A New Approach To Kick Detection and Diagnosis in Drilling Operation

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Abstract
Through the years many tools have been developed to detect kicks in their early stages, when they can be handled more easily and safely. However, most of these tools are dependent upon the well being full of fluid with the liquid at the surface. When drilling wells where there are severe lost circulation problems (e.g., no returns to the surface) many of the major kick detection tools do not function properly since the liquid level may be hundreds or thousands of feet below the surface. During tripping operations, the major kick indicator is measurement of the volume of drilling fluid required to "fill" the hole to replace the volume of steel removed. If the annulus cannot be filled, again due severe losses to the open formation, measurement of the fluid pumped into the annulus does not give meaningful information as to formation fluid influx until the influx is great enough to begin to unload the annulus. The implications of being able to detect kicks and losses far ahead of conventional methods are significant, from overall safety and reduced risk to equipment and personnel, to drastically improved ability of crews to manage and control an influx that has been minimized by early detection and early response. This study proposes a drilling management system method of monitoring early warning of kick based on riser pressure principle. This tool measures riser pressure combined with the use of finger printing baseline recording. The drilling management system detects the start of a kick two times faster than the current methods.

Keywords
Kick Detection, Kick Indicator, Kick Monitoring, Drilling Management System

I. Introduction

In terms of drilling and well control, the industry faces more and bigger challenges as wells are drilled in more remote areas to greater depths; all these elements reduce the margins within well control. Operational and technical options for handling some typical scenarios which include simultaneous occurrence of losses and influx; are not unfamiliar to the industry, but application of these measures in a logical sequence can help produce successful outcomes [2]. The focus during a drilling operation is to keep the wellbore pressure stable and prevent any type of influx of formation fluids. Inflow of formation fluid is what is called a well control situation. In every well stage e.g. drilling, completion, production, intervention etc. barriers are the most important system to prevent an unwanted situation. Their intention is to avoid a catastrophe and to have the ability to regain well control if a situation should arise and escalate. All operations must be planned and conducted in a way that no uncontrolled inflow of formation fluid enters the wellbore.

A **kick** is an unwanted influx of fluid or gas into the wellbore. The influx enters the wellbore because a barrier, such as cement or mud, has failed to control fluid pressure in the formation. In order to control the kick, personnel on the rig must first detect it, and then stop it from progressing by adding one or more barriers. The crew must then circulate the influx out of the wellbore. If the crew does not react properly, fluids will continue to enter the wellbore. This will eventually escalate into uncontrolled flow from the well; thus, a blowout. In order to detect a kick, rig personnel examine various indicators of surface and downhole conditions. These indicators include pit gain, flow-out versus flow-in, drill pipe pressure, and gas content in the mud.

Until now, drillers have relied on kick detection and kill methods that have changed very little over the years. Kicks are traditionally detected by monitoring the drilling mud balance in the well. During drilling, the flow into the well is measured indirectly by multiplying the number of strokes the drilling mud pump makes by the pump's volumetric displacement. This is compared with the mud flow-out, which is usually determined using a paddle flow meter and the observed change in total volume in the mud pits. When the flow-out exceeds flow-in, gas has entered the well and a kick has started. An influx of fluids into the wellbore may also be indicated by tell-tale pressure drops and a change in the mud pump's stroke rate.

A. Reasons for kick

There are several factors that affect the extent of a kick, these are the differential pressure between the wellbore and formation. Also the formation properties like porosity and permeability are important. In order to get a kick the pushing force from the formation and into the wellbore must be higher than the force holding formation fluid back or containing it in its original place. When the hydrostatic wellbore force is not able to hold back the formation pressure it will lead to inflow of formation fluids, this is what we call a kick situation. As mentioned the formation properties are also important factors with respect to the kicks magnitude.

If the formation has a high permeability the rocks ability to allow fluid flow is high, as it is in sand formations. However, if the permeability is low the fluid flow within the rock is low and shale is a rock with low permeability. Porosity is how much empty space there is in a rock.

But in order to get the fluid moving differential pressure is needed. The differential pressure is the pressure from the formation; the difference between the force that wants to push the fluids out of the rock, and the hydrostatic column from the mud that tries to hold back the formation fluid from entering the wellbore. The larger the negative differential pressure between wellbore and formation gets, the higher the inflow – if the formation also have high permeability and porosity inflow will accelerate [1].

B. Limitation of current kick detection methods

The main drawbacks of current kick detection methods are their slowness and inaccuracy. This inaccuracy is as a result of the time that elapses when using the current kick detection methods before a kick is detected at the surface. Thus, a great deal of gas may have found its way up the wellbore and a particularly hazardous situation in this scenario is shallow wells. The driller in this situation then has only a few minutes in which to shut in the well and prepare a kill strategy.

Current differential mud flow measurements are particularly prone to error due to the principles that based on. Mud flow-in calculations depend on pump efficiency, normally assumed to be about 90 percent.

Literature has shown that pump efficiencies fluctuate between 80 and 95 percent. These variations alone can introduce a 10 percent error in the flow-in measurement. Flow-out measurements are prone to even greater inaccuracies. Paddle-type flow meter measurements often used in the field vary according to the fluid's density, viscosity and level in the return line. Accurate differential flow rate measurements and pit gain observations are particularly difficult to obtain on floating drilling rigs because of heaving and rolling of the vessel in response to wind and waves. Under optimum conditions, traditional differential flow measurements over the entire range of mud flow and type are accurate only within 25 percent (300gal/min) in 1200gal/min which is a typical pumping rate [3].

Other inaccuracies in kick monitoring and control are introduced because of rudimentary assumptions about gas flow within the well. Traditional kick theory assumes that the incoming gas initially occupies the well's entire cross-section area and then rises in the annulus at the same speed as the mud. But laboratory experiments from research studies have shown that this is not the case and that there is a need to improve the modeling of gas flow within the wellbore. The use of oil rather than water-base muds in most drilling operations has added further impetus to efforts to model gas flows more accurately. This is so due to the fact that gas dissolves easily in oil-base muds and this has made kick detection to become more difficult. As a result, greater amounts of gas may enter the wellbore and be transported in solution up the well before reaching a depth at which the hydrostatic pressure falls below bubble point. At this level, the gas bubbles will emerge from solution and displace more drilling fluid from the well. This causes the bottom hole pressure (BHP) to decrease further allowing more gas to enter the well from the formation. If the kick is left uncontrolled, it can displace all the drilling fluid from the well, causing a Blowout [3].

II. Empirical Reviews

Common kick detection systems in use today include pit gain or differential flow measurements. Pit gains or losses are most often measured by floats located in the rigs mud pits. These floats generally have recorders and alarms to monitor any unusual gains or losses in surface mud volumes. These gains or losses can signify either a kick or lost circulation respectively.

Reference [3] conducted a parametric study on the relationship of various drilling system and kick parameters at the seafloor using a well control simulator. The goal of the study was to understand the relationships and determine the delta flow accuracy required based on a given kick size. This study reviewed that a sensor capable of detecting a 10 barrel kick would require an accuracy of 2.4% and a 20 barrel kick would require 4.6% accuracy for detection. This case was shallow water, low kick intensity scenario. This accuracy for the drilling and kick parameter range provides the boundaries for a well control sensor to be placed at the seafloor. Detection of kicks, or the unscheduled entry of formation fluids into the wellbore, is vital to well control. It has been determined that return flow rate is the parameter most sensitive to detecting kicks and lost circulation. One kick detection method associated with this parameter is delta flow early kick detection or simply the delta flow method. This method has limitations on floating vessels. Inaccurate readings can occur due to the heave motion of a vessel. This is a result of the sensor being downstream of the compensatory slip joint. Expansion and compression of this joint can result in return flow readings that are not representative of the actual value. Inaccurate readings could create situations in which a false kick or false lost circulation is detected. Other inaccurate readings could result in an actual kick or lost circulation situation not being detected.

Reference [5] in their study concluded that, by selecting the appropriate network training sample and test sample, training adjacent wells data by BP neural network; well kick warning model was built, characterization of well kick weight value and threshold value matrix were obtained through putting the real drilling data into the neural network for calculation. Finally according to maximum similarity principle the training results and the expected output is compared, the difference of the existence of the output result is the result of early warning. Thus, for matter of low correct rate in early warning of kick, this study proposes a method of early warning of kick based on BP neural network.

III. Methodology - Drilling Management System as New Approach to Kick Detection

The drilling management system will provide a complete influx detection package during drilling and tripping. It monitors the drillpipe and casing pressures to determine a dynamic and more reliable downhole pressure, influx density and volume.

The software was developed using the platform of Microsoft Visual Studio. The developments were divided into modules depending on the number of available class of problems / parameters.

1. Software Testing and Validation

Testing the software involved running the software with data that have been processed by known software. The software was tested for the following:

1. Accuracy / Consistency
2. Error(Mathematical / Programming errors)
3. User Friendliness
4. System Compatibility
5. Security and Efficiency

In other to run the kick model, several other input parameters that describe the well and formation conditions are required:

01. Well Geometry
02. Physical Properties (formation description, mud and gas properties)
03. Well / Model control (control parameters, setup conditions and grid condition

Other information such as annulus and bottom hole pressure were also considered.

IV. Results and Discussion

To provide a tool that is capable of detecting influx more quickly and reliably than conventional well control method (Pit Gain), the tool must measure riser pressure and also combine the use of finger printing baseline recording. The developed tool also complements and enhances conventional methods of detecting flow anomalies while drilling. The drilling management system detects the start of a kick faster than current methods; thus, enables preventative action to be taken much more quickly than with conventional methods.

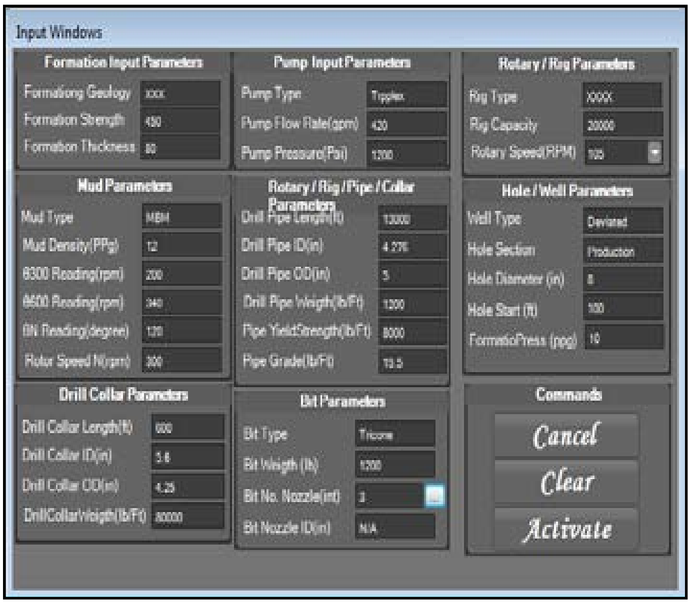

Fig.1: Input Phase of the Tool

It carries a data base of drilling information (such as annular volume and drill string capacity) to automatically answer some of the real time consuming "Kill Sheet" questions. The results are presented on a computer screen in a form identical to the traditional paper sheet, incorporating a drillpipe pressure drop graph (Fig. 2 and 3).

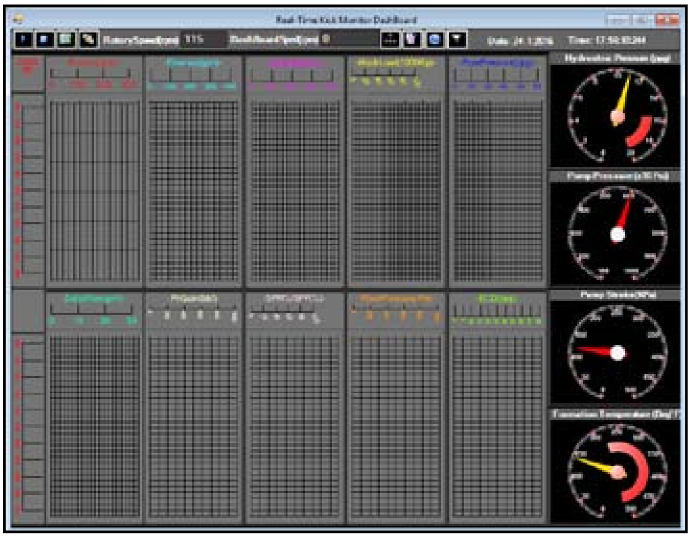

Fig. 2: The Tool Real-Time Kick Monitoring Board

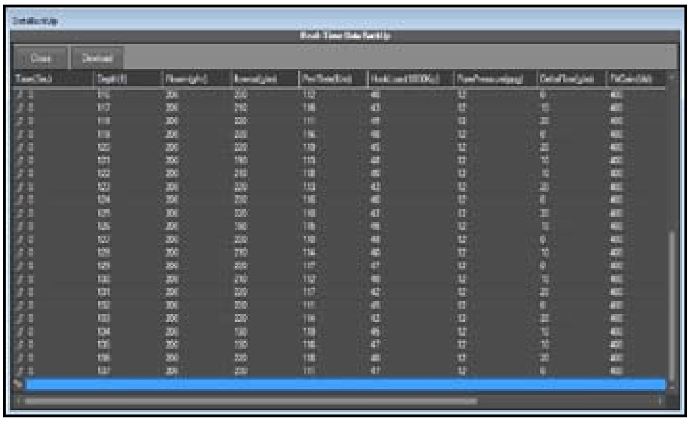

Fig. 3: Real-Time Data Base of Drilling Information

A. Kick Detection with the Tool

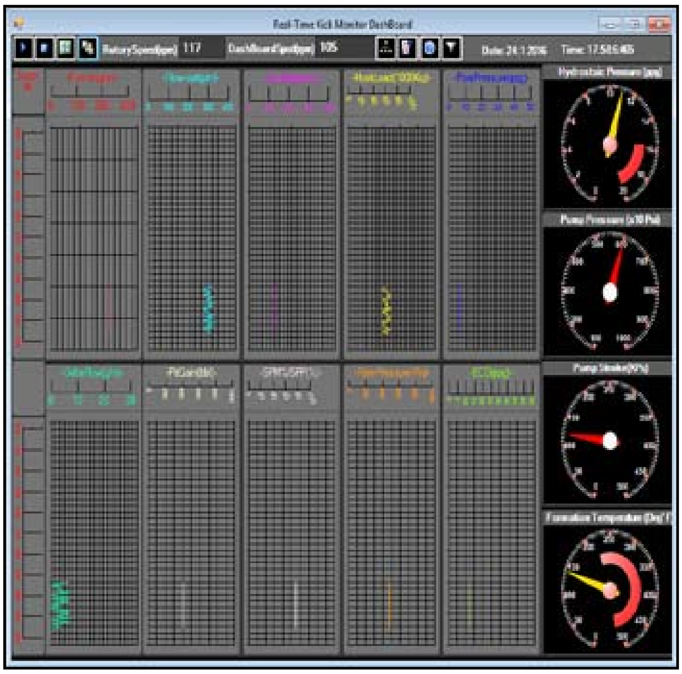

Fig. 4: Monitor for Real-Time Drilling Operation without a Kick

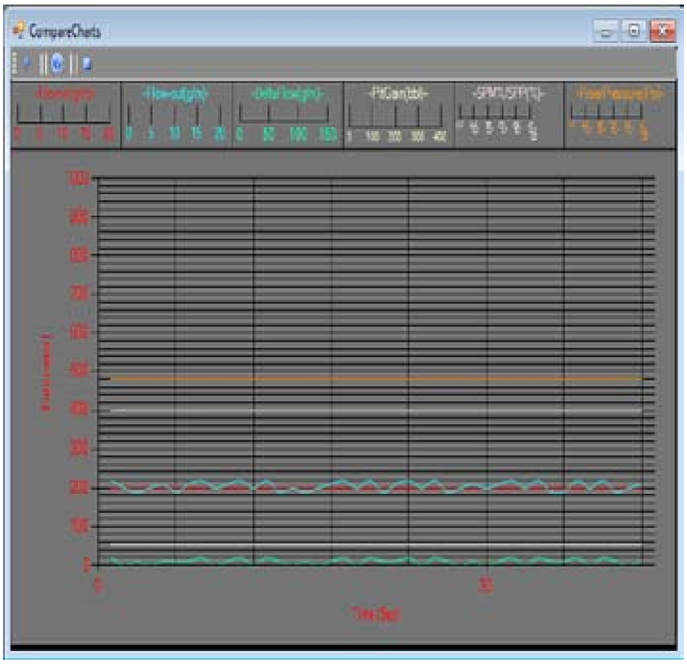

Fig. 5: Real-Time Finger Print Graph for Detecting a Kick

Figure 4 illustrates how real time drilling operation is being monitored using the tool, the Delta Flow, Pit Gain and Riser Pressure methods of kick detection are constant. The flow-in (Green Line) and Flow-Out (Blue Line) signatures are close to each other because no pit gain was recorded (Figure 5). Also the riser pressure maintained a straight because of the balance between mud and formation pressures.

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Fig. 6: Deviation in Formation Pressure

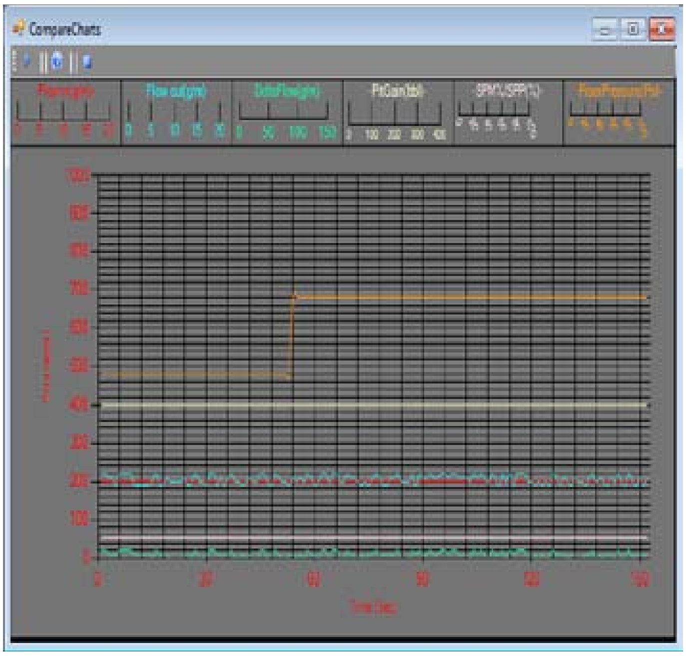

Fig. 7: Riser pressure Finger printing baseline recording for the Influx

In Figure 6, the Riser pressure method of Kick detection indicates an influx. Though the volume might not be enough to cause a kick, but other conventional methods were not able to indicate the same influx at real time. The influx baseline recording is shown in Figure 7. The tool gives a significant improvement in kick detection while drilling.

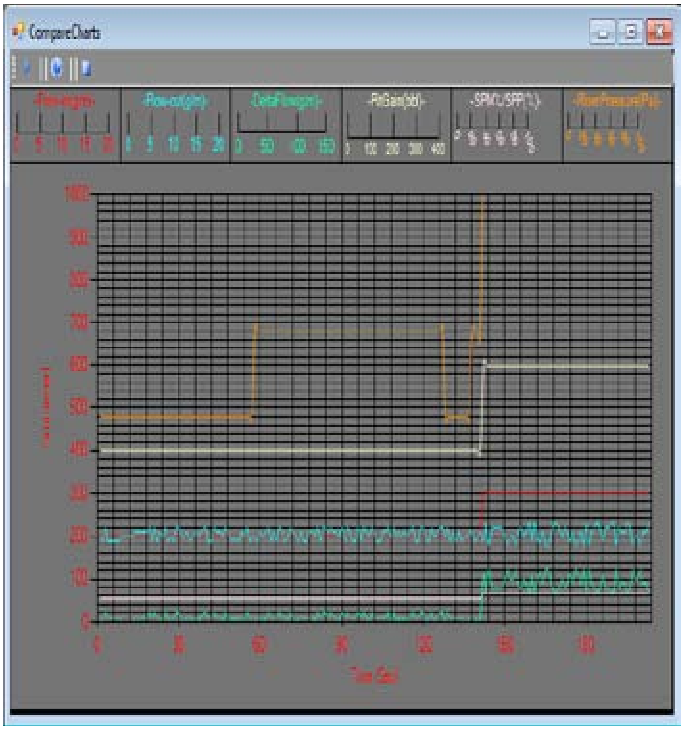

Fig. 8: Finger Print baseline record for a Kick

This composite display in figure 8 shows that in the well, an influx of formation fluid occurred during the drilling operation. It is also observed that, the riser pressure is a smarter alarm system to alert the driller of a possible influx of formation fluid.

B. Software Validation and Application using Niger Delta X-Offshore Field

Table 1: Well Data from Niger-Delta X-Offshore Field

Depth (m)	G_{OV} psi/ft	G_P psi/ft	G_{fr} psi/ft	MUD WT.
0	0.45	0.45	0.45	0.46
30	0.45	0.45	0.45	0.46
100	0.63	0.45	0.57	0.46
500	0.77	0.45	0.67	0.46
1243	0.91	0.45	0.77	0.50
1315	0.91	0.45	0.77	0.50
1360	0.92	0.45	0.78	0.50
1824	0.95	0.45	0.80	0.52
1874	0.96	0.45	0.81	0.59
2209	0.98	0.45	0.82	0.59
2415	0.99	0.47	0.83	0.59
3150	1.02	0.48	0.86	0.60
3210	1.03	0.50	0.87	0.60
3258	1.03	0.50	0.87	0.61
3356	1.04	0.52	0.88	0.61
3405	1.04	0.52	0.89	0.61
3474	1.04	0.52	0.89	0.77
3617	1.05	0.68	0.91	0.77

3656	1.05	0.68	0.91	0.77
3950	1.06	0.59	0.92	0.67
4083	1.06	0.73	0.93	0.67
4083	1.07	0.73	0.93	0.78
4100	1.07	0.73	0.93	0.79
4120	1.07	0.73	0.93	0.79

Table 2: Kick Computation using the Data from X-Offshore Field

PARAMETERS	VALUES
KICK	4750m
MW	1.55kg/l
SIDP	770psi
SICP	930psi
PP	687.04

Fig. 9: Real-Time Kick Simulation for X-Offshore Field

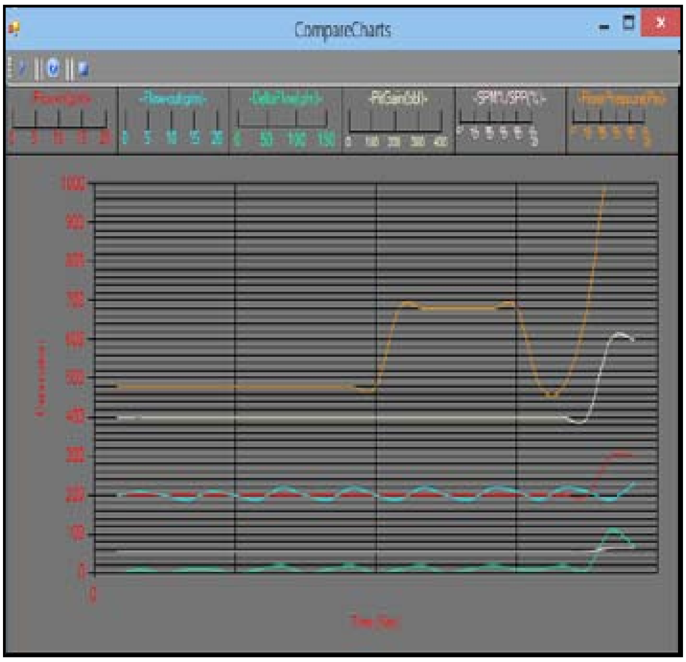

Fig. 10: Real-Time Finger print of Kick in X-Offshore Field

Using the data in Table 1, the depth at which kick occurred in the X-Offshore Field under consideration was computed (Table 2). The computations indicate that influx from the formation happened at 4750m.

From the X-Offshore Field drilling information, the real time monitoring system using the developed tool showed that the riser pressure indicated influx at approximately same depth as computed. This indication by riser pressure is two times faster than other current methods (Fig. 9). The finger print graph showed the influx and the time it took each method to indicate the influx. Thus, the riser pressure method proof to be more effective and faster in indicating influx from the formation during drilling operation (Fig. 10).

V. Conclusions

Through the years many tools have been developed to detect kicks in their early stages, when they can be handled more easily and safely. However, most of these tools are dependent upon the well being full of fluid with the liquid at the surface.

The implications of being able to detect kicks and losses far ahead of conventional methods are significant, from overall safety and reduced risk to equipment and personnel, to drastically improved ability of crews to manage and control an influx that has been minimized by early detection and early response. We can conclude that;

1. The drilling management tool developed in this study gave improved faster and accurate results more than the current kick detection methods.
2. The tool using riser pressure principle detects a level or form of influx not minding if the volume is sufficient to cause a kick.
3. The tool will help the driller make a sound judgement without much stress on which kick killing procedure to use when a kick is detected.

The operator gains a 'step change' in kick detection with this technology.

VI. Acknowledgement

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[5] *Hu Yin, Menghan Si and Haibiao Wang (2014): The Warning Model of the Early Kick Based on Bp Neural Network. Pakistan Journal of Statistics, Vol. 30(6), 1047-1056*

SOURCE CODE

```
Imports System.Timers
Imports System.DateTime
Imports System.IO
Imports System.Drawing
Imports System.Messaging
```

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```
Imports System.Math
Public Class FrmDashBoard

    Private Sub Timer1_Tick(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Timer1.Tick
        REM: First check if condition is met
        REM: REAL CODE STARTS HERE
    Me.Label1.Text = Val([Date].Now.Hour) & ":" & Val([Date].Now.Minute) & ":" & Val([Date].Now.Second) & ":" & Val([Date].Now.Millisecond)
        Dim PrAnn, Footage, TVD, MudWt, Q300, Q600, QN, Nrpm As Double
        Me.UlblTime.Text = "Time: " & Val([Date].Now.Hour) & ":" & Val([Date].Now.Minute) & ":" & Val([Date].Now.Second) & ":" & Val([Date].Now.Millisecond)
        Me.UlblDate.Text = "Date: " & Val([Date].Now.Day) & ":" & Val([Date].Now.Month) & ":" & Val([Date].Now.Year)

        'If Footage < TVD Then
        '   Me.Label1.Enabled = False
        '   Me.Label1.Hide()
        '   Me.Label1.Visible = False
        '   Timer1.Start()
    '   Me.CmdRunPuase.Image = My.Resources.DataContainer_MoveNextHS

        'ElseIf Footage >= TVD Then
        '   Me.Label1.Enabled = True
        '   Me.Label1.Show()
        '   Me.Label1.Visible = True
        '   Timer1.Stop()
        '   Me.CmdRunPuase.Image = My.Resources.PauseHS

        'End If

        PrAnn = Val(FrmInport.UtxtPrAnn.Text) : Footage = Val(FrmInport.UtxtHoleDepthStart.Text)
        MudWt = Val(FrmInport.UtxtMudDensity.Text) : Q300 = Val(FrmInport.UtxtQ300.Text)
    Q600 = Val(FrmInport.UtxtQ600.Text) : QN = Val(FrmInport.UtxtQN.Text)
    Nrpm = Val(FrmInport.UtxtNrpm.Text) : TVD = Val(FrmInport.UtxtTVD.Text)

        Dim Dh As Double = Val(FrmInport.UtxtHoleDiameter.Text)
        Dim Dp As Double = Val(FrmInport.UtxtPipeID.Text)
        Dim POD As Double = Val(FrmInport.UtxtPipeOD.Text)
            Dim PipeMiniYeild As Double = Val(FrmInport.UtxtPipeYieldStrength.Text)
      Dim PipeGrade As Double = Val(FrmInport.UtxtPipeGrade.Text)

        REM: Declaring Variables
        Dim NoOfNozzle As Integer
        Dim MudDens, FlowRate, PumpPressure, Nozzlediameter, NozzleArea As Double
    Dim PipeMinimumYieldStrength, PipeOD, PipeID As Double
REM: RotaryTorque
        MudDens = Val(FrmInport.UtxtMudDensity.Text)
        FlowRate = Val(FrmInport.UtxtPumpFlowRate.Text)
        PumpPressure = Val(FrmInport.UtxtPumpPressure.Text)
        NoOfNozzle = Val(FrmInport.UtxtNoOfBitNozzles.Text)
            PipeMinimumYieldStrength = Val(FrmInport.UtxtPipeYieldStrength.Text)
        REM: PipeFreeLenth = TVD and declared in for-next loop below
        PipeOD = Val(FrmInport.UtxtPipeOD.Text)
        PipeID = Val(FrmInport.UtxtPipeID.Text)


        REM: THESE ARE THE MODIFIED LINES OF CODES THAT ARE CORRENTLY BEING USED FOR THE REAL TIME PROCESS
        Me.DataGridView1.Rows(0).Cells(0).Value = 0
        'Me.DataGridView1.Rows(0).Cells(1).Value = 0
        Me.DataGridView1.Rows(0).Cells(1).Value = Footage

        REM: GENERATING RANDOM NUMBER
        Dim generator As New Random

        'Dim sec As Integer
          For j As Integer = 1 To Val(Me.DataGridView1.Rows.Count) - 1
            'sec = (Me.DataGridView1.Rows(j - 1).Cells(1).Value) + 1
            Footage = Footage + 1
        Next
        Me.DataGridView1.Rows.Add(1)
```