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BLOWOUT WELL CONTROL CHALLENGES AND RELIEF WELL GUIDELINES FOR PAD WELL DRILLING OPERATIONS

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Abstract

In oil and gas drilling and exploration activities, there are instances when an oil/gas well may encounter uncontrolled flow of hydrocarbons to the surface, usually termed as a blowout. A blowout may result in loss of human life, valuable natural resources, financial losses, and it may even damage a country / company's reputation. Moreover, it may lead to extended periods of environmental air pollution, noise pollution, ground water/surface water pollution and soil contamination.

A relief well is usually drilled when all attempts of surface intervention to control the blowout well have either failed or is taking too long. In terms of relief well planning, significant regulatory reforms have taken place in oil industry worldwide, especially after the Deepwater Horizon incident in Gulf of Mexico. However, the regulations for land operations are yet to be enforced by various regulatory bodies. With growing demand for oil and cost optimization initiatives, many land drilling operations are now opting for pad drilling.

The risks of a well control incident is much higher when it comes to pad drilling due to the proximity between nearby wells. Thus, handling of a blowout situation for a pad well can get extremely challenging compared to a single well location. Therefore, this paper will focus on importance of proactive approach towards relief well and blowout contingency planning and demonstrate design of a relief well for a hypothetical blowout, using blowout and kill software simulations. It will also bring together various industry standards and environmental regulations to provide concise guidelines for relief well design.

Keywords: Oil and gas; drilling; blowout; relief well; contingency planning; environmental pollution; pad drilling.

Introduction

A kick situation occurs when the primary well control is lost, which usually can easily be controlled by applying secondary well control that is by using Blowout Preventer (BOP) and related well control equipment. The kick is safely circulated and well is usually killed using kill Mud with higher density and primary well control is reestablished. However, in the event of failure of primary and secondary well control, a blowout situation may occur which needs to be handled efficiently to control the disaster which may cause damage to human life, environment, and huge financial loss to the company.

A blowout situation in oil and gas industry is highly undesirable and is often addressed by a reactive approach. This may delay the response time required to bring the well under control and threatens

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human life, environment, company assets and reputation of a country. There is also a common myth that only high-pressure wells can have blowout and relief well shall be designed after actual blowout only by well control specialists. However, advanced softwares are now available that provide reliable tools to engineers to prepare blowout contingency plans during well planning. Many factors may change when an actual blowout situation occurs but having a blowout contingency plan ready can help understand the feasibility of the desired operation and be a reference to prepare actual plan and execute it with minimum lead time. Objective of drilling a relief well is either to divert the pressurized hydrocarbons in a controlled manner or to pump heavy mud and kill the blowout and secure the well, to mitigate damage from a potential blowout.

Fig.1 Baghjan Well Blowout (Courtesy: Economic Times)

A relief well plan should consider following aspects as a minimum:

- A minimum of two suitable surface locations should be identified to drill a relief well.
- Calculations or simulations to be done as per the geological data to establish kill rate and number of relief wells required.
- If the simulations show that there is a requirement to drill two relief wells, then a minimum of three suitable surface locations should be identified which can be used to drill relief wells.
- Shallow gas assessment shall be done of the proposed surface locations.
- Carryout Casing design.
- Well trajectory design should be done keeping in mind possible survey errors.
- Selection of suitable directional drilling tools based on well trajectory, along with logging and ranging tools which will ensure precise interception of the blowout well.
- Description of primary killing method. In most cases, this will be a high-rate dynamic kill operation through the relief well.
- Based on the kill simulations, the Rig and pumping requirements and their mobilization time needs to be estimated.
- To decide on suitable wellhead for the relief well.
- Similarly, any requirement for special services and material should also be planned.
- Time estimates for drilling a relief well shall be prepared.
- Based on all the above considerations, the relief well plan should be prepared with risk assessment to demonstrate the feasibility of the operation, signed, and approved by management.

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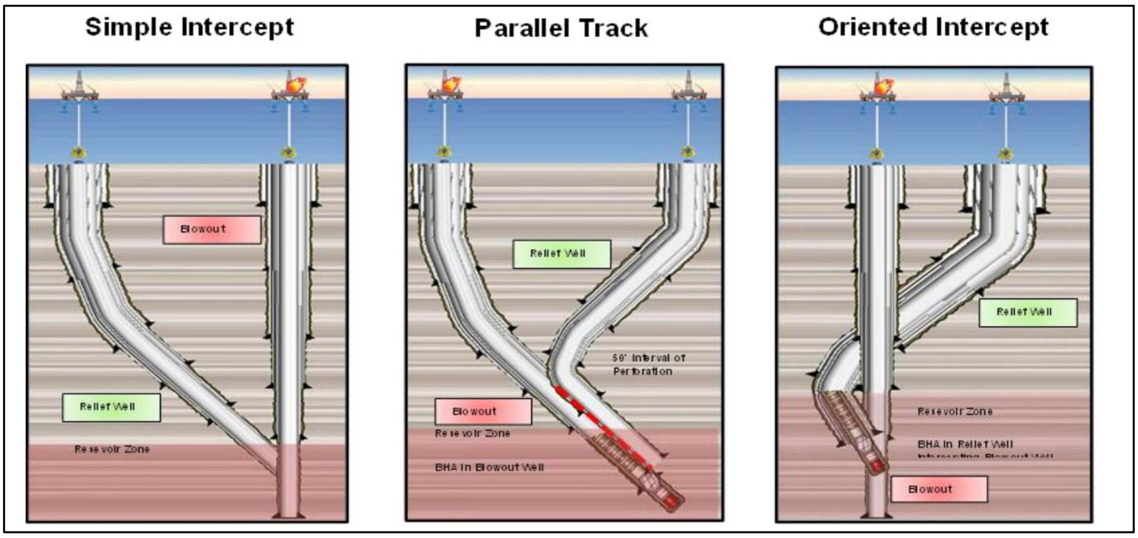

Fig.2 Various examples of relief well design (SPE/IADC-173097-MS)

Minimum guidelines for Relief Well and Blowout Contingency Planning:

1. **Selection of Relief Well surface location:**
   - For onshore wells, the minimum distance of relief well surface location should be 300 metres in the upwind direction with respect to the blowout well.
   - If there are any gas hazards like H_2S the relief well location may have to be moved further away from the blowout well. In such a case, the minimum distance of relief well surface location should be 500 metres in the upwind direction with respect to the blowout well.
   - The farther the relief well surface location is, higher the inclination of the tangent section would be. Therefore, care should also be taken that the surface location is not very far as this may increase the hole's inclination which will increase the torque and drag values which affects efficient hole cleaning and wireline operations.
   - Many factors are to be considered when deciding a suitable surface location for a relief well. A detailed study and survey of the proposed location should be carried out before finalizing a surface location. Based on the findings if the data shows many constraints, then an alternative spud or surface location should be chosen.
   - Offset wells data, within a radius of around 1500 metres of the relief well should be taken into consideration to assess any challenges while drilling and avoiding any possible subsurface problems as much as possible.
   - Shallow gas, faults or any other subsurface challenges which may complicate the drilling and well killing operation should be avoided.
   - For new wells, shallow seismic site survey, for shallow gas prognosis, should be carried out at the proposed relief well surface locations along with the original well.
   - For existing wells, a shallow seismic site survey for the relief well surface location should be conducted if not carried out earlier during drilling of the original well.
   - The type of rig that is chosen, or that is available, for the relief well may pose additional constraints for the surface location.
   - A proper location survey should be done to ensure there is enough space to position a Rig and related equipment and it is at a safe distance from human habitat.

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- A road survey should be done, to check if the access road to location is suitable to move heavy equipment, check for height of power and communication cables which might obstruct the movement of truck loads.
- Check if there will be access to a water source which can give continuous supply of water for drilling and kill mud preparation.

2. Directional planning for relief wells:

- A relief well is planned to intercept the blowout well as deep as necessary or to intercept at the last casing shoe before the hydrocarbon bearing zone is encountered.
- Anti-collision checks should be carried out.
- Kick-off point selection is very critical as the well trajectory, ranging zone and precise target intercept would depend directly on the kick-off-point.
- There will always be uncertainty about the exact well position of both blowout well and the relief well. Therefore, any trajectory planned for a relief well to direct intercept is certainly not feasible.
- The most preferred relief well trajectory is "S" profile as it has higher probability of intercepting the blowout well at the correct depth. If intersecting a cased hole, motor and milling BHA can be used to first locate any magnetic interference and then just follow the ranging procedures. If it's an open hole intersection, drilling bit and rotary steerable system (RSS) can be used to first locate any magnetic interference, in this case it would be from the last casing point or fish, and then just follow the ranging procedures.
- A relief well trajectory should be planned such that ranging process starts as early as possible, at a point along the wellbore approximately 300 metres (MD) above the planned intersection depth to allow sufficient distance for course corrections ahead of the interception point.
- Gyro while drilling, may be preferred for taking directional surveys while drilling relief well, as magnetic interference from the target well's casing or drill string will affect the MWD readings.
- As hole cleaning is a challenge in wells with inclination of 40-60°, max inclination of the relief well should ideally be less than 40° and should not exceed more than 60° to avoid any wireline logging challenges, and the planned DLS should be less than 3°/100 feet in the build section and 1.5°/100 feet in the drop section.
- The incidence angle at which the relief well would usually be planned to intercept the blowout well at the last casing shoe above the target hydrocarbon bearing zone, should be planned to be between 2° - 6° to successfully range and mill into the blowout well

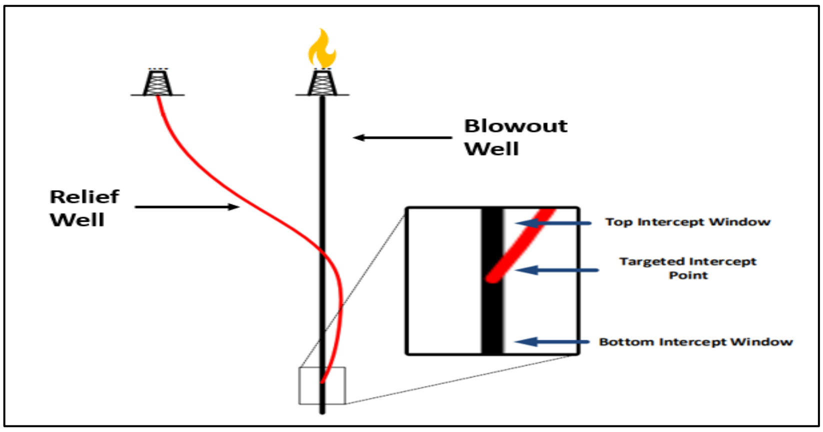

Fig.3 Schematic showing a blowout well intercepted by relief well.

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3. **Well Design considerations:**
    - The casing design for relief well should be similar to the blowout well, with casing seat selection having the same TVD as the original well.
    - The casing shoe-setting depths for the relief well should be kept the same as the blowout well casing shoe depths, except for the deepest casing shoe, which may be set shallower to allow for the contingency liner.
    - The presence of H2S or other harmful gases should be checked.
    - Optimum hole sizes, casing sizes and wellhead sizes along with rating should be considered.
    - When pumping kill mud through the relief well, the flow rate should not exceed the formation fracture pressure while maintaining adequate bottom hole pressure. The limiting factor during this process is the surface pressure required to achieve the selected kill rate.
    - However, if calculations show that the applied pressure during well killing operation may exceed the mud pump or manifold rating or tubular burst rating then, relief well casings sizes can be increased to one size bigger than the original well that is larger casing internal diameter or smaller tubing outer diameter. Other option would be to use higher kill mud density or drilling additional relief wells.
    - Casing and liner shall be designed to withstand all planned and/or expected loads and stresses including those induced during potential well control situations.
    - Burst load case and collapse load case taking into consideration higher than normal burst and collapse forces during kill mud pumping, well control, total losses, and expected torque & drag should also be considered.
    - Planned well trajectory and bending stresses induced by doglegs and hole inclination.
    - Pore pressure (PP) and fracture pressure (FP) data for both target well and the planned relief wells should be available with respect to well TVD.
    - Potential mud loss and stuck pipe depths.
    - Water based muds provide the best circumstances for injecting current into the formations and onto the blowout casing. If possible, water-based drilling fluids should be used in the relief well.
    - Oil based mud system tends to reduce the detection range of the electromagnetic tools due to electrode insulation and should be avoided.
    - In case a direct intercept is planned, it is advisable to plan the intercept point in an interval where formation strength is high. This provides some mechanical back up to the drill bit while making the direct intercept into the target well. On the other hand, if the plan is to perforate between relief well and target well then, the intercept point should be placed in an interval of lower compressive strength so that the maximum penetration from the perforating guns can be obtained.

4. **Equipment, Material and Services planning:**
    - Depending on the number of relief wells planned, the minimum required number of Rigs for the Relief Well Drilling operation needs to be mobilized.
    - The Rig specification should be either similar or with higher specifications than the Rig which drilled the original or blowout well which needs to be intersected.

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- As the mud density is expected to be higher with kill mud being used for dynamic well killing operation, having adequate mud pumps with pressure rating and pumping capacity is important.
- There should be sufficient active and reserve mud tanks for mixing drilling fluid and kill mud which will allow mixing and pumping of kill fluid for an extended period. Additional high-pressure pumping trucks can be mobilized as contingency.
- There should always be access to an updated or real time inventory management system to mobilize tangibles like casings, pup joints, float equipment, wellhead, drill bits.
- Some of the services required will be directional drilling tools, mud, solid control, cementing, mud logging, casing running tools, wireline logging and ranging and fishing tools.
- As a special service, companies can consider involving a reputed well control management company, preferably a company which has experience in the region or with similar relief well planning and execution.

Blowout & Kill Software Simulation:

Historically, blowouts are uncommon and hence not many drilling engineers are used to considering the blowout scenarios and dynamic kill requirements while designing a drilling well. However, as the wells are getting more challenging, there is an overwhelming need to consider the relief well and blowout contingency plans from the well planning stage. Especially, for pad well drilling locations with increased surface and directional challenges, it is important to prepare all contingency plans ready.

The software simulations which are available nowadays allows drilling engineers and subsurface teams to collaborate and run blowout and kill simulations inorder to understand the requirement based on surface and subsurface conditions of a well. With these advanced softwares, relief well planning which would otherwise take a few days can now be carried out in few hours. Moreover, the software allows us to generate multiple options considering various possible scenarios and prepare the blowout contingency plan accordingly.

As part of the study, Oliasoft's Blowout & Kill simulation engines were used for simulating dynamic kill rates for various scenarios. Different options were considered like pumping through the relief well intercepting the blowout well at a given depth, pumping through drill string existing in hole, pumping through annulus etc., to check the blowout potential during well design stage and calculate the dynamic kill rates, pump pressure, required pump power, and number of relief wells required. Below figures show some the results from the simulation.

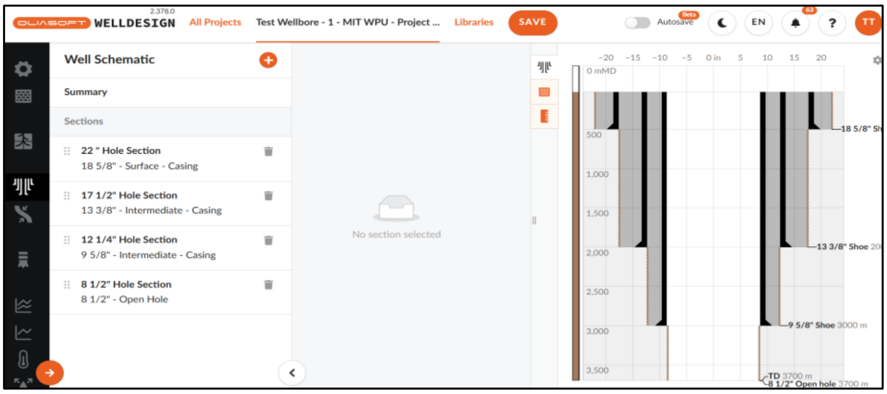

Fig.4 Well Schematic of the blowout well

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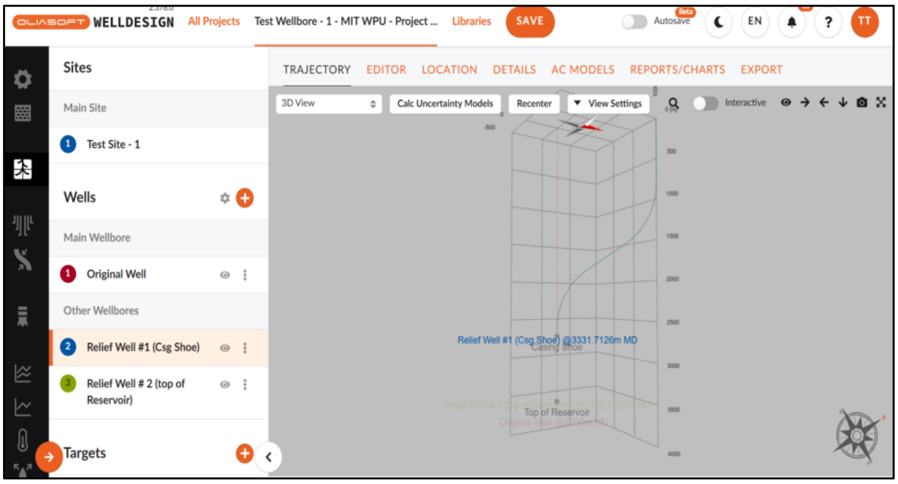

Fig.5 Well Trajectory of Original/Blowout Well and Relief Well

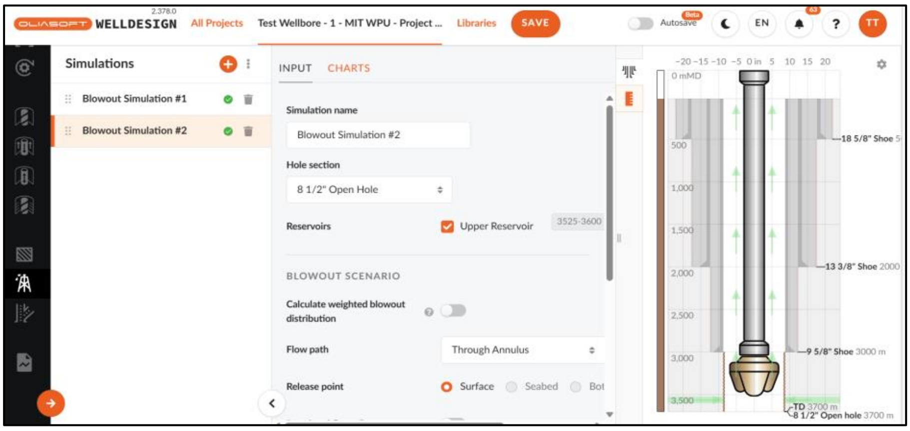

Fig.6 Blowout Simulation

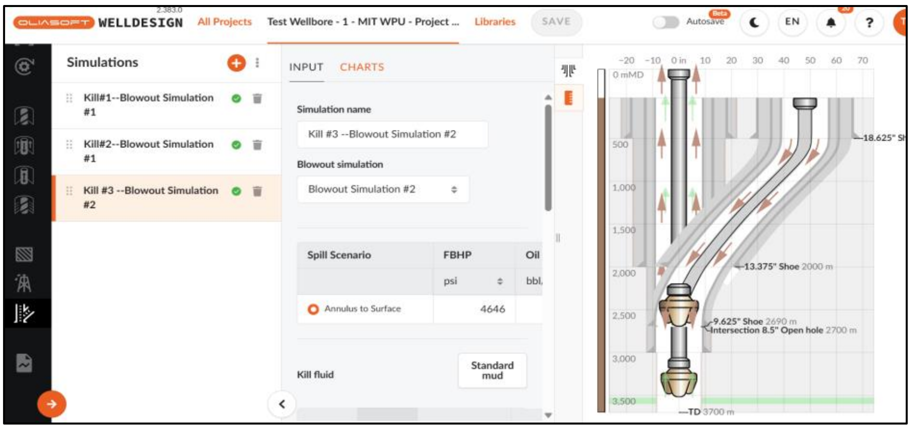

Fig.7 Kill Simulation

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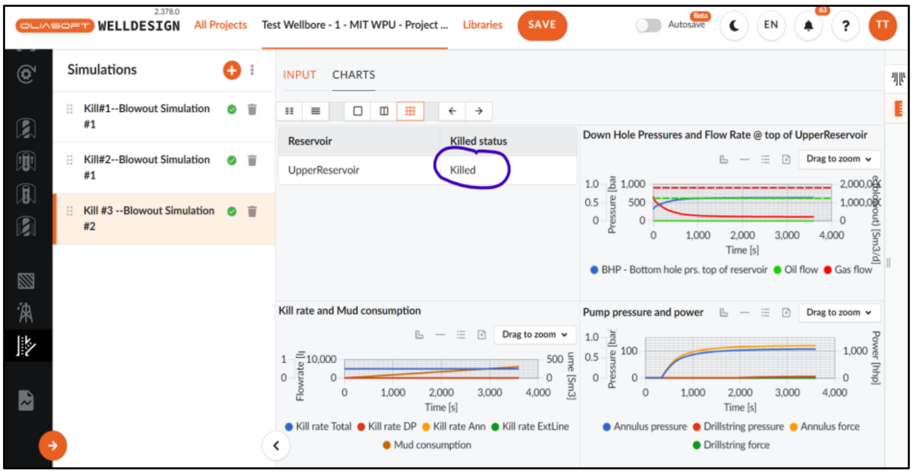

Fig.8 Simulation results showing well status (killed)

Results and Conclusion

(1) Relief well is the last line of defense for controlling a blowout, with highest probability of success. Hence, this safety critical aspect should not be ignored during well planning stage.

(2) The extent of environmental damage caused by an uncontrolled blowout can be significantly reduced if there is a robust and comprehensive blowout contingency plan.

(3) Still most operators create a relief well plan only after a blowout has occurred, and many government bodies are yet to introduce mandatory requirement to submit relief well plan prior to commencement of drilling a new well.

(4) The results from the blowout and kill simulations presented in this paper shows the importance of considering these during planning a new drilling well, and how it can help identify the challenges associated with stopping a blowout and help mitigate most of the risks.

(5) It will also help to identify material, services and suitable rig with required specifications in advance, e.g., mud pumps which can provide the required pumping rate and pressure for a dynamic well kill.

(6) Drilling of actual relief well should commence simultaneously with the surface intervention attempts to control blowout, to considerably reduce the extent of damage.

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Nomenclature

- BHA- bottom hole assembly
- BOP- blowout preventer
- DLS- dogleg severity

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- H_2S- hydrogen sulfide
- MD- measured depth
- MWD- measurement while drilling
- TVD- true vertical depth

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