The paper will discuss the development of abrasive cutting technology deployed via coiled tubing for cutting production tubing, drill pipe, drill collars, exotic stainless steel completion components, single strings of casing and multiple strings of casing. This technology is performed utilizing a sealed bearing, positive displacement motor and a cutting head along with conventional coiled tubing tools and conventional coiled tubing. This technology gives operators an additional tool when severing of the drill string or production tubing is required.

Additionally the paper will discuss perforating tubing and casing using abrasives, particularly in horizontal wells where conventional wire-line operations are not possible.

The paper will discuss:
1. Utilizing a positive displacement motor to perform abrasive cuts via coiled tubing,
2. Design and testing phases of the abrasive cutting system,
3. Initial field runs to prove the viability of this technology,
4. Total jobs completed to date,
5. Lessons learned throughout the process,
6. Where this technology leads from here.

The paper will also discuss future applications for this technology which include cutting casing for plug and abandonment programs, permanent packer retrieval, and abrasive perforating all deployed via coiled tubing.
A gelled slurry sand was pumped at a maximum rate of 1.0 BPM. After 75 seconds of pump time, initial penetration through the production tubing was observed. Pumping was continued at 1.0 BPM to complete the cut. After 4 minutes the production tubing was completely severed. Both ends of the production tubing were inspected and shown to be clean cuts with no flaring of the tubing ends, easing possible fishing operations.

**Initial Field Run**

*Figure 2* shows the well schematic where the Abrasive Cutting System was required. This is a deep gas well in western Oklahoma. The goal of the workover was to pull the 2.875" production tubing from inside the 5" casing. There was dehydrated drilling mud in the 5" casing annulus making it impossible to pull the tubing and the 5" casing was slightly collapsed at approximately 16,000' so conventional overshots and washpipe could not latch the 2.875" tubing couplings.

After numerous failed chemical cuts and failed jet cutters the abrasive cutting system was run on 1.50" coiled tubing to a cutting depth of 16,697'. The tubing had previously been cut at 16,540' using a chemical cutter. A sand slurry was mixed and pumped through a 1.70" OD positive displacement motor and the tubing was cut in approximately 4 minutes. With the clean ends from the cut, a 157' section of the tubing was readily retrieved from the well. An additional abrasive cut was required to cut the tubing near the production packer at 17,250' so the production packer could be washed over and pulled from the well. The second abrasive cut was run to 17,202' and cut in the same manner as previous in approximately 4 minutes. A 505' section of tubing was pulled from the well and the production packer was washed over and retrieved. The well was recompleted and is currently producing.

**Total Field Runs**

To date over 30 successful field runs have been made utilizing the abrasive cutting system on coiled tubing.

- ~25 operations cutting tubulars up to 3.50" OD
- ~10 operations cutting drill pipe or drill collars up to 6.25" OD
- ~4 operations cutting casing up to 13.375" OD
- ~6 operations cutting inconel or chrome completion components

In plug and abandonment applications we have successfully, and reliably, cut single and multiple casing strings. Successful multiple casing applications include cutting both 9-5/8" and 13-3/8" casing at the same time.

All of these operations were completed on coiled tubing sizes ranging from 1.25" OD to 1.75" OD.

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**Testing of Abrasive Cutting System**

The first field application for the Abrasive Cutting System was to cut 2.875", 8.7#/ft, P-110 production tubing. A test was set up to prove the viability of the abrasive cutting system.

A joint of 2.875", 8.7#/ft, P-110 production tubing was mounted in a test fixture. The abrasive cutting BHA consisting of the following was made up to the coiled tubing and lowered into the production tubing:

- ~1.70" OD Coiled Tubing Connector for 1.25" coiled tubing
- ~1.70" OD Dual Back Pressure Valve
- ~1.70" OD Hydraulie Disconnect
- ~1.70" OD Sealed Bearing Positive Displacement Motor
- ~2.00" OD Abrasive Cutting Head
Figure 2
**Abrasive Cutting Stainless Steel Components**

Further testing on both chrome and inconel completion components has been successfully completed.

The inconel component with a 0.80” wall thickness was successfully cut with the abrasive cutting system in 4 minutes 35 seconds. This test was completed in the horizontal position to simulate the actual completion.

The 13 chrome component with a 0.80” wall thickness was successfully cut with the abrasive cutting system in 7 minutes 50 seconds. This test was completed in the horizontal position to simulate the actual completion.

Both of these tests were completed with the following BHA:

- 2.88” OD No-Go Sub
- 2.88” OD Spacer Subs
- 2.88” OD Sealed Bearing Positive Displacement Motor
- 5.25” and 4.25” OD Abrasive Cutting Heads

Both of the cuts were successfully made with no flaring of the component ends.

**Abrasive Perforating**

After the successful abrasive cutting operations, we began to abrasive perforate using similar technology. The Abrasive Perforator System is basically the same BHA without the sealed bearing positive displacement motor that creates the rotation for cutting. *Figure 3* shows an abrasive perforating BHA. The sand slurry is pumped through the orifices to create a hole in the casing.

Numerous abrasive perforating jobs have been performed using this technology. Typically conventional explosive perforating could not be used, or abrasive perforating was more economical than TCP perforating.

**Case 1**: An operator had a 9.625” service packer cemented in a vertical well that had a 2.44” ID and needed to perforate 9.625” and 13.375” casing. There was cement behind both the 9.625” and 13.375” casing. A 2.13” OD Abrasive Perforator was designed with 9 orifices that could perforate a 10 foot interval. A 50 BBL sand slurry was pumped through 1.50” coiled tubing to achieve the perforating. This was repeated twice in order to perforate the 30 foot interval on a single trip in the hole.

**Case 2**: An operator had run 1,000’ of 2.875” liner into a horizontal section of the Mississippi formation in northern Oklahoma and required it to be perforated over the complete 1,000’. TCP guns were not economical so abrasive perforating was chosen to perforate this section. The well was perforated with 4 shots per foot over a 5 foot interval then repeated every 50 feet over the 1,000’ interval. A 2.13” OD Abrasive Perforator was ran on 1.75” OD coiled tubing to the total depth of the well. A sand slurry was pumped at 2.0 BPM and 2 holes were perforated using 2.0 BBL of slurry. A pressure change across the tool gradually occurred while perforating the first 208 holes. The Abrasive Perforator was pulled and replaced with a new perforator and the perforating was completed by perforating an additional 180 holes. *Figure 4 & 5* are photos the the Abrasive Perforating heads at the completion of the job.
Case 3: An operator in the Barnett Shale area of north Texas had ran a 3 ½”, 9.3 lb/ft production liner from a sidetrack well. The well was perforated with TCP guns at 6 shots per foot across the toe and heel of the horizontal section at 8400-8406 and 8900-8906. The frac job was attempted and only 5 bpm rate was achieved. The zones were reperforated at 12 shots per foot with TCP guns and again only 5 bpm was achieved.

An Abrasive Perforator was ran on a tapered work string. Both zones were perforated with 4 shots per foot. The well was successfully fraced at 55 BPM, 5400 PSI. At the time of writing the well was still flowing back the frac fluids. All indications are that the well will be commercial.

Conclusions
1. The Abrasive Cutting System is a proven and efficient method for cutting all types of tubulars via coiled tubing.
2. The Abrasive Cutting System can cut tubulars without flaring or deformation of the tubulars so no milling run is required to “dress” the cut.
3. The Abrasive Perforating System is a viable alternative to TCP or conventional wireline perforating.
4. The Abrasive Perforating System can perforate wells where TCP and conventional wireline perforating cannot.
5. The Abrasive Perforating System may create deeper penetration into the formation than TCP or conventional wire-line perforating.

Acknowledgments
The authors thank GMX Resources, Sojourner Drilling, Crawley Petroleum, Schlumberger, and Merritt Energy for permission to publish this paper.

References