# DYNAMIC DRILLING DISPLAYS

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ABSTRACT

Gas and oilwell drilling is a hazardous business which relies on human vigilance to detect a sudden influx of gas from the formation into the well bore, and human control activity to manage the migration of this gas bubble to the surface. The result of human error in either case can result in a blowout which can cause considerable damage to people, equipment and the environment.

Human performance in such situations is limited by the harsh physical environment, variable levels of training and variable standards of instrumentation. Recently, computer displays have been introduced to present information in a more appropriate form for aiding human performance. The design of these displays appears to have had very little human factors input.

This paper describes some of the ways in which computers displays can be used to reduce the probability of human error and enhance human performance in gas and oilwell drilling.

## Introduction

Human error and human efficiency are critical issues in oil and gas well drilling. The implications of an accident due to human error may be catastrophic in terms of injury to personnel, damage to equipment, lost production time and cost of restoring the system to its original level of function. Engineering and administrative controls have been developed over the years to reduce the likelihood of such occurrences and to minimize the consequences. However, the weak link in the system will always be the human being acting inappropriately in his role as a designer, maintainer, trouble shooter, monitor, operator, user, etc.

The implications of human decisions in terms of productivity are equally important. The decisions to change a bit, drilling rate, mud characteristics, maintenance operations, etc., can all have effects on the efficiency, and therefore, cost of the operation.

## The Drilling Process

In the drilling process, a hardened bit which is able to cut into geological formations is attached to the bottom of an extendable series of piping. A motor is used to rotate the bit and drive the piping into the drilling hole. A viscous fluid called drilling mud is used to lubricate the pipe and bit as they travel down the hole. The mud circulates downward through the inside of the drill pipe and comes back up through the annulus between the drillpipe and the drilling hole. At various points in the drilling process, the hole is encased in cement to ensure the stability of the hole and that the proper direction of drilling is maintained.

Care must be taken to ensure that the pressure inside the drilling hole is always greater than that of the surrounding fluid in the formation. The density of the drilling mud is an important factor in controlling this pressure. For a variety of reasons, formation fluid may occasionally seep into the drilling mud. If the formation fluid is gas or some other fluid less dense than the drilling mud, the drilling mud could be forced out of the hole at a high velocity. The influx of formation fluid into the drilling mud is known as a "kick", and is an indicator of a potential oil-well blowout. A blowout is defined to be the "uncontrolled flow of formation fluids or gas from a wellbore into the atmosphere or into low pressure subsurface zones" (Sheffield, 1981). Clearly, a blowout can be catastrophic, resulting in huge losses and grave physical risk. The monitoring and control of blowout indicating kicks comprise the tasks to be studied in this research.

## Instrumentation

The development of drilling instrumentation and displays has been based on the demand for a particular function by drilling site personnel. Sometimes this "demand" is encouraged by equipment manufacturers in order to increase the sales of their products which may not always be of critical importance to the operation. Equipment manufacturers and drilling site personnel also follow fashion in their designs and demands for new products. The current pressure for discrete digital presentation of information is one such fashion. Although the precision and resolution afforded by digital information has its place, accuracy and efficiency are not guaranteed in all situations. Conversely, the recent trend towards computer graphics may not always provide the best solution to a display problem.

Appropriate display design requires a close analysis, not only of the function of a particular instrument, but also of the way in which it is likely to be used by users with varying abilities, experiences and habits. Roughnecks do not always have the finesse of airline pilots whose requirements have been very influential in the evaluation of display design principles.

It should be remembered, however, that the characteristics and training of the users of future information systems may be very different from those of the current incumbents. The drilling control centers of the future will be manned by people whose experience and training will be a mixture of exposure to the practicalities of the drilling site and the knowledge of the classroom.

## Related Display Design Literature

Conventional analog and digital displays have been shown to be inadequate for the presentation of trend oriented or time dependent information as is commonly found in process control settings. (McCormick, 1980; Geiser, 1980; Tullis, 1981). Tullis (op cit) showed that the accuracy of subjects responses did not vary significantly with display format. However, response times differed between formats with the best mean response time obtained using the color graphics display, followed by the black and white graphics and the alphanumeric displays. The subjects showed a clear preference for the color displays. Another observation was that graphical presentation is particularly useful for unpracticed users, and may be especially effective for training.

Shutz (1961, a) compared line type graphs with vertical and horizontal bar graphs. The results showed that the subjects performed better with and favored the line type graphs. A second study by Shutz (1961, b) compared multiple lines on a single graph with the use of multiple graphs, each with a single line. Point reading and line comparison tasks were employed. Display format appeared to have no effect on performance accuracy however performance time deteriorated on the point reading task with an increasing number of lines when using the multiple line format. This did not occur with the multiple graph format. There was a clear superiority of multiple lines over multiple graphs in the comparison tasks.

Pennial (1980) suggests that computer graphics displays can replace the conventional chart recorder in the process control room. He indicates that research in this area will usually be applications oriented rather than theoretically motivated.

## Evaluation of Drilling Displays

A survey of currently used drilling instrumentation indicated a wide variety of instruments with no objective means of comparison. Consequently research has been started on the design of a versatile simulator that can be used to evaluate alternative display formats as well as fulfill conventional training and operator evaluation functions.

The procedure has been to develop a set of generic display types using a Tektronix (4054) high resolution graphics system. These generic display types can be selected, scaled and labelled to represent specific functions.

One such function was the display of pressure variables to simulate the changes associated with the influx of gas into the well bore during a drilling operation. The purpose of the experiment was to compare four display formats with regard to their use in the detection and subsequent control of a gas kick. The formats that were tested were

a. Digital

b. Conventional analog gauges

c. Horizontal line graphs

d. Vertical line graphs

It was hypothesised that the subjects would show shorter response and control times on the line graphs than on the other display forms.

## Methods

The subject monitored a CRT screen until a deviation away from the "normal" condition was perceived. This corresponded to a kick in the drilling process. The subject then controlled the position of a choke through the use of two keys on the computer keyboard, one key to open the choke, the other to close it. The subject's task was to return the displayed pressures back to the "normal" level and bring the kick under control.

Each of the four displays contained information concerning pump stroke rate and mud weight, and uses a semicircular gauge to represent choke position. The display of drillpipe and casing pressures differed for each format.

An indication of the target pressure was included in each display. For the digital display, numerical values of the pressures were shown and the target pressure is also represented numerically. The analog display included two gauges and a marker on the dial of each gauge for the target pressures. The line graph displays used the multiple line feature investigated by Schutz, and two different line styles to ensure that the pressure indicators are discriminable. Additional lines, paralleling the time axis for each of the line type displays, were used to show the target pressures.

The dependent variables were response time and control time. Response time was defined as the time required for the subject to detect the deviation from normal drilling conditions. This time was measured by the real time clock module of the computer system and recorded in a data file. Control time was defined as the time it took the subject to bring the process back to the normal conditions. It was measured as the time from the initial deviation to the point at which the process had been stabilized within specified upper and lower limits. Measurement of control time was also accomplished via the computer's real time clock.

The major control variables for this experiment included viewing distance, ambient lighting levels, and brightness of the computer display. Other factors which were held fixed are room temperature, noise level, and access to the laboratory.

## Results

The use of the SAS General Linear Model Procedure indicated a significant display effect for Response Time ($P < 0.01$) and for Control Time ($P < 0.002$). As would have been expected there were significant subject effects but no significant learning (trial) effects. The error mean squares for response time was 6.58 and that for control time was 959.22. The details of the mean performance times are given in Table 1. For response times it is seen that the guages and horizontal line graph were associated with shorter times than the other two display formats. For control times, however, it can be seen that the digital format was worse than the other forms which were not different from each other.

## Discussion

### Experimental Results

The inference from these experimental results is that analog or graphical means may be better ways of communicating deviations from normal conditions in a process control situation. Furthermore these media are also better than digital displays in the control of a process once a problem has been recognized. However a surprising negative result of this experiment was that the use of a memory aided display-time history was presented on the line graphs-showed no advantage over the conventional analog guages which only convey current status and control limits.

### Drilling Displays

The driller's routine task is to monitor, periodically or continuously, the state of the process by observation of the various displays of process variables. Following these observations he makes well defined and preplanned decisions to implement control actions. If his displays indicate that the bit isn't on the bottom of the hole, then he drops it accordingly. In general such decisions are not hurried. Or, if there is some time pressure as in the tripping operation, the driller is usually capable of handling the information, decision and control action in a smooth manner.

A point to note here is that it is common for the driller to use information that is not conveyed by the formal displays. For example, the first sign of a problem with the circulation system may be a change in the sound of the mud pump; direct observation of the return mud characteristics is another common source. The importance of such "informal" information sources should not be overlooked.

A second monitoring function requires the driller to detect process changes that are beyond the normal or safe range. This function requires that his attention be attracted to the appropriate information source, that he can then detect the relevant information and that some indication of appropriate action is provided. Such monitoring activity is commonly aided by audible and/or visual annunciation in addition to the usual process displays. This

TABLE 1: Summary of Experimental Results in Seconds

| Display Format | Response Times | | | Control Times | | |
|---|---|---|---|---|---|---|
| | N | $\bar{x}$ | SD | N | $\bar{x}$ | SD |
| Digital | 21 | 5.24 | 1.45 | 31 | 114.71 | 42.17 |
| Guages | 31 | 4.29 | 1.19 | 32 | 89.44 | 39.18 |
| Horizontal Graph | 29 | 4.69 | 1.37 | 31 | 87.77 | 29.03 |
| Vertical Graph | 28 | 5.1 | 2.01 | 30 | 93.33 | 36.20 |

annunciation is based on prescribed control limits which are not always pertinent to particular process stages. Consequently annunciation may be too frequent and not always informative, or may be turned off!

Another characteristic of the driller's activities is that he monitors many process parameters related to the hoisting, rotating, circulation and pipe joining systems. He therefore may have a variety of indications that something is wrong and his diagnosis may be based on associations of a number of indications. In computer based systems some of this analgamation is performed automatically to create indices such as the "D" exponent.

Given this level of complexity in the drilling task the human factors design problem is to create displays to aid the drillers. It is likely that fashion will lead to the adoption of computer graphic displays but such displays will require thorough investigation along the lines described in the experiment. Further research topics will include the use of the computer to perform action prompting functions and as a parallel simulator to resolve 'what if' questions.

Another problem of display design is related to the fact that once a gas kick has been detected the driller may be under considerable time and safety stress. Furthermore the drastic decision to radically block off the hole may be very costly. The physical environment may also be harsh. Hence the driller, or more commonly his supervisor, the tool pusher, may be faced with a delicate control problem under many sources of stress. Thus the displays that find their way on to the drilling sites will be used under conditions that cannot be adequately simulated in the laboratory.

To resolve this problem the display design simulator will be developed to provide facilities that impose time and informational stress along with motivation through performance feedback and competition. These approaches have had clear success in the video game arena.

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