False Positive Indicators Management Strategy

Drilling Ahead Module

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1. Purpose

The purpose of this document is to acknowledge that the effectiveness of an Automated Well Control system could be affected by the perception of false positive indicators that will result in well closure.

The functionality of the Automated system is outlined, together with its built-in filters (and their functionality). Additionally, a list of reasons why false positive indications and a view of the probability of occurrence are summarised. A full description of the Automated system can be found in SPE Paper 202091-MS (Atchison 2021)

Finally, the document considers the possibility of reducing time delays to enhance influx control.

2. Operational Overview

The Automated Well Control system continuously monitors fluid flow from the well while simultaneously monitoring the status of selected drilling and well control equipment using the relevant I/O data through its PLC server.

When the system identifies and confirms a self-sustained influx, a message appears on the drillers HMI screen indicating that an automated shut-in procedure is initiated. This prompts the system to automatically perform the necessary sequence of operations with the rig equipment to safely shut in the well whilst the driller adopts a verification role based on the operation being conducted.

Safe Influx Automated Well Control Procedure (detailed in Figure *1*):

1. The system receives a kick indicator signal.
2. The system initiates an audible alarm signal.
3. The system sends a warning message to the driller "Auto Well Control Initiated".
4. The system takes control of the assigned rig equipment and performs the following automated sequence:
    a. Continues pumping and rotating whilst picking up the drill string using the draw works to the first available safe space out location.
    b. Stop top drive.
    c. Stop mud pumps.
    d. Monitor flow from well. If flow continues, shut in the well.
    e. Activate BOP to shut in the well following company prescribed procedure.

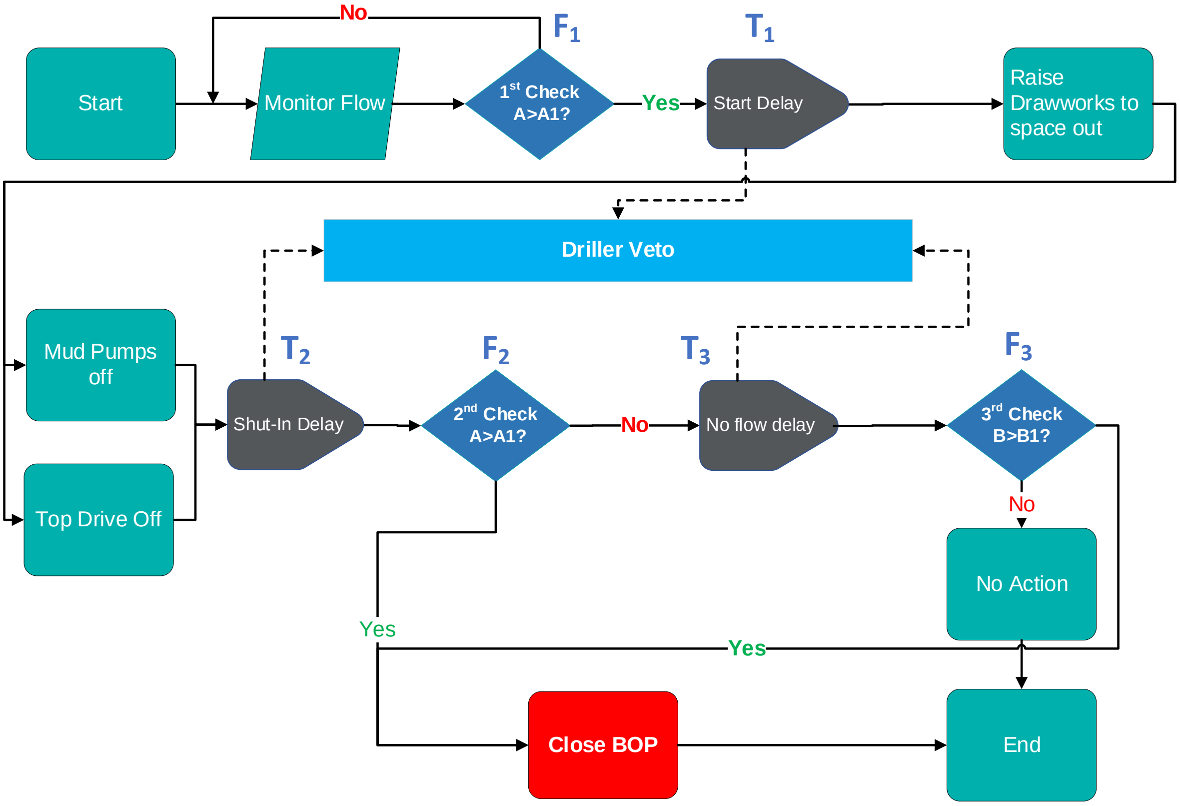


Figure 1 - Automated Well Control Sequence

On confirmation of an influx, the ultimate executive action of the automated system is to close the Blowout Preventer (BOP) and hand rig control back to the driller for subsequent remedial operations.

Key advantages of the Automated Well Control system are:

- Without human interaction, the well has defaulted to a fail-safe (closed) position.
- Speed of well closure is reduced.
- Consistency of Operation is achieved.

3. System Triggers and Filters

As depicted in Figure *1*, triggers and delays are incorporated into the process to ensure that the positive indication of an influx is sustained for sufficient time to filter any signal noise or errors.

The trigger commands relate to pre-set values that are entered by the driller at commencement of operations.

3.1 Definitions

Refer to Figure *1*.

Flowrate	
A (%)	Measured drilling flowrate at sensor in %
A1 (%)	Pre-set drilling flowrate from system in %
B (%)	Measured no-flow flowrate at sensor (%)
B1 (%)	Pre-set no-flow flowrate at sensor (%)

Table 1 - Definitions

3.2 Sequence

While drilling ahead		
F_1	Measured flowrate > pre-set flowrate	Possible Influx detected
T_1	Start delay	
If no Driller Veto		Confirmed sustained flow increase Commence Automated Sequence • Drill string Space out • Mud Pumps shut down • Top Drive Shut Down

Table 2 - Phase 1 Automated Sequence

Scenario 1		
T_2	Shut-in delay	
F_2	Measured flowrate remains > pre-set flowrate	Flow is sustained, influx is confirmed
		Commence BOP closure • BOP Closed

Table 3 - Phase 2a Automated Sequence

Scenario 2		
T_2	Shut-in delay	
F_2	Measured flowrate reduces < pre-set flow rate	Flow is decreasing, possible false positive
T_3	No flow delay	
F_3	Measure no flow flowrate > pre-set no flow flowrate	Influx still possible
		Commence BOP closure • BOP Closed

Table 4 - Phase 2b Automated Sequence

4. False Positive Identification

Tables 3 and 4 depict how the built-in filters can reduce the risk of a false positive trigger to the Automated Well Control system. However, in the paper SPE-173052-MS (Brakel et al 2015), several practical studies have been conducted to identify the frequency of false positive indications during drilling operations which may mask influx detection.

Alarm Variable	False Alarm Frequency %
Kick Indicators	
Return Flow Increase (drilling)	0
Return Flow with zero flow rate (Connections)	2
Active Pit Volume Gain (drilling or Connection)	31
Trip Tank Volume Difference Gain (Tripping)	2
Total % Kick Alarms	**35**

Table 5 - False Alarm Frequency of the SMART Kick Detection System

Table *5* clearly shows that in a drilling ahead mode and using a flowmeter sensor, the occurrence of false alarms was zero.

Section 5 below details the additional protection from false positives that may be achieved using the built-in triggers and time delays of the Automated Well Control system.

5. False Positive Analysis

The following matrix details the mechanisms that may produce false positive inputs to the drilling ahead module of the Automated Well Control system and lists the filters that can be used to mitigate these. A reduction in probability of occurrence (and necessarily a reduction in risk) is evident by applying these filters.

False positive training will be given to all personnel before using the system. It is also expected that the probability of occurrence will be location specific, and that the matrix will be changed in line with company policy and perception of local probability.

Mechanism		Probability	Observation and Mitigation	Automation Filter	Residual Probability
Increase in Pump rate	During drilling operations, the driller may choose to vary the pump rate. **Increase pump rate** Will manifest as an increase in flowrate at the sensor. **Decrease pump rate** Will manifest as a decrease in flowrate at the sensor.	High	A change in mud pump rate is controlled by the driller and resultant variations in flowline volume is predictable and expected. Any change in pump rate will result on the resetting of the drillers flow meter and the Automated Well Control system. Training and documentation will advise of the actions to be taken if pump rate is varied.	F_1 & T_1	Medium

Mechanism		Probability	Observation and Mitigation	Automation Filter	Residual Probability
Stuck paddle	A paddle can become stuck for several reasons: • Mud solids build up. • Bearing Failure. • Obstruction.	Medium	A stuck paddle is characterised by a constant signal and indication with no variation over a period. A stuck paddle is unlikely to generate a signal that can be interpreted as an influx. Training and documentation for the Automated Well Control system will encourage regular maintenance and verification of the flow paddle during pumps off events. The driller will be encouraged to reduce flow rate for a limited time if he suspects a stuck paddle.	F_1 & T_1	Medium
External Source	This is the case where external influences unrelated to wellbore conditions affect the reaction of the flowmeter. Cleaning and Maintenance Operations Mud dilution operations. External Fluid Influence.	Medium	**Cleaning and Maintenance** Inevitably during drilling operations, cleaning and maintenance operations will be required, introducing additional fluid into the flowline (via drip trays and drains). This is a planned and observed operation and should be easily interpreted by the driller. **Mud dilution** Introduction of dilution fluids (water or base oil) is unlikely at the flowline upstream of a flowmeter sensor.	F_1 & T_1 (F_2 & T_2)	Low

Mechanism		Probability	Observation and Mitigation	Automation Filter	Residual Probability
			External Fluid Influence This case refers to accidental introductions of fluid into the flow line (again via drip trays and drains). This may be caused by incorrect valve line up, pump surge, or flange leaks.		
Rig Heave	This is applicable to floating units where rig movement will affect the indications of mud flow at the flow sensor. The reaction of the sensor will be an increase and decrease according to rig movement.	High	Alignment of the flow line with relation to the rig movement means that there will be a variable oscillation of the flowmeter depending on rig motion. Rig heave is predictable and cyclic Modification and optimisation of both the flow gain set point and the time delay will mitigate the effects of rig heave.	F_1 & T_1	High
Cuttings Unloading	This case is to cover a sudden unloading of cuttings from the well. Causes of this effect may be poor hole cleaning procedures, cuttings build up in wellhead areas.	Low	A sudden unloading will cause a momentary increase in flow which will return to normal as cuttings volumes are reduced. Evidence of cuttings unloading will quickly be seen at the shale shaker area and be discounted. In any case a rapid unloading from the well should be considered as an event and well shut-in is the correct response.	F_1 & T_1 (F_2 & T_2)	Low

Mechanism		Probability	Observation and Mitigation	Automation Filter	Residual Probability
Pipe surge	As pipe is run into the well, fluid volume will be displaced into the flowline. This volume will be interpreted as an increase in flow. **While drilling** This is the case when drilling flowrate is at the pre-set level and downward pipe movement causes a fluid surge. **While tripping** This is the case where circulation is stopped, and downward pipe movement causes displacement of drilling fluid.	Low	Pipe movement is controlled by the driller and variations in flow line volume is predictable and expected. While drilling – flow surge is predictable and well control automation can be vetoed. In addition, effects of pipe surge can be effectively fingerprinted before operations commence (see Section 7). While tripping – Automated Well Control (drill ahead module) is not deployed.	F_1 & T_1	Low
Pipe swab	As pipe is pulled from the well, fluid volume will be displaced into the wellbore and be manifested at the flowline as a reduction. However, the piston effect of a drilling assembly may 'drag' fluid into the flowline when moving upward. This volume will be interpreted as an increase in flow.	Low	Pipe movement is controlled by the driller and variations in flow line volume is predictable and expected. While drilling – flow surge is predictable and well control automation can be vetoed. While tripping – Automated Well Control (drill ahead module) is not deployed.	F_1 & T_1	Low

Mechanism		Probability	Observation and Mitigation	Automation Filter	Residual Probability
	While drilling This is the case when drilling flowrate is at the pre-set level and upward pipe movement causes a fluid surge. **While tripping** This is the case where circulation is stopped, and upward pipe movement causes evacuation of drilling fluid from the wellbore manifested as an increase in flow.				
Wellbore Response	Variations in flowrate can cause the wellbore to expand and contract according to the additional dynamic pressures applied in a circulating environment. Manifested as 'wellbore ballooning' (wherein fluid flows returning from the well can be markedly different to applied flowrates).	Medium	Several logic sequences can be applied to wellbore ballooning; however, wellbore response observations tend to not to be rapid and can be interpreted accordingly.	F_1 & T_1 F_2 & T_2 F_3 & T_3	Low

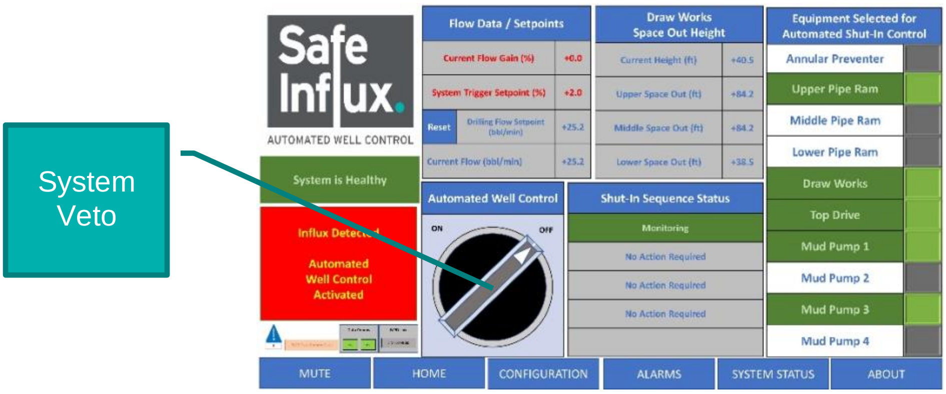
Table 6 - False Positive Identification

6. Driller Veto

The Automated Well Control system is designed operate at automation level 6 *'the computer selects action and informs human in plenty of time to stop it'* (Sheridan and Verplank 1978)

This level of automation in the well control system allows the driller to immediately stop the closure process by a 'double tap' on the HMI interface in the case where late realisation of a false positive indication occurs. This veto prevents further action of the system and will halt the final process of well closure.

In the case that the Veto command is issued, full control of the rig systems is reconnected to the driller. Re-arming of the automated system can only be done by resetting the Automated Well Control system.



7. Fingerprinting

Time delays are built into the automated sequence to preclude or reduce the false positive frequency during drilling operations However, any time delay introduced to a well control sequence will allow an increased volume of influx to enter the wellbore.

An increased influx size will influence:

- Time for operational recovery.
- Time when equipment and personnel are under stress.
- Pressures manifested at surface (with an equipment breach if too great).
- Pressures manifested at the wellbore weak point (with an integrity failure if too great).
- Volumes of effluent to be handled.
- Review of casing design parameters.

To reduce influx sizes, a comprehensive fingerprinting exercise is recommended prior to deployment. This exercise can be conducted during offline time and is recommended for the commencement of each hole section where Automated Well Control systems are deployed.

Comprehensive fingerprinting will enable the Automated Well Control built-in variables to be optimised for a particular well or hole section. This will provide a system that is sensitive to the well and de-tuned to reduce or eliminate false positives.

A clear result of this exercise will be to reduce delay times to a minimum such that the advantages of automation can be realised.

8. Conclusions

The advantages of Automated processes are clearly understood and are comprehensively deployed in many applications and industries.

Automated well control is a process that ensures that influx control is rapid, consistent, and free from external organisational issues and human factors. Research by Atchison, B.W. and Sarpangal, V in 2021 suggests that automation in well control operations may reduce the influence of human factors by 94%

False positive reactions can cause premature or unnecessary closure of a well. The time-based filters and double checks incorporated into the systems will significantly reduce the probability of occurrence.

- Research evidence indicates that false positive indications are not significant in a steady state drilling ahead operation.
- Built-in filters and time delays coupled with a formal fingerprinting exercise will allow the Automated Well Control system to be fine-tuned to the drilling environment.
- Simple and intuitive driller veto will ensure that false positive indicators can be overridden.
- Formal training will ensure that crews are familiar with the cause and effect of false indications.

Making a well safe by effective closure under a false positive indication
is better than *not making the well safe after a real positive indicator.*

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