Gas broaching incident at a gas production well – a case study

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An incident of gas broaching in cellar pit and adjacent area of a shut-in gas producing well took place which resulted in uncontrolled flow of gas through tubing and cellar pit area.

Brief Description:

The construction of the well was based on two CP policy. 13 3/8"casing was lowered up to 255 meters depth and cemented. After this, 8 1/2"hole was drilled up to the target depth 1055 meters. 7" 23 ppf casing was lowered upto 983 meters and cemented with cement top behind the casing at 793 meters.
Completion string consisting of 2 7/8"tubing with retainer packer was lowered and packer was set at 883.5 meters depth. The preformation interval was 915.50 – 920.50 meters. Before temporary shut in, the well was producing gas @ 0.061 MMSCMD through 8 mm beam. **The producing hydrocarbon gas contained about 12 % Carbon di-oxide gas.**
The gas leakage from the well was first noticed on 1st March 2015 in the form of gas bubbles in the cellar pit and adjacent area which was filled with rain water due to rain.
On 1st February 2015, the Shut in tubing pressure and 7"X 2 7/8" production casing pressure was recorded as 82 Kg / squire cm and 76 Kg / squire cm respectively. This indicates clearly communication between tubing and production casing.
The (STHP Shut-in Tubing Head Pressure) remained constant at 82 Kg / squire cm upto 16th September 2015 then dropped to 67 Kg / squire.
The production casing annulus (7"X 2 7/8") pressure dropped to 12Kg / squire cm on 4th March 2015 indicating development of communication between 7"casing and formation.

On 24th October 2015, effort was being made to subdue the well by bulldozing kill fluid and surface pressure of 1300 – 1800 psi was applied. This resulted in further damage to already damaged tubing, production casing and induced fracture to surface in the formation against the un-cemented portion of 7"production casing
Gas broaching started from cellar pit and adjacent areas. The cellar pit and side foundation sinked due to erosion by uncontrolled gas broaching.

First attempt was made to kill the flowing well by pumping kill mud of 1.3 ppg through tubing. It did not work because the kill mud circulated out from the upper communications between tubing, production casing and formation. This enabled to establish and maintain the required hydrostatic head to counter the formation pressure.

Coil Tubing Unit was arranged and 1.25 inch coil tubing was lowered up to top of the perforation. An attempt was made to kill the flowing well with circulation. This attempt also did not work due to the reason that the initial pumping pressure was very high because of very high frictional losses of 6000 meters length of 1.25inch diameter coil tubing. The

required discharge / pumping rate could not be achieved to displace the gas volume from the well.

Arrangements were made to divert the well fluid, gas, at a safe distance from the well for safety of the operational personnel working at the well site and to reduce the gas broaching from area adjacent to the well. For this, pipe lines were fabricated and well was flowed with full opening from tubing and production casing (7"X 2 7/8") annulus.

A Coil tubing Unit having shorter length of coil tubing was then arranged. The length of coil tubing was reduced to 1400 meters by cutting approximately 1600 meters coil tubing from the spool in order to reduce the frictional losses and ultimately increase the discharge rate for well killing operation. All the equipment were function tested and pressure tested.

The 1.25 inch coil tubing was lowered to the bottom of the flowing wel DND #9. Circulated with water followed by kill fluid of 1.15 specific gravity. The gas in the well was circulated out and further entry of the gas influx into the well was stopped by establishing required hydrostatic head to counter the formation pressure. The well was killed with this procedure and gas broaching is successfully stopped.

Root Cause Analysis:

1. The well was an old well drilled in the year 1997. The well was drilled with two CP casing policy. 7" diameter, N-80 grade and 23 ppf casing was lowered as production casing upto a depth of 983 meters and cemented with top of cement behind casing upto 793 meters. This means that 538 meters of production casing (TOC to 13 3/8" surface casing shoe) was directly exposed to formation.
2. The produced hydrocarbon gas from this well was having 12 % Carbon di oxide gas which is highly corrosive and prone to pitting. Continuous extraction of carbon di oxide gas has the potential to make the internal surface of pipes, casings to suffer from corrosion affects and reduce the thickness drastically resulting loss of mechanical integrity and material degradation. Mechanical properties like burst strength, collapse rating, tensile strength, ductility etc. is reduced and ultimately, pipes, casings fails.
3. There was communication between tubing string and the production casing which is evident from the annulus pressure readings with effect from 1st February 2015 onwards. STHP (Shut in Tubing Head Pressure) = 82 KSC and SCP (Shut in Casing Pressure) = 76 KSC. This was due to leakage through production packer or leakage in tubing string or both.
4. The SCP (Shut in Casing Pressure) dropped from 76 KSC to 12 KSC with effect from 7th March 2015 confirming development of casing failure and communication between casing and formation. The communication may have developed below the shoe of previous surface casing and gas may have travelled to surface via channelling through upper unconsolidated loose formations.
5. During bulldozing with applying surface pressure of >1300 psi through tubing to subdue the well for workover operations, the gas leak channels widened drastically and gas broaching started in cellar pit and adjacent areas.

Recommendations:

1. The casing policy i.e. surface casing landing depth, cement rise behind production casing should be reviewed. The landing depth of surface casing should be deepened or an intermediate casing should be introduced. The cement rise behind the production casing should be at least 50 meters inside the previous casing.
2. It should be ensured that the production casing material grade for wells having toxic gases like Carbon-di-oxide or Hydrogen sulphide is compatible to carbon di oxide gas / Hydrogen sulphide gas.
3. Wells having internal communications should not be subdued by bulldozing technique. These should be subdued by bottom killing.
4. During bulldozing through tubing to subdue the well, the outer annuluses should be monitored diligently. It should be ensured that the annulus pressure in any of the annulus should not exceed the MAOP for that particular annulus.
5. Annulus pressures in production casing annulus and other outer annulus should be monitored regularly. MAOP (Maximum Allowable Operating Pressure) should be calculated for each annulus of the wells. The annulus pressure, if any in any of the annulus, must not exceed the MAOP value. If any of the annulus is having pressure, it should be diagnosed for assessing the cause and workover program should be formulated accordingly.