-type: none"> Red zone operator installs frac head cap 	10
	<ul style="list-style-type: none"> Re-pressure test flow iron 	15-20
	<ul style="list-style-type: none"> Open swab valve to let ball fall 	
	Total Time:	75-95 Min.

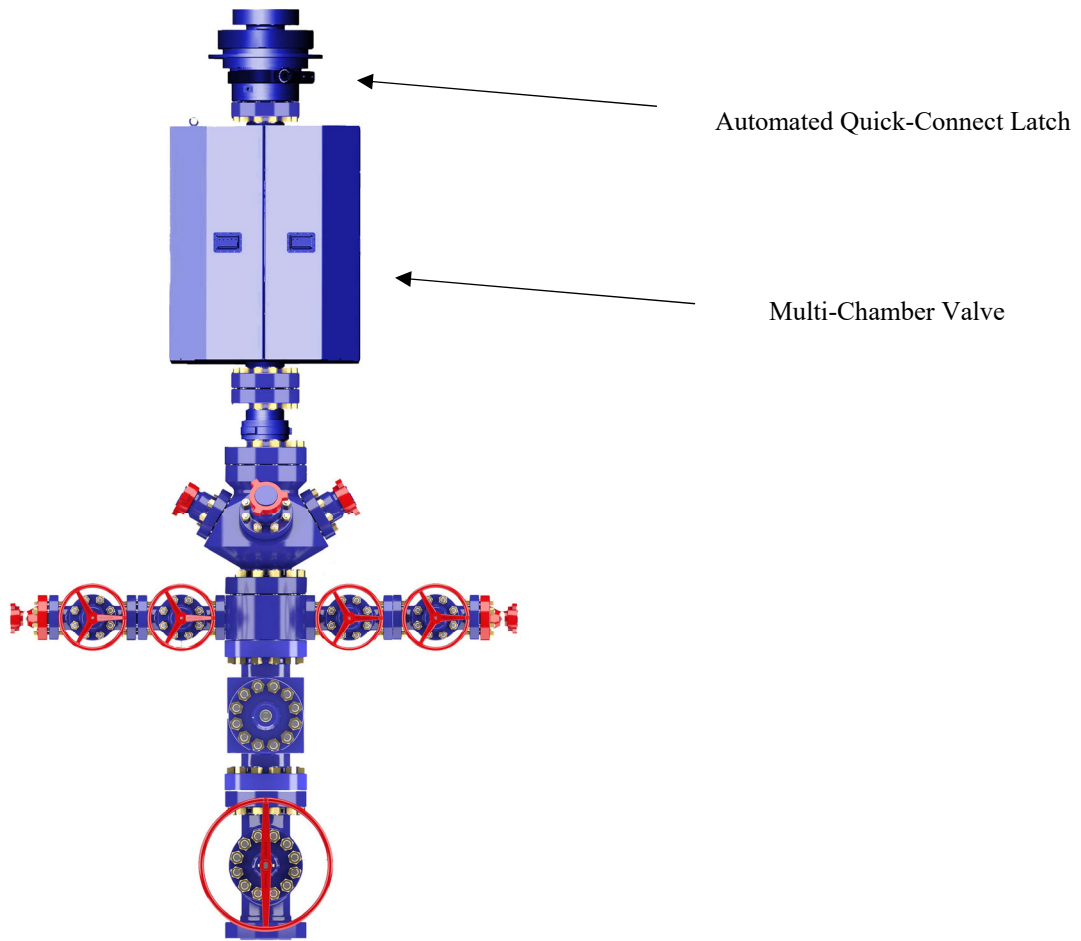


Figure 2.
Multi-Chamber Valve and Automated Quick-Connect Latch



Figure 3. Control Center Enables Remote Actuation of Valve and Latch



Figure 4. Computer Interface for Controlling Valve and Latch

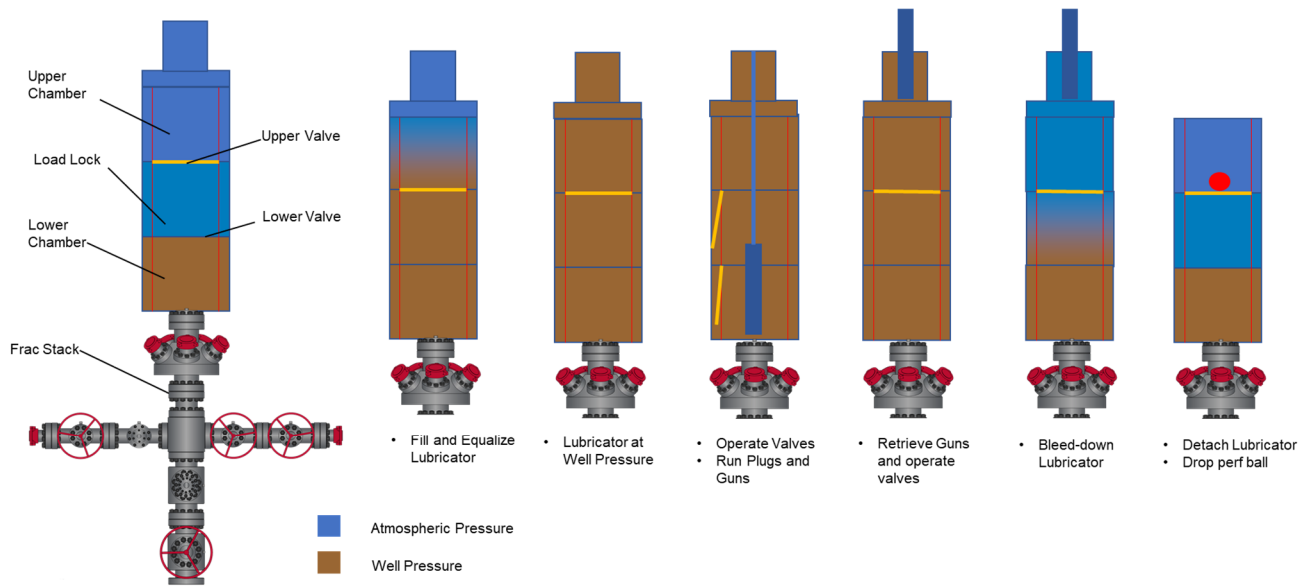


Figure 5. Multi-chamber Valve Operation during Wireline Deployment

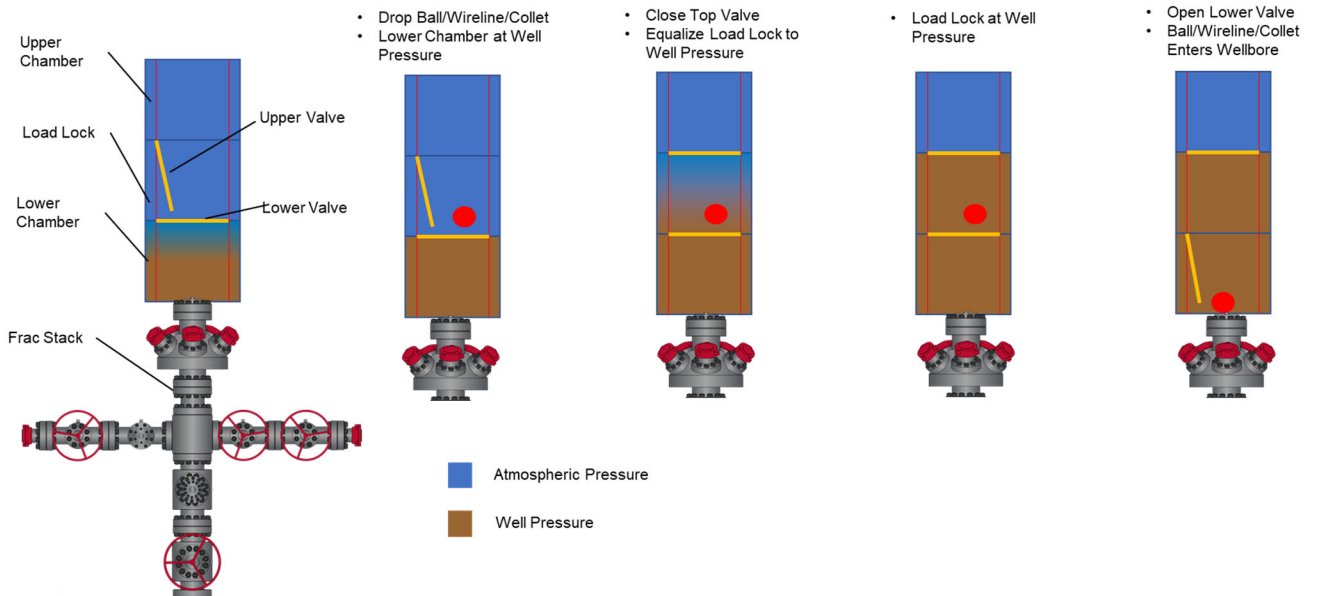


Figure 6. Multi-chamber Valve Operation during Ball Drop Procedure

Table 2. Traditional vs Multi-chamber Valve Operations

Summary of Traditional Plug & Perf Swap Operations			Summary of Multi-Chamber and Automated Latch Plug & Perf Swap Operations		
Traditional Process	Steps	Time in Minutes	New Process	Steps	Time in Minutes
Initial Wireline Process (30-45 Minutes)	<ul style="list-style-type: none"> Frac Completes 		Initial Wireline Process (3 Minutes)	Frac Completes	
	<ul style="list-style-type: none"> Working valve is shut and well pressure is bled Wireline operator picks up perf gun and swings over; tools are hanging over head of red zone operator 	5		<ul style="list-style-type: none"> Wireline operator picks up guns; stabs on to the well with latch during flush 	
	<ul style="list-style-type: none"> Red zone operator installs wireline lubricator 	10			
	<ul style="list-style-type: none"> Pressure test iron and lubricator If successful, open working valve 	15 - 30		<ul style="list-style-type: none"> Remotely equalize and open flapper valves Go down hole 	3
Post Wireline Process (30-45 Minutes)	<ul style="list-style-type: none"> Red zone operator closes working valve, uninstalls lubricator and bleeds off pressure Wireline can be cut during this process, causing in excess of \$300k in unplanned costs and 24 hours of non-productive time (NPT) 	20	Post Wireline Process (4 Minutes)	<ul style="list-style-type: none"> Multi-chamber valve is closed remotely Lubricator is de-pressurized Latch releases lubricator from multi-chamber valve Ball is dropped remotely from mini-ball drop into well 	3
	<ul style="list-style-type: none"> Red zone operator drops ball on to swab valve 			<ul style="list-style-type: none"> Computer equalizes and initiates multi-chamber valve ball drop sequence into well bore 	
	<ul style="list-style-type: none"> Red zone operator installs frac head cap 	10		<ul style="list-style-type: none"> No closing of working valves, no pressure test Frac crew can commence frac operations 	0
	<ul style="list-style-type: none"> Re-pressure test flow iron Open swab valve to let ball fall 	15-20			
	Total Time:	75-95 Min.		Total Time:	7 Min.



Figure 7. Multi-chamber Valve on Location in Oklahoma



Figure 8. Multi-chamber Valve with Quick Connect Latch on Location