**A case study : Underground Blowout Control at Well NHK #285**

**Author:** Dr. K. Saikia, Chief Engineer Drilling - CMT

**INTRODUCTION**

The well NHK # 285 (Loc-HBS), a gas well, in the Deohal area of Naharkatia mining lease, was producing @ 20,000- 30,000 SCMD of gas from 2427m Barail Sand through 3.0 mm bean in the month of July, 2011. On 14.07.2011, a high intensity sound from the well was reported and gas leakage was observed at various places of the wellhead. Several attempts were made to kill the well for repairing/replacement of the wellhead, but the well could not be killed following normal killing methods. During the process of killing severe mud loss were experienced. Attempts were made to arrest the mud loss and during the process of placing loss circulating material surface broaching of gas & water occurred around the well plinth. Subsequently, surface broaching was also noticed at few spots around 1 to 2 km away from the well plinth. This is the first occurrence of underground blowout in the history of Oil India Limited.

**About Underground Blowout**

An underground blowout occurs when formation fluids flow from one subsurface zone to another in an uncontrolled manner. The results range from being indiscernible to catastrophic. An underground blowout can result in minor transfers of fluids that may never be identified or in flow which reaches the sea floor or ground surface. If the flow reaches the surface, a crater, loss of equipment, and sometimes loss of life may result. A major complication in handling underground blowouts is the difficulty in diagnosing what is actually happening in the subsurface. Another major difficulty is the lack of a systematic approach to analyzing and controlling the flow. They are the most common of all well control problems. This phenomenon differs from crossflow, which typically occurs within a long perforated interval and involves little or no reserves loss or escalation hazard.

Underground blowouts can occur in drilling wells or producing wells, and are thought to be the most common in the latter because of tubulars corrosion in older completions. Unfortunately, no statistics on underground blowouts are available because most go unrecognized or unreported. What is known is that many surface blowouts begin as underground blowouts. And prompt, correct reaction to an indicated underground flow can prevent an even more serious and costly surface blowout. That leads to the observation that "experience is the best of schoolmasters, only the school fees are heavy.

**Symptoms of Underground Blowout in production wells:**

- Unable to get mud returns with blowout fluids at surface in annulus. Mud flows to loss zone with blowout fluids.
- Thermal anomalies are apparent on temperature log. Higher temperatures occur opposite shallower loss zone when flow is from bottom up. Lower temperatures occur opposite loss zone if flow is from top down. Spinner logs and other production logs may also provide indications.
- Lower than normal shut-in tubing and annulus pressures on a producing well.
- Sudden change in GOR or WOR in a producing well with annulus pressure.
- Christmas tree or BOP vibration of shut-in well with abnormal sound.
- Sudden tubing or drill pipe vibration and/or drag when pipe is lowered past point in the well where flow is occurring.
1.1 History of well

The well NHK#285 was drilled in the year 1976 to a target depth 3913m within basement. It was the first exploration well on Deohal structure for probing hydrocarbon prospects on a structure closure at Lakadong + Theria (Paleocene – Eocene), Barails (Oligocene) and Tipam (Mioene) formation levels. The well was drilled in four stages - 20”, 13¾”, 9½” & 5½” casing was set with shoe at 33m, 301m, 2097m & 3902.96m respectively.

Fig.-1 : Well Diagram of NHK#285 (Loc.- HBS)

The well was initially tested in 3825-m Langpar Sand through perforations in the range 3850.2-3853.3 m on 08.08.76. The well produced formation water with minor amount of gas. Subsequent to this, 3808-m LK+TH Sand was tested through perforations in the range 3808.2-3811.2 m on 11.08.76, the well was found to have practically no inflow. 3304-m Kopili Sand was tested through perforations in the range 3304.0-3308.6 m on 17.08.76 after plugging back the lower sets of perforations. In view of inflow of formation water, 3304-m Kopili Sand was plugged back by setting a bridge plug at 3294-m.

2427-m Barail Sand was tested through perforations in the range 2436.6-2439.6 m on 21.08.76. The well started flowing and produced gas @ 0.0312 MMSCUMD and condensate @ 3.9 klpd through 4 mm bean with flowing tubing pressure of 208 Kg/cm². Subsequently, open flow potential test, followed by BHP build-up (14 hrs) were carried out. The results showed that extrapolated reservoir pressure was slightly above hydrostatic and absolute open flow potential of the well was about 3.68 MMSCUMD. However the well could not be brought into production due to lack of market demand of gas at that time. Subsequently, the well was killed with 83 pcf mud and a bridge plug was set at 3294-m.

On 31.01.2005, prior to recording of SBHP, dummy got held up at 970 m. The well was reopened on 17.06.2005 and was on intermittent production at an average rate of 0.076
MMSCUMD through 8.0 mm beam with FTHP 175 Kg/cm$^2$ to gas production set up. Finally, the well was shut in on 09.08.2005 (SITP=210 kg/cm$^2$).

In a workover carried out during October, 2005, the well was killed with 78 lbs/cft CaCl$_2$ solution as safety measure to facilitate drilling of NHK-558 (Loc. HNQ) from the same plinth.

The well was enlivened on 17.08.2006 and was under production @ 84,000 SCUMD through variable choke with FTHP of 200 kg/cm$^2$.

In a workover carried out in March 2007, the well was perforated in the range 2430-2435 m in live condition. Since then, the well was on regular production @ 1,20,000 SCMD of gas & 7.0 KLPD of condensate (Deg API-49.2 ) with the FTHP 185 kg/cm$^2$ through 7mm bean.

In July, 2010 sand production was observed at the surface and hence production was reduced to 60,000 SCMD with 5.0 mm beam. However sand production continued at reduced production rate also. Caving level was checked on 06.09.2010 and found at 2451m (Perforation: 2430m- 2442m). Production was further reduced @ 20,000 - 30,000 SCMD by reducing beam size to 3.0 mm on 30.10.2010 to arrest sand production at surface.

On 14.07.2011 at around 1 A.M, it was reported about a high intensity sound from the well plinth of NHK 285. On examination it was found that there was leakage from the wellhead fittings above the master valve. Subsequently the master valve of the wellhead was closed. On close examination of the wellhead, it was observed that there were some deep impressions of damages (Spots) along with displacement of 2.9/16” Master Valve Bonnet Flange from its body in downwards direction. Gas leakage was also observed from this displaced portion. Recorded shut in THP 2000 psi, CP: 2000 psi. AP: 600 psi.

1.2 WELL KILLING OPERATION

Following the gas leakage at several places of the wellhead it was decided to kill the well and repair the wellhead. Accordingly, attempt was made to kill the well by pumping 77 pcf brine using conventional killing methods. A total of 600 bbls of brine was pumped in the process but the well could not be killed. Total hole volume including 9.5/8” casing is 508 bbls.

A hole probing trip was made by wire line and got held up at @ 1500m. Through tubing Impression block was run in and found impression of parted tubing at @ 1526m. Considering the fluid loss it was decided to pump Xan-vis to arrest the loss and pumped Xan-vis through tubing in two steps – 66 bbls & 81 bbls respectively, but no result could be achieved. After pumping Xan-vis, wellhead pressure recorded as- SITP= 1450 psi, SICP=1450 psi & AP=1250 psi.

Thereafter, it was decided to kill the well with drilling mud. A mud weight of 100 pcf was considered to balance the reservoir pressure at 1526 m where tubing parting was suspected based on impression result. Prior to killing the well, 5½” × 9½” casing annulus was filled up with 71 bbls of 100 pcf mud and the annulus pressure came down to 250 psi from 1200 psi.

Attempt was made to kill the well up to tubing parted portion using 100 pcf mud by direct circulation (Wait & weight) method. During killing process, found kill mud surfaced after pumping 13 bbls, indicating tubing puncture at shallower depth. Thereafter, filled-up tubing and casing (using volumetric method) with 90 bbls of 100 pcf mud to cover-up 1526 m in both the conduit. The well could not be killed even after pumping more than hole volume and placing loss
circulation material (LCM), but the tubing and casing pressure came down to 900 psi each from 1450 psi respectively.

Mud weight was reduced to 90 pcf and tried to kill the well after placing LCM (4% : Mica + sawdust). As no positive result was achieved, finally, placed LCM pill treated with 2.5% walnut shell, sawdust & mica against perforation. In this process tubing bore got choked and tubing bore was cleared by reverse circulation. During the repeated process of killing the well, a total of 520 bbls of mud was pumped but the well could not be killed.

Mud weight was further reduced to 80 pcf and tried to kill the well by pumping 310 bbls of mud, however, the well could not be killed. Thereafter, mud weight was further reduced to 68 pcf, just to balance the formation pressure against perforation.

Initially, 46 bbls (tubing volume) of 68 pcf mud was pumped through tubing keeping casing open through choke and then pumped 90 bbls (annular volume : tbg.-csg) of 68 pcf mud through casing keeping tubing open through choke. In both the cases no return of mud was noticed (except gas). Pumped 25 bbls of LCM (treated with 1% Mica and 1% Wall Nut Shell) followed by 25 bbls (1.5%) of Xan-vis through tubing and placed against perforation. During the process of pumping tubing pressure came down from 900 psi to 380 psi, casing pressure from 900 psi to 520 psi and annular pressure remained at 380 psi. Thereafter, the well was kept shut-in for observation.

After 45 min of observation found tubing, casing and annular pressure rose to 800 psi, 820 psi and 450 psi respectively and noticed gushing out of gas with water at various spots around the cellar in a radius of 50m. Slowly the gushing out intensity increased and mud + gas column rose up to around 8 feet high (Fig.-2). Immediately, bled off annular pressure and brought to zero. However, gushing out of gas and water continued and it subsided after two days of its own. Thereafter, an attempt was made to kill the well dynamically with water, but the same gushing out of gas with water was observed again and it subsided of its own after one day.

Fig.-2: Gushing out of gas at well plinth
After the incident, on confirmation of underground blowout at the well, the well killing plan was reviewed on consultation with well control expert from ONGCL and decided to go for bottom kill. Prior to bottom kill, the X-mass tree was changed with new one by setting two numbers of retrievable tubing plug at 26 & 27m and the plugs were retrieved after replacement of the X-mass tree.

After installation of X-mass tree, tried to lower coiled tubing, but got held up at 323 m. Subsequently, the 2¾” tubing could be cleared after several attempts and lower down CT to 1672 m using special tool provided by ONGCL. Tried to kill with water and 75 pcf brine at this depth, but observed no change in pressure. Thereafter, lowered BHP tool with slick line which got held-up at 1351m. Took BHP & Temperature measurement survey from 1350m upward and the results indicates that there is outward flow from the well at depth @ 400m. (Fig.-3 represents the summarised BHP result).

**Fig.-3 : Depth vs SBHP & SBHT of well NHK#285**

![Depth vs SBHP & SBHT (NHK #285) Recorded on 12.01.2012](image)

After getting anomalies in bottom hole pressure and temperature from BHP survey, a temperature log was recorded to reconfirm the results from a depth of 1500m (as logging tool could not be lowered beyond this point). Spinner log was also recorded along with temperature log. Another temperature log was taken at the adjacent well NHK#558 from the reservoir depth for comparison. Fig.-4 shows the summarised logs at well NHK#285 and NHK#558. The BHP survey and logs indicate that there is outflow from the well at around 400m.

**Fig.-4 : Temperature log at well NHK#285 and NHK#558**
During the 2nd week of December, 2011, surface broaching of gas at around 1.5 km away from the well NHK#285 in N-E direction was reported and there was a fire incident in night hours on 31.12.2011. Subsequently, in the first week of January, 2012, surface broaching of gas was noticed at an area about 1 km away from the well in N-W direction (Fig.-5). Gas sample was collected from these spots and it was found to be of similar composition as of NHK#285 gases.

**Fig.-5 : Map showing wells and gas broaching spots**
Considering the gravity of the situation, M/s Boots & Coots, a world renowned blowout control agency, were called to tackle the situation and they tried to kill the well with 75 pcf brine, lowering coiled tubing up to 2300m. However, they could not kill the well by this process and after assessment of the well condition they proposed for Snubbing Operation (HWO) to control the well.

**Possible scenarios**

While working on M/s Boots & Coots HWO (Hydraulic Workover Operation) proposal, a tubing inspection log was recorded using “Multifinger Imaging Tool” from 19.01m...
to 1513.26m (Logging tool could not be lowered beyond this depth) and it indicate that there are possible holes in 19 numbers of tubing at various depths. Fig.-8 shows the 3D view of 49th joint.

**Fig.-8: 3D view of 49th tubing joint extrapolated from MIT log**

(Mred spots indicates total metal loss, Yellow indicates partial metal loss & Green indicates no metal loss)

Meanwhile, it was planned to drill a replacement well from the nearby well plinth of NHK#552 (distance 602.84m towards 296°30’24″ True bearing) with sub-surface position within 30m radius of the well NHK#285 at depth of present producing zone. It was aimed to use this replacement well for killing the NHK#285 if required.

The HWO proposal was discussed in details with ONGCL experts and it was decided to attempt to kill the well, prior to Snubbing operation, using drilling mud & lowering Coiled Tubing (CT) beyond 2⅞” tubing shoe. Accordingly, a detailed plan was made in consultation with ONGCL experts and all necessary arrangement was made for well control operation.

### 1.3.1 How the underground blowout was controlled

*Mud parameter consideration:* Mud weight was designed to balance the reservoir pressure at 600m below the surface (2430m – 600m = 1830m) and Viscosity of mud was kept optimal to minimize friction loss inside CT as well as to arrest gas percolation rate.

**Mud Weight (MW)**

\[
MW = \frac{\text{Pressure (psi)}}{\text{Depth (ft.)} \times \text{const. (0.0069)}} \text{ pcf}
\]

\[
MW = \frac{(239.4 \times 14.23)}{(2430-600)(3.28) \times 0.0069} \text{ pcf}
\]

\[
MW = \frac{3406}{6002.4 \times 0.0069} \text{ pcf}
\]

\[
MW = (3406 \div 41.42) \text{ pcf}
\]

\[
MW \approx 82.23 \text{ pcf}
\]

\[
MW \approx 85 \text{ pcf} \text{ (considering safety margin)}
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**Mud Properties:** Weight-85 pcf, M/F vis- 48 sec., AV- 27.5cp, PV-15cp, YP-25 lbs/100 ft², O’ gel-11 lbs/100 ft², 15’ gel- 25 lbs/100 ft², PH-9.5, MBC-5
As planned, on 29.03.2012, coiled tubing was lowered slowly pumping high viscous fluid (XC-polymer + CMC-HVG of 75sec/quart) using high pressure kill pump. By this process any debris inside the tubing was cleaned and finally the CT could be lowered beyond 2⅞" tubing shoe. After lowering CT to 2200m, started pumping mud and finally the CT was lowered near to the perforations. Thereafter, increased the pumping rate up to the 80% of CTU pressure limit and could pump up to 1.2 to 1.3 bbls/min. During the process, kept casing and annulus open through choke to avoid further charging of the loss zone at around 400m. After pumping 30 bbls of mud observed entire annuli pressure trend to decrease and gradually pressure decreased proportionate to the volume pumped. Continued pumping at high rate, controlling the choke, till all three pressure (2⅞" Tubing, 5¼" Casing & 5⅛" × 9⅝″ Annulus) came to zero. All three pressure came to zero after pumping 170 bbls of mud. Pumped another 30 bbls of mud and shut the well after pulling out the CT. After half an hour of observation, the wellhead pressure became stable at 250 psi which was expected back pressure from the charged formation. However, the well kept shut-in overnight for further observation. It was decided not to pump mud further which may push back charged gas away from the well and contaminate nearby water bearing zone.

On 30.03.2012, the wellhead pressure was found to be stable at 250 psi after 12 hours of observation and decided to place a cement plug against perforation to isolate the producing zone. A BHP survey was carried out and the fluid level was found to be at @ 250m. After BHP survey, lowered CT with mud circulation and got held up at 2458m, 16m below the perforation bottom (perforations: 2430m – 2442m). Pumped 270 gallons of 114 pcf cement slurry and placed a plug from 2458m to 2358m (100m length). Pulled out CT and kept the well shut-in for 48 hours to set the cement. On 01.04.2012, checked the cement top with sand bailer and found cement top at 2366m.

On 01.04.2012, bled off wellhead pressure through out the day light and pressure came down from 250 psi to 150 psi. Again, on 02.2012, bled off wellhead pressure through out the day light and pressure came down from 150 psi to 100 psi. Finally, wellhead pressure came down to zero after bleeding off accumulated gas within 4 days. By this process the charged gas at shallower depth near the well was bled off through the wellhead and subsequently, the gas broaching at distant areas also decreased to a great extent.

**CONCLUSION**

Underground blowouts are a growing problem because of aging wells. Underground blowouts involve a significant downhole flow of formation fluids from a zone of higher pressure (the flowing zone) to one of lower pressure (the charged zone or loss zone.). Operators need to closely monitor existing producing wells for signs of problems. Tubular corrosion/erosion is the single largest cause of underground blowout in producing wells. In producing wells, internal tubing corrosion or pipe defects can lead to failure and sudden imposition of tubing pressure on production casing. Defects or external corrosion of outer casing can lead to either a subsurface or surface blowout depending on depth of the flowing zone.

Surface broaching of an underground blowout can lead to loss of rig and severe environmental impact (e.g. fresh water aquifer contamination, shallow supercharging). Operators many times fail to respond immediately and correctly when an underground blowout occurs. That makes control more difficult as flow paths erode, downhole tubular degrade (erosion added to corrosion) and supercharging occurs.

If a top kill is impossible, alternatives exist particularly if there are two independent flow paths to allow mixing of reactant plugs into the flow. This has been accomplished with coiled tubing, snubbing and directional relief wells. If possible, mechanical plugs may be used to isolate
the flowing zone. Experienced personnel are required to simulate flow paths, make kill calculations and apply reactant plugs.

In this particular well, recognition of underground blowout was little late because of inexperience as this is the first well having such problem in the history of OIL and due to the restriction inside the tubing to lower inspection tools. Initially, it was thought to be a loss circulation problem only and utmost attempts were made to arrest lost circulation. On recognition of the problem, detailed control plan was made for bottom kill and accordingly the well was controlled as described in clause-1.3.1.

Probable causes for this incident may be drawn as- (i) Aging of the well (35 years) and/or production of gas with sand content for a long duration (July 2010 to 14.07.2011) might have caused erosion added to corrosion leading to loss of tubing and casing integrity. (ii) As per recommended practice, gas tight (premium threaded) casing and tubing should be used in gas wells completion. But, this well was completed with round threaded casings and tubing. This could have led to leakage in the thread connections of the tubing and production casing string. (iii) 78 pcf Salt Solution (CaCl₂) was the packer fluid since October, 2005, which might have accelerated tubular corrosion leading to loss of tubular integrity. (iv) Annular pressure build-up was not addressed in time – 5½” pressure was recorded as 2700 psi (190 kg/cm²) on 9th September, 2009 and 9¾” casing pressure was recorded as 1160 psi (82 kg/cm²) on 1st May, 2010. But, no action was initiated to address these unwanted pressures. (v) Prolong attempt to arrest loss circulation and inexperience in pumping heavy mud & cement slurry through Coiled tubing led to delay in operation and aggravated the situation.

Key Learning:
1. Sand control measures must be taken immediately after observation of sand problem / unconsolidated sand stone reservoirs.
2. Gas tight (premium threaded) casing and tubing should be used in all gas wells & HGOR well completion.
3. Production packers to be used in wells are to be procured from the reputed and proven manufacturers only for reliable performance and services during setting, sealing during well production life and subsequent recovery.
4. Packer fluid should be suitably selected and designed based on reservoir fluid considering long life of the well.
5. Annular pressure build-up must be addressed immediately once it is noticed.
6. Well control operation must be executed by trained & experienced person and well control problems must be studied properly.
7. Recompletion of the existing wells in higher up prospects is to be done only after assessing the integrity of production casing.

ACKNOWLEDGEMENT: The author acknowledge the help and co-operations of each & every executive & employee who directly or indirectly were involved in the well control operations in NHK#285 and extend special thanks and heartfelt appreciation to ONGCL’s experts who have guided OIL officials all throughout the operations in controlling the well. M/s Boots & Coots also deserves our appreciation as they have encouraged our people by association with the well even for a small duration. The authors also acknowledge their gratitude to OIL Management for their help, guidance & motivation in managing the well.