

**Best Practices -
Coiled Tubing Deployed
“Ball Drop Type”
Perforating Firing Systems**

As a result of a recent job incident utilizing a “Ball Drop Type” firing system deployed on coiled tubing, the following best practices have been identified:

1. The pumping company must provide calculated volumes and pressures of fluids required to activate the firing system. The anticipated pressure “pumping profiles” should be reviewed and understood by all parties involved in the job.
2. The Tubing Conveyed Perforating (TCP) supervisor must document and review the job design with the TCP specialist(s) who will perform the job. The TCP specialist must review the procedures and contingencies with coil tubing operator, oil company representative, and any other personnel involved in this job. This review must be completed with documentation and signoff by all parties involved.
3. Jobs requiring nitrogen to be pumped after fluid require review by a Halliburton Global Advisor.

The above practices have been documented and communicated internally within Halliburton via a Technology Bulletin. These practices will also be incorporated in technical manuals and in the Halliburton Management System (HMS) and processes will be implemented to ensure compliance. These procedures will not be deviated from unless the customer signs off that he understands the implications of the deviation and such variance is consequently reviewed by a TCP Global Advisor.

These requirements rely on a combination of safe engineering designs and best practices.

These recommendations are being shared with the industry as they could be applicable to all perforating jobs performed by any company using coiled tubing, a “standard” coiled tubing motor head assembly, and a “Ball Drop Type” perforating firing system.

REVIEW OF JOB EVENTS

Design

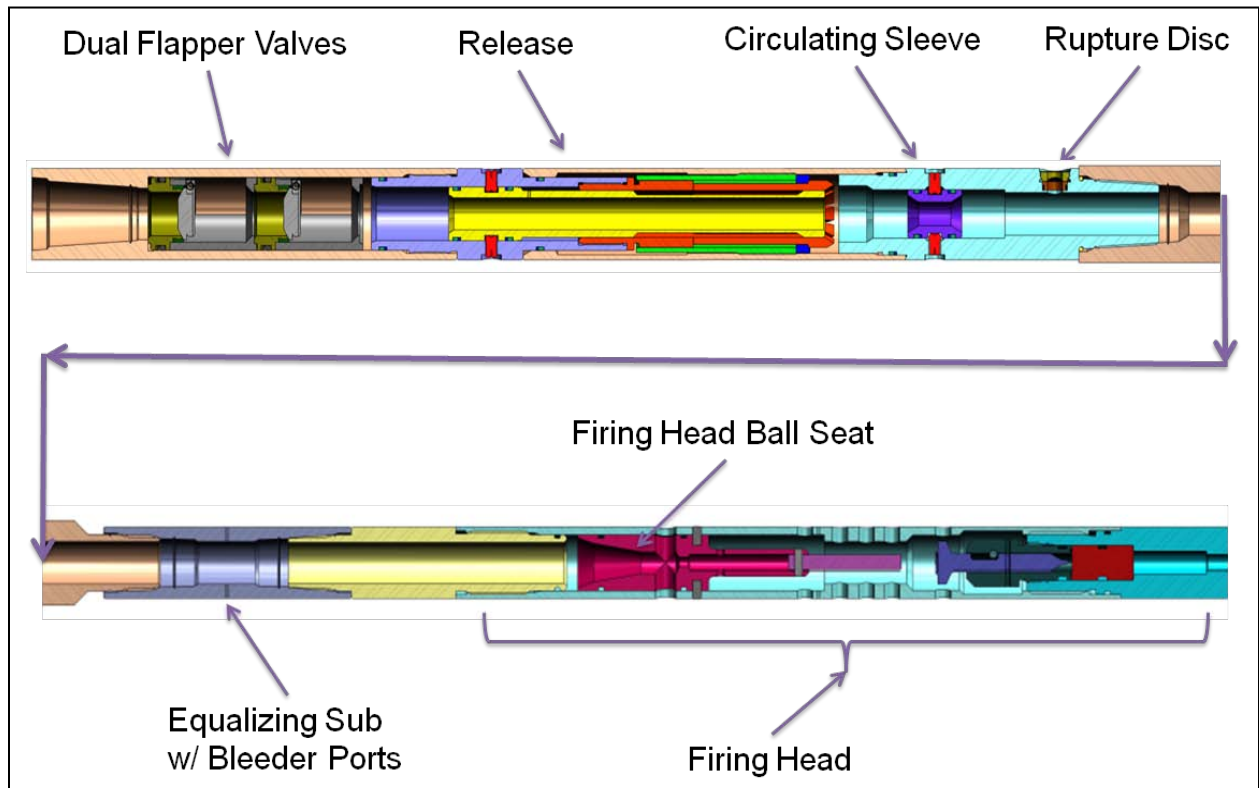
- Gas well with open perforations.
- Re-perforate on coiled tubing utilizing a Hydraulic Actuated Firing Head (HAFH) (“Ball Drop Type”).
- Placed ball in coiled tubing and circulated through surface coil with brine.
- Followed brine with Nitrogen (N₂) to fire guns.

Execution

- Noticed pressure increase and then stopped pumping after initial pressure falloff.
- Personnel believed guns had fired.
- Pull Out Of Hole (POOH) and into riser.
- Closed Christmas tree valve and bled off riser, noticed that pressure remained on coiled tubing.
- Personnel evacuated from rig floor.
- ~25 minutes later guns fired.

Bottom Hole Assembly (BHA)

A standard coiled tubing BHA consists of a “Ball Drop Type” firing head, equalizer sub with pressure bleed ports, and a motor head assembly comprised of a secondary circulating sub, a rupture disc, a disconnect mechanism, and dual flapper valves.



Firing Event

The firing head was not activated downhole.

Upon retrieval to surface pressurized liquid was trapped below the flapper valve(s) and an obstruction within the BHA assembly. Following the bleeding down of the riser, a subsequent temperature increase caused the pressure of the trapped liquid to increase enough to activate the firing head and fire the guns.

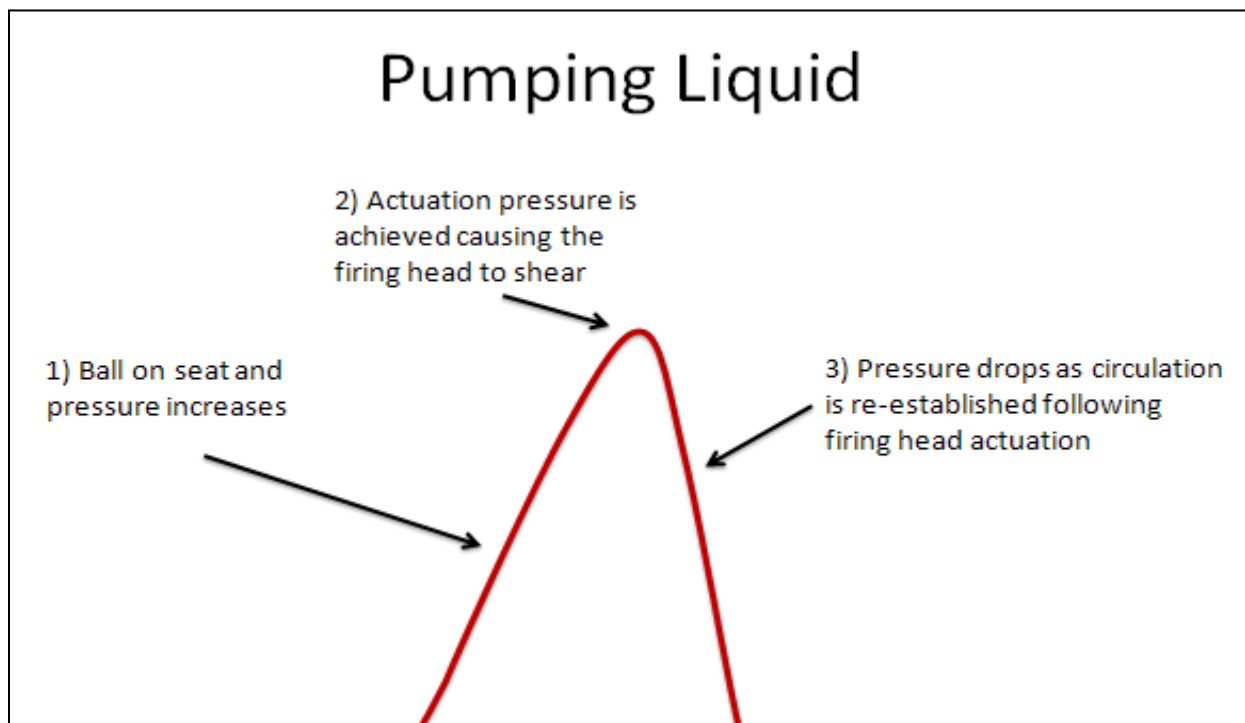
CORRECTIVE ACTIONS

- **Pressure profile for HAFH Jobs.**

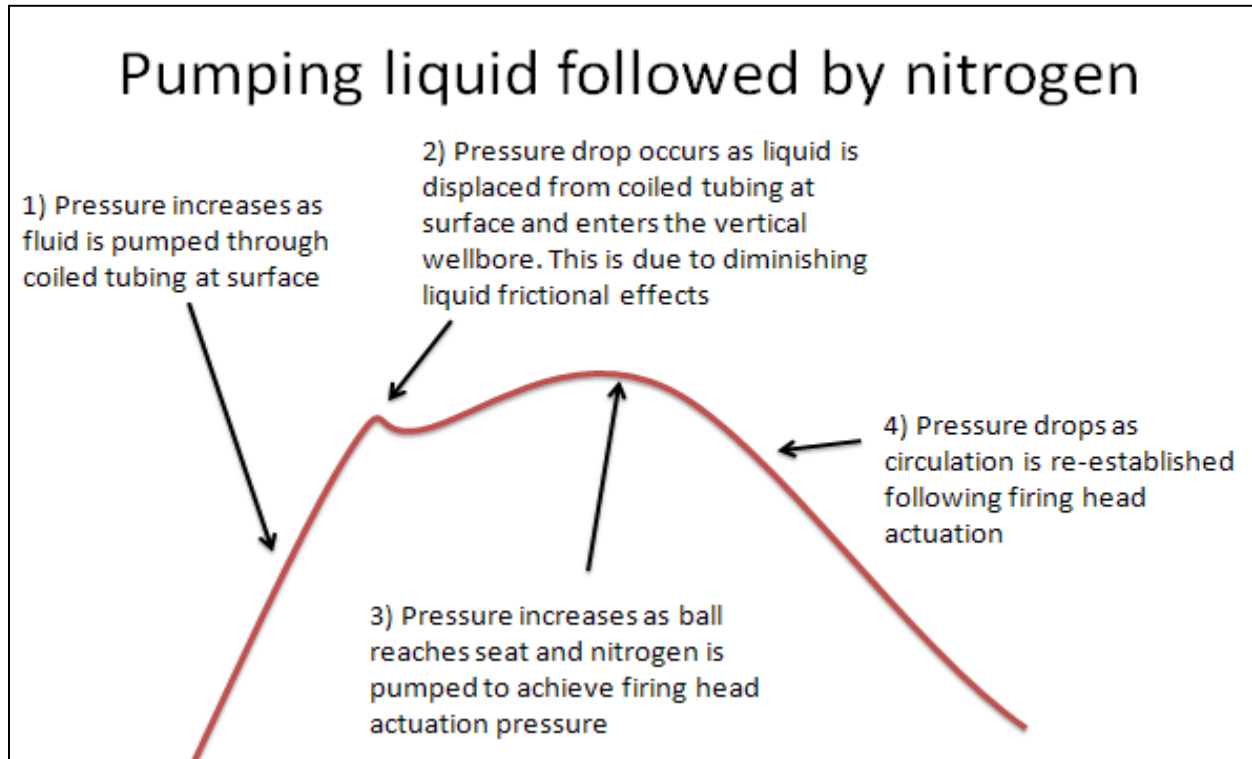
Pressure profile when pumping a ball down-hole with liquid vs. pumping a ball down with liquid followed by nitrogen to activate a HAFH.

When pumping down a ball to activate a HAFH, different pressure profiles may occur depending upon many parameters including the sequence of the pumping operation and the type of fluid being pumped.

- If the fluid being used to pump a ball down-hole is a liquid the expected pressure profile should be similar to the diagram below.



- If the fluid being used to pump a ball down-hole is a liquid followed by nitrogen the expected pressure profile should be similar to the diagram below.



Note: The above are examples only; the pressure profile should be discussed and understood on an individual job basis. This should involve the TCP personnel and any other personnel involved in this activity.

Therefore; it is important to confirm that sufficient volumes and pressures have been achieved to actuate the firing head when utilizing both liquid and nitrogen to pump a ball to activate a HAFH.

- **As an additional safety feature, a “shot blocking device” located between the firing head and the top gun should also be utilized.**

As a reminder, such a “shot blocking device” should not be considered as a failsafe device, and cannot be used as a way to circumvent or negate other prescribed safety measures.

Procedures and Contingencies for Running the HAFH (Ball Drop) Firing Head on Coil Tubing.

The following procedures should be followed in all situations involving this type of operation. TCP technical services should be contacted if clarification is required.

1. Before starting in hole with guns, the following calculations must be completed and discussed with the Coil Tubing operator and Company representative. Discussions *must* be documented on job log.
 - a. The minimum volume of liquid, and/or gas that will be required to be pumped to place the ball at the firing head.
 - b. The minimum surface pressure on the CT that will be required to create the necessary differential across the firing head to shear the pins and fire the guns.
 - c. The maximum surface pressure on the CT that could be required to create the necessary differential across the firing head to shear the pins and fire the guns.

Note (1) – the difference between the min and max CT surface pressure may be large, if there is a partial column of liquid, and the ball is ahead of the liquid or behind the liquid column as it is being pumped through the coiled tubing.

2. After ball has been dropped to fire the guns.
 - a. It is required that you must keep pumping until reaching at least the minimum calculated volume and pressure.

Note (2) – Depending on well geometry, deployment method and fluids used; the pressure profile may be misleading. Observation of a pressure increase and pressure drop should not necessarily be interpreted as the guns firing. The minimum pressure AND volume must be reached before a determination can be made that the guns have fired.

3. Before starting out of the hole with guns, after the calculated minimum pressure and volume have been reached.
 - a. Circulation between the CT and annulus must be established and verified by the TCP supervisor and CT operator.

Note (3) -- The HAFH is caused to function by the creation of sufficient differential pressures across the firing head between the Coil Tubing and annulus. If it can be established that there is circulation between the Coil and the annulus, this means that there is no differential

pressure across the firing head, and it is safe to continue out of the well, and bring the guns to the surface.

4. While pulling the guns out of the hole.
 - a. Approximately every 1,000 ft, the coil must be stopped and circulation between the CT and annulus must be re-established and verified.
 - b. At 200 ft below surface, mud line or the sea bed, circulation between the CT and annulus must be re-established and verified.

Note (4) -- If at any of the above points, circulation cannot be established between the CT and annulus, the guns must be run back to perforating depth and the CT pressure must be increased until circulation is regained, either by the guns firing, or bursting the rupture disc in the Motor Head Assembly. After establishing circulation, a ball should be pumped down to open the circulating valve in the Motor Head Assembly to increase the flow area.

5. With the guns at surface or in the lubricator.
 - a. All personnel should be cleared from within a 100 ft radius of the lubricator.
 - b. To ensure that there is no trapped pressure above the firing head, the coil pressure should be bled off through the annulus. Begin bleeding the pressure in the lubricator off slowly in increments of 100 psi. The CT pressure must be monitored to ensure it is also being bled off simultaneously with the lubricator pressure.
6. If the pressure in the CT does not bleed off simultaneously with the lubricator.
 - a. The guns must be run back to perforating depth and the CT pressure must be increased until circulation is regained, either by the guns firing, or bursting the rupture disc in the Motor Head Assembly.
 - b. Once circulation has been regained, a ball should be pumped down to open the circulating sleeve in the Motor Head Assembly to increase the flow area before starting out of the well.
 - c. If it becomes necessary to run back to bottom, and circulation cannot be established between the CT and the annulus, the operations should be halted until a path forward is agreed upon by the Customer and Halliburton Management. TCP Global Advisors should be contacted immediately.

- **All jobs designed for a ball to be pumped down with N2 to fire the guns are to be reviewed and approved by TCP Global Advisor.**
- **Any deviations from these procedures will require a written variance signed by a customer representative authorizing the deviation.**
- **The above described Motor Head Assembly (MHA) is considered standard. If it is determined during the job design phase that use of a third party coil tubing results in equipment different than the one documented (i.e. that includes release, circulating sub and rupture disc), a risk assessment must be completed and documented with the oil company and coil tubing representatives. If the assembly to be used still deviates from the standard, contact a TCP Global Advisor.**
- **Incorporate the above in HMS processes and ensure compliance.**