

Basic Job Configurations

The following pages illustrate various basic configurations for performing TCP jobs. Since each job is tailored specifically to both the properties of the formation, as well as the long term plan for completion and production, the number of typical configurations may be unlimited. However, a few basic configurations have been presented along with a brief discussion of each accompanied with some design considerations.

TCP Design Considerations

Although it is nearly impossible to establish a rule of thumb when designing TCP jobs, there are certain design considerations that may be applicable to all scenarios. These scenarios or parameters of the well completion are usually established by the Reservoir or Completion Engineer employed by the Oil Company, in such that the Engineer decides the completion of the well. **For example overbalance vs underbalance, well stimulation techniques, or retrievable vs permanent completion.** These parameters assist in the design of the TCP perforating systems. These designs can range from basic to complex depending on the completion operation the company is trying to achieve. A close working relationship with the oil company Engineer is required to ensure a highly efficient, economical and safe operation.

Several considerations when designing TCP systems follows:

- Gun system required and intervals to be perforated
- Well deviations: vertical, dog legged, horizontal
- Type of firing system: Impact style (Mechanical, Safety); Pressure Activated (Absolute, Differential); Redundant System
- Circulation: before and after perforating
- Overbalance or Underbalance perforating and how to achieve it: Time Delay Firing Systems
- Retrievable system or permanent completion: if permanent, will the system be released. Method of release (mechanical shifting or automatic release)
- Type of packer required for the completion

**No Packer
Mechanically Activated with Gun Release**



Equipment

Item	Description
1	Mechanical Firing Head
2	Fill/Flow Sub
3	Gun Release
4	Radioactive Marker Sub

Description

This TCP configuration is intended primarily as a simple means of gun conveyance, with limited options for a temporary completion. Although there is no packer in place, the guns may be released from the tubing and dropped into the sump to provide full tubing bore (when TC-062 is used) to the lower wellbore. This gives the ability to run wireline production logging tools through tubing if production testing data is insufficient.

Applications

- Shallow Gas Wells
- Long Perforating Intervals
- Heavy Oil

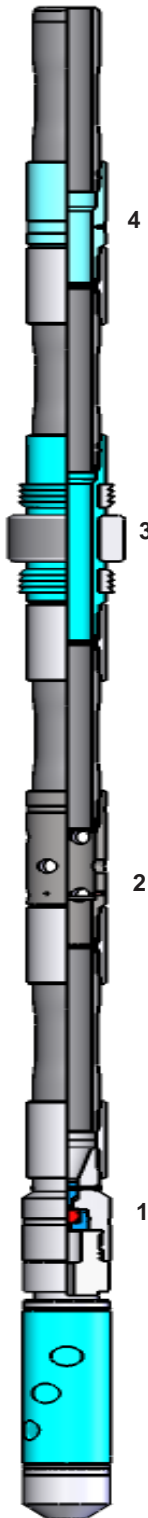
This string is a minor variation of the most basic TCP configuration and is primarily used for shallow gas wells where shooting is done in a dry hole. With the addition of the gun release, the temporary completion will have a full tubing bore to allow the passage of wireline logging tools out of the end of the tubing.

Design Notes

It is recommended to have a fluid filled tubing joint placed above the Mechanical Firing Head to fully retain the drop bar. If the Drop Bar is partially held in the Fill/Flow Sub, this may reduce the flow area through the tool. This joint is also used to pick up the guns with the Firing Head connected.

Perforated pup joints may be added to the string if it is important to have more flow area into the tubing. However, they should be placed above the Fill/Flow Sub so that the glass disk may still act as a debris barrier.

When using a Gun Release of any design, it is important to determine the amount of sump available so a portion of the released gun assembly does not block any perforations.



Retrievable Packer Mechanically Activated

Equipment

Item	Description
1	Mechanical Firing Head
2	Fill/Flow Sub
3	Packer
4	Radioactive Marker Sub

Description

This TCP configuration permits the gun string to act as a temporary or permanent completion after perforating. This simple completion gives the option of performing stimulation treatments after the well has been evaluated by production testing. The presence of the packer allows high pressure treatments and gives the versatility of having completion equipment in place after evaluation.

Applications

- Oil or gas completions
- Potential stimulation operations

As previously mentioned, this configuration allows not only perforating and production testing, but the ability to perform stimulation treatments. This hookup may be tailored to individual applications by placing flow control profile nipples in the string at strategic locations, such as below the packer or in the On-Off Tool of the packer, so the work string may be exchanged for production tubing.

Design Notes

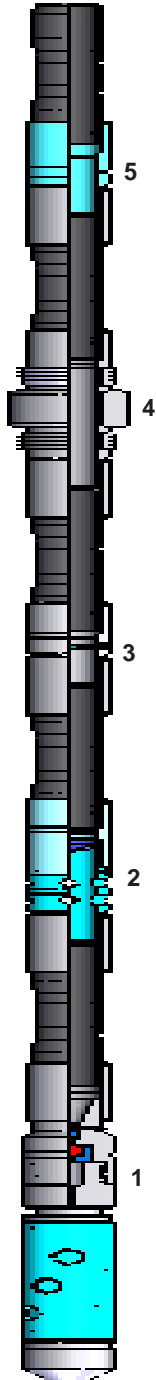
It is recommended to have a fluid filled tubing joint placed above the Mechanical Firing Head to fully retain the drop bar. If the Drop Bar is partially held in the Fill/Flow Sub, this may reduce the flow area through the tool.

If it is important to have more flow area into the tubing, perforated pup joints may be added to the string. However, they should be placed above the Fill/Flow Sub so the glass disk may still act as a debris barrier.

Retrievable Packer Mechanically Activated with Differential Sub

Equipment

Item	Description
1	Mechanical Firing Head
2	Ported Differential Sub
3	Pressure Release (KOBE) Sub
4	Packer
5	Radioactive Marker Sub



Description

This TCP tool configuration is primarily intended to perform underbalanced perforating while leaving completion equipment in place. The Differential Sub is designed to keep wellbore fluids from entering the tubing above the tool. The KOBE Sub is included directly below the packer to allow for pressure testing prior to perforating.

The packer may be pressure tested by breaking the frangible hollow pin in the KOBE Sub and applying pump pressure to the tubing-casing annulus. After the test has been successfully completed, the logging tools may be retrieved and the Drop Bar released. Once the bar passes through the Differential Sub, shattering the ceramic dome, it strikes the Firing Head and detonates the guns. At this point, the reservoir pressure is released into the dry tubing and allowed to flow freely to surface.

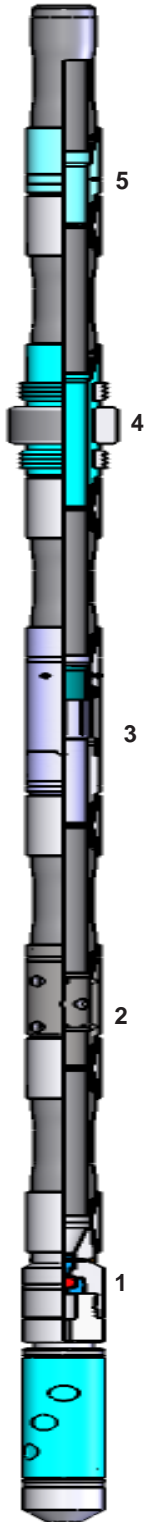
Applications

- Debris sensitive formations
- Prevents plugged perforations

This configuration permits underbalanced perforating in situations where perforation tunnel plugging may be a problem, or where underpressured reservoirs require swabbing to initiate production. After the ceramic dome has been shattered, the Differential Sub ports allow reservoir fluids to be produced with no restriction.

Design Notes

It is important to have a fluid filled tubing joint placed above the Mechanical Firing Head. If the Drop Bar is partially held in the Fill/Flow Sub, this may reduce the flow area into the tubing.



Retrievable Packer Mechanically Activated with Gun Release

Equipment

Item	Description
1	Mechanical Firing Head
2	Fill/Flow Sub
3	Mechanical Gun Release, Shift Up
4	Packer
5	Radioactive Marker Sub

Description

This TCP tool string may be used to perforate and perform stimulation operations such as high pressure fracturing after the spent gun system has been released. This hookup provides the flexibility of having full tubing bore diameter (when TC-062 is used), and the ability to access the wellbore after the guns have been dropped off. This feature permits not only production testing, but wireline production logging if required.

Applications

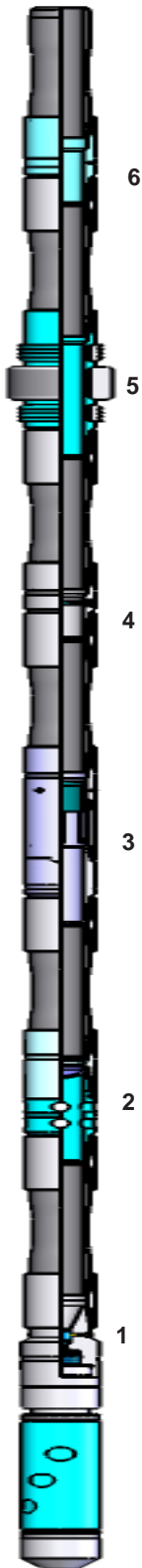
- Production logging of well after perforating
- Fracturing or acidizing with completion in place

As previously mentioned, with the addition of the Gun Release, the tubing will be open at the bottom permitting passage of wireline logging tools into the wellbore. In most applications, the production packer is equipped with an On-Off Tool with internal flow control profile which will allow a plug to be set in the packer tailpipe, the workstring to be retrieved, and a string of production tubing replaced without killing or snubbing the well.

Design Notes

It is important to have a fluid filled tubing joint placed above the Mechanical Firing Head. If the Drop Bar is partially held in the Fill/Flow Sub, this may reduce the flow area through the tool.

When using a Gun Release of any design, it is important to determine the amount of sump available so that a portion of the released gun assembly does not block any perforations.



Retrievable Packer Mechanically Activated with Differential Sub and Mechanical Gun Release

Equipment

Item	Description
1	Mechanical Firing Head
2	Ported Differential Sub
3	Mechanical Gun Release, Shift Up
4	Pressure Release (KOBÉ) Sub
5	Packer
6	Radioactive Marker Sub

Description

The configuration shown is designed to perform underbalanced perforating, while leaving a completion in place, with a maximum of flexibility in terms of adapting to various contingencies.

With the tool string as shown, the packer may be logged on depth and then pressure tested prior to perforating by breaking the frangible hollow pin of the KOBÉ Sub with the logging tools. The packer may be tested by applying pump pressure to the tubing-casing annulus. With the logging tools retrieved from the tubing, the Drop Bar may be released and the guns fired. Production testing may be undertaken to evaluate the formation, and decide whether the guns may be released in preparation for stimulation treatments.

After the guns have been dropped, the tubing is open ended with a full bore (when TC-062 is used), allowing high pressure stimulation treatments such as fracturing or acidizing. Upon completion of the stimulation, the formation may be produced or production logging operations may commence.

Applications

- Long term completions
- High pressure stimulation such as fracturing or acidizing
- Production logging or through tubing workovers after perforating

As previously mentioned, this hookup provides the maximum in flexibility when planning a completion around TCP.

Design Notes

The Gun Release should be positioned above the Differential Sub and separated by a pup joint to allow easier access by slickline shifting tools. However, if an influx of fluid is expected (in an extreme underbalance situation) the positions of the gun release and differential sub should be reversed to avoid premature shifting of the gun release.



Retrievable Packer Hydraulic Firing Head with Tubing Drain

Equipment

Item	Description
1	Hydraulic Firing Head
2	Hydraulic Tubing Drain
3	Packer
4	Radioactive Marker Sub

Description

The TCP tool string shown allows firing of the gun system by applying hydraulic pressure to the tubing rather than releasing a Drop Bar from surface. Gun firing pressure is determined by calculating fluid hydrostatic pressure and applying a safety margin. Since the Tubing Drain is also a hydraulically activated device, the opening pressure must be calculated prior to running in the well.

Because the tubing string must remain pressure tight prior to firing, this hookup is rather limited in terms of its application as a completion after perforating.

Applications

- Horizontal or highly deviated wellbores
- Extreme overbalance perforating
- Coil tubing perforating

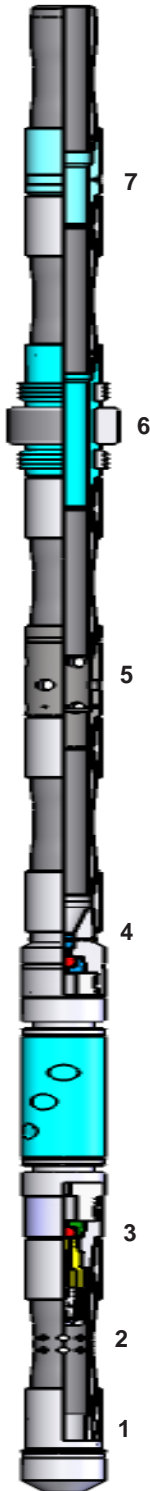
In horizontal or deviated wells where the Drop Bar will not reach the Mechanical Firing Head, or may reach it with questionable impact force, the Hydraulic Firing Head is primarily used. In this case, the job is designed so the Firing Head fires the guns first, and then by increasing the pressure in the tubing, opens the Tubing Drain.

For the application of extreme overbalanced perforating where a small pad of acid is spotted on top of the Firing Head (near the Tubing Drain), it is important to have the Drain open first on applied pressure, and have the guns fire at a higher pressure. This ensures the stimulating fluid is under pressure against the casing and can immediately rush into the newly formed perforations.

Design Notes

The Hydraulic Firing Head and Hydraulic Tubing Drain should be separated by a short pup joint to reduce some of the impact from the gun detonation.

The Coil Tubing Hydraulic Firing Head should be used for coil tubing applications



Mechanical Firing Head with Hydraulic Firing Head Backup

Equipment

Item	Description
1	Bull Plug
2	Perforated Pup Joint
3	Hydraulic Firing Head
4	Mechanical Firing Head
5	Fill/Flow Sub
6	Packer
7	Radioactive Marker Sub (Not Shown)

Description

The tool string configuration shown in the diagram depicts a system with firing redundancy using a Mechanical Firing Head as the primary firing system, and a Hydraulic Firing Head as a backup system.

After the Drop Bar has been released from surface and an appropriate amount of time has elapsed without evidence of gun detonation, it may be decided to activate the guns hydraulically. Applying hydraulic pressure to the tubing acts on the casing below the packer (via the Fill/Flow Sub). Fluid pressure enters the Hydraulic Firing Head through the perforated pup joints below the gun, and fires the gun.

After perforating, the assembly may be left and utilized for formation evaluation and stimulation.

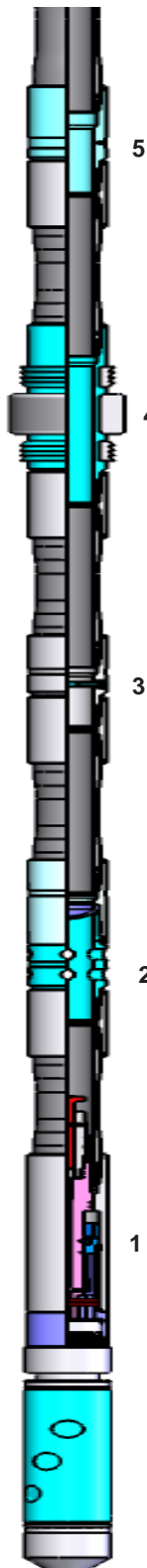
Applications

- Deviated wellbores
- Deep wells

The most common use for this configuration is where the wellbore is slightly deviated and is questionable whether the Drop Bar will have sufficient energy to activate the Mechanical Firing Head. It may also be used where tripping the tubing out of the well due to a misfire may be cost prohibitive. However, in any application where firing redundancy is required, this provides the simplest solution to the problem.

Design Notes

The bull plug and perforated tubing joint protects the Firing Head from obstructions in the wellbore, and from becoming plugged by debris and from any pressure “spikes” which may be created when running into a fluid top.



Automatic Gun Release Mechanically Activated

Equipment

Item	Description
1	Automatic Gun Release and Impact Firing Head
2	Ported Differential Sub
3	Pressure Release (KOBE) Sub
4	Packer
5	Radioactive Marker Sub

Description

The Automatic Gun Release is configured with an Impact Firing Head for this hookup. By releasing a Drop Bar from surface which strikes the Firing Pin, the guns are detonated and the gas pressure generated is used to disengage the guns from the tubing. The top sub of the gun release remains attached to the tubing and acts as a re-entry guide.

In the configuration shown, the packer may be logged on depth and pressure tested prior to perforating. After the wireline logging tools have been retrieved and the packer tested, the Drop Bar may be dropped, both firing and releasing the guns. After release of the guns, the re-entry guide provides a full tubing bore and gives accessibility to the wellbore.

Applications

- Wells with high solids production
- Applications where slickline costs are prohibitive

It is anticipated the primary application for this hookup is where there will be high solids production after perforating. These solids may pack off around the guns in the time interval required to shift a Mechanical Gun Release, making an Automatic Gun Release attractive. This tool may also be used where mobilizing slickline, or the added cost of a run to shift a Mechanical Gun Release may be excessive.

Design Notes

It is important to allow the tubing to be equalized to the annulus fluid level so the guns can easily disengage. This may be accomplished with the Pressure Release KOBE Sub aided by filling the tubing while running in the hole.



Automatic Gun Release Hydraulically Activated

Equipment

Item	Description
1	Automatic Gun Release and Pressure Activated Firing Head
2	Pressure Release (KOB) Sub
3	Packer
4	Radioactive Marker Sub

Description

The Automatic Gun Release incorporates a Pressure Activated Firing Head and release the guns upon detonation. By applying hydraulic pressure to the tubing string at a predetermined pressure, the guns will fire. Simultaneously, the gas generated by detonation is used to disengage the guns from the tubing string.

The tools arranged as shown in the diagram, permit the string to be logged on depth, and the packer pressure tested prior to firing the guns. After the tubing has been placed into the wellhead, pump pressure may be increased on the tubing until the guns fire. As the guns fire, the gun release activates and disengages from the tubing. Once the guns have been released, a re-entry guide remains on the tubing with the full bore of the tubing through it for easy access to the lower wellbore.

Applications

- Wells with high solids production after perforation
- Applications where slickline costs are prohibited
- Deviated wellbores less than 60°

The tool hookup as shown in the diagram may be used where an Automatic Gun Release will be of operational benefit, such as in a wellbore which a Drop Bar can not be used. Another option is to use a Fill/Flow Sub in place of the Pressure Release (KOB) Sub and allow pressure up the inside of the casing.

Design Notes

This configuration may be altered by removing the packer and KOB Sub, to simply use the tubing as a means of getting the guns to bottom. However, the No-Go Nipple should remain to allow the tubing to be snubbed out.

It is highly recommended that this system not be used in wellbore deviations greater than 60°.

Horizontal Wellbores Absolute Pressure Firing Head

Equipment

Item	Description
1	Absolute Pressure Firing Head
2	Fill/Flow Sub
3	Radioactive Marker Sub

Description

Horizontal well perforating is usually initiated with the use of a pressure activated firing system. This configuration is a basic system using an absolute pressure firing head, and a fill/flow sub for circulation. This system can be run with or without a packer. After the guns have been logged on depth, pressure is applied to the wellbore or down the workstring (if a packer is used), activating the absolute pressure firing head, detonating the guns.

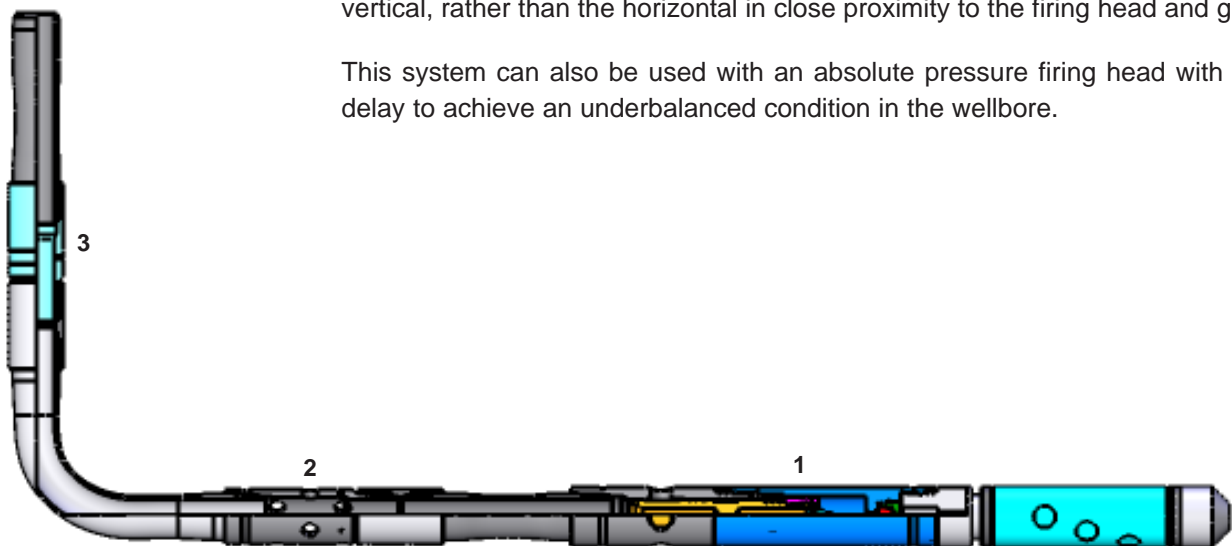
This hookup allows the circulation while running in hole, or to change wellbore fluid prior to firing the guns. However it is important to maintain circulating pressure well below the firing pressure of the guns.

Design Notes

This system is only effective if you can obtain an absolute pressure on the wellbore (no open perforations).

If using a Radioactive Marker Sub for depth control, this should be positioned in the vertical, rather than the horizontal in close proximity to the firing head and guns.

This system can also be used with an absolute pressure firing head with a time delay to achieve an underbalanced condition in the wellbore.



Horizontal Wellbores
Vented Absolute or Ball Activated Differential Firing Head

Equipment

Item	Description
1	Vented Absolute Pressure FH or Ball Activated Differential FH
2	Radioactive Marker Sub

Description

This configuration can be used to perforate a horizontal well with existing perforations. It uses a closed system absolute pressure firing head which will vent after detonation so you will be able to circulate through, provide well control, or pull a dry workstring.

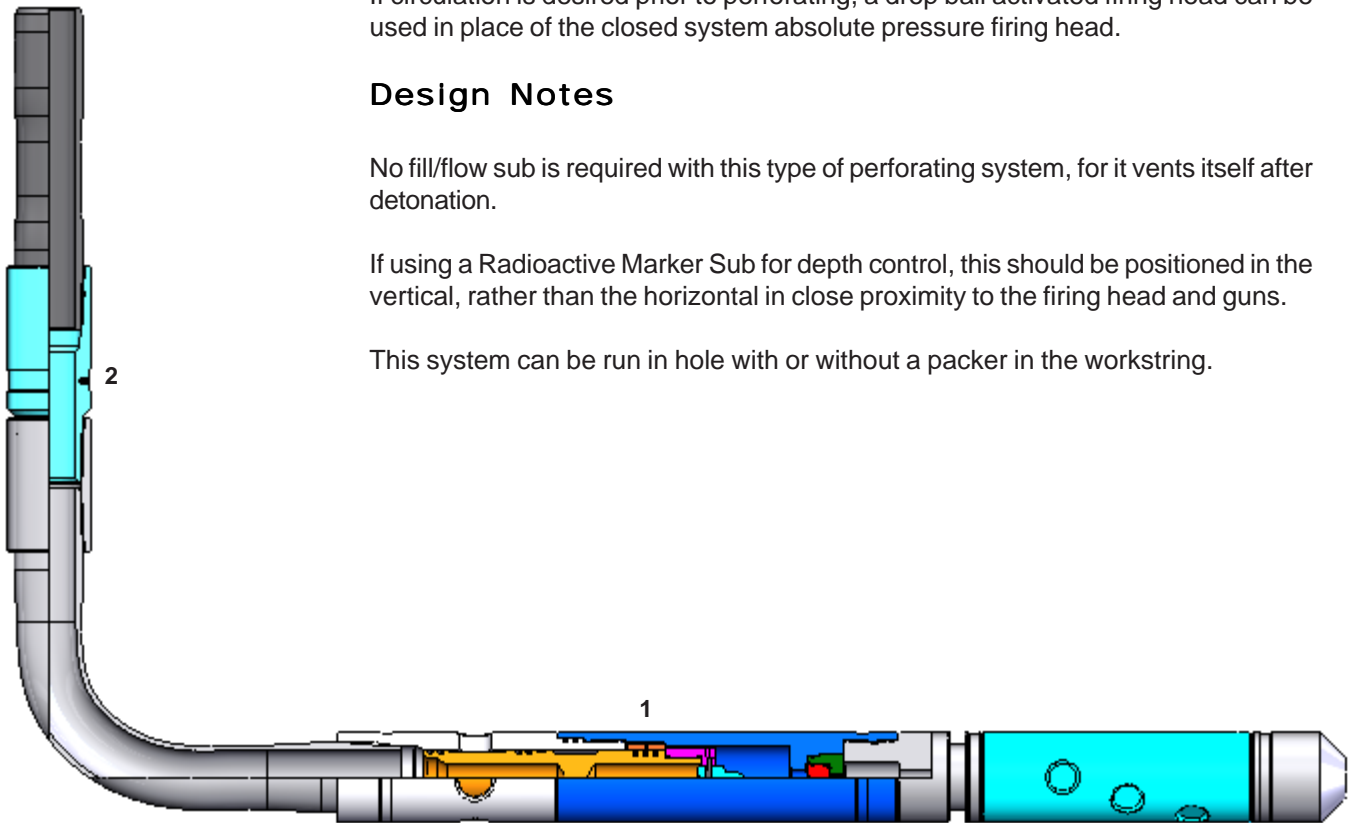
If circulation is desired prior to perforating, a drop ball activated firing head can be used in place of the closed system absolute pressure firing head.

Design Notes

No fill/flow sub is required with this type of perforating system, for it vents itself after detonation.

If using a Radioactive Marker Sub for depth control, this should be positioned in the vertical, rather than the horizontal in close proximity to the firing head and guns.

This system can be run in hole with or without a packer in the workstring.



Horizontal Wellbores Orienting Gun Systems

Equipment

Item	Description
1	Guns with Orienting Finned Bullplug and Tandem Gun Subs
2	Hydraulically Operated Firing Head
3	Tubing Swivel
4	Radioactive Marker Sub

Description

This TCP configuration shows a means of orienting the perforating guns to the High Side or the Low Side of the wellbore. This can be accomplished by the use of orienting fins on the gun bullplug and tandem subs and the use of a downhole swivel above the firing head.

When running in the well bore, the orienting fins will tend to force the guns to their correct orientation position. The swivel ensures the guns will remain in the correct orientation regardless of the torque in the workstring.

Applications

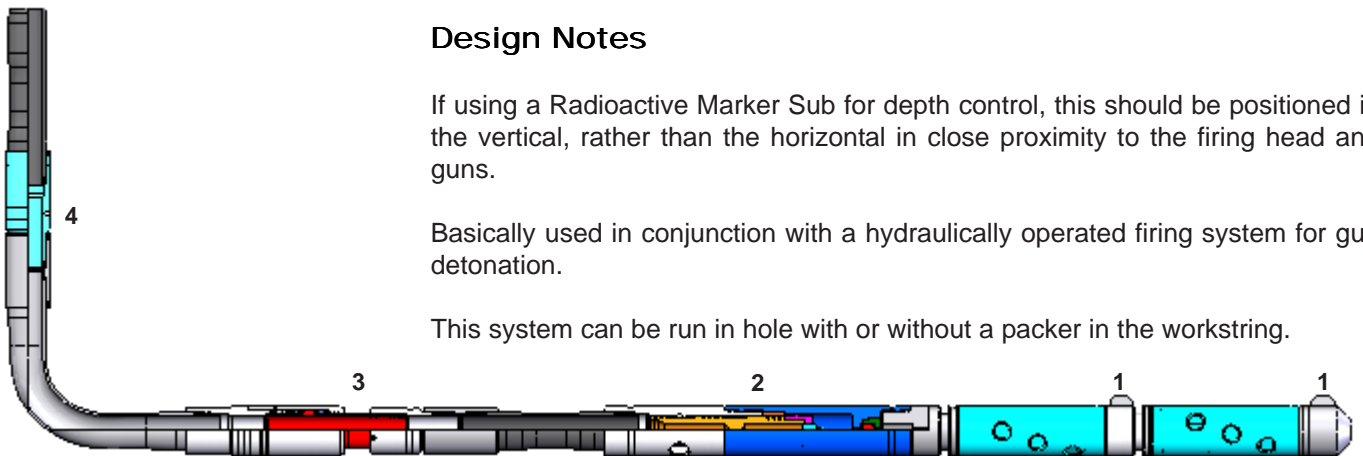
- Horizontal or deviated wellbores

Design Notes

If using a Radioactive Marker Sub for depth control, this should be positioned in the vertical, rather than the horizontal in close proximity to the firing head and guns.

Basically used in conjunction with a hydraulically operated firing system for gun detonation.

This system can be run in hole with or without a packer in the workstring.



Annular Pressure Firing System Absolute or Differential

Equipment

Item	Description
1	Absolute Pressure or Differential Pressure FH
2	Tubular Joint(s) (Used as a Fluid Volume Chamber)
3	Circulation/Pressure Port Sub (if control line used)
4	Packer with Packer By-Pass System
5	Radioactive Marker Sub

Description

This configuration shows a TCP hookup where it is desirable to use annular pressure to activate a firing system. For example, a highly deviated wellbore where a drop bar would not be effective, or a well operation where achieving an underbalance is desired.

A Packer By-Pass system is required for this type of perforating to divert the annular pressure between the casing ID and the workstring OD to the firing head. The pressure is conveyed to the firing head from the packer by-pass system via a control line or tubular sections. This system can be set up to run either the Absolute Pressure Firing Head or the Differential Pressure Firing Head.

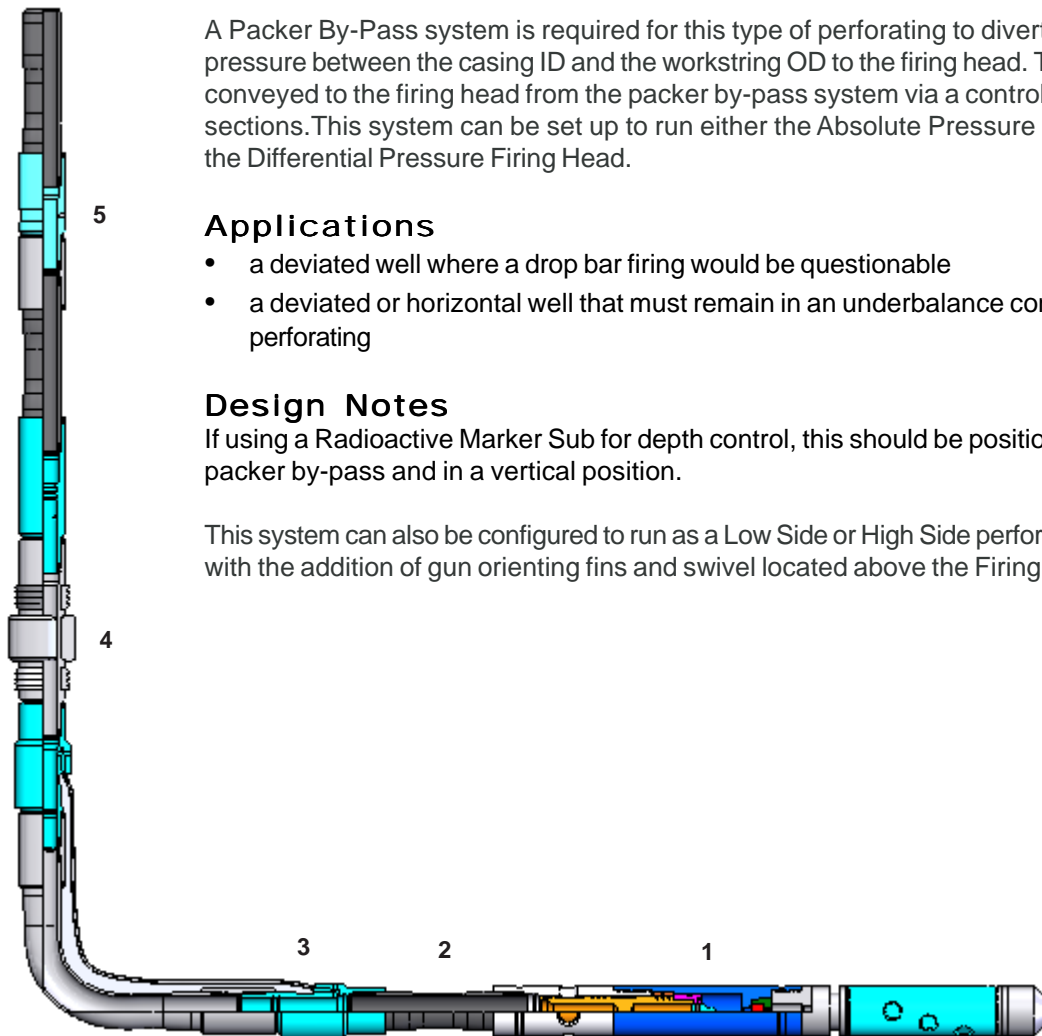
Applications

- a deviated well where a drop bar firing would be questionable
- a deviated or horizontal well that must remain in an underbalance condition during perforating

Design Notes

If using a Radioactive Marker Sub for depth control, this should be positioned above the packer by-pass and in a vertical position.

This system can also be configured to run as a Low Side or High Side perforating operation with the addition of gun orienting fins and swivel located above the Firing Head.



Horizontal Wellbores Time Delay Firing Head

Equipment

Item	Description
1	Time Delay Firing Head
2	Fill/Flow Sub
3	Packer
4	Radioactive Marker Sub

Description

When activated, the Time Delay Firing Head will give 8 - 9 minutes from the activation of the firing head to the firing of the gun. Multiple time delay firing heads can be used in conjunction to increase the time to fire. During this time, the pressure used to activate the firing head can be bled off to create an underbalanced perforating condition.

Applications

- Horizontal, deviated or vertical wellbores.

Design Notes

The Radioactive Marker Sub, when used for depth control, should be positioned in the vertical, rather than the horizontal, in close proximity to the firing head and guns.

The system can be run in the hole with or without a packer in the workstring.

When running multiple Time Delay Firing Heads separated by pup joints, a Fill/Flow Sub should be used at both ends of the pup joint to prevent air from being trapped in the pup joint.

