

Eliminating Human Error During Coiled-Tubing Operations

A study of coiled-tubing (CT) pipe-failure causes over a 5-year period indicates that a substantial percentage of incidents can be attributed to human error. The full-length paper presents an effective means to reduce human error in CT failure. Incorporating a specialized system into the CT-unit (CTU) controls provides a shutdown feature when specific job set-points are exceeded. The full-length paper discusses the features and capabilities of such a system and cites details of recent experiences demonstrating the benefits of the device in actual CT interventions.

Introduction

During the last decade, the oil and gas industry has witnessed continued technology innovation in conjunction with CT use. Primary drivers for these innovations include tougher wellbore conditions and more-complex intervention objectives. The effect of operating failures (OFs) during execution of these high-technology CT interventions becomes more critical. These OFs can be the direct result of equipment failure, procedural inadequacy, product incompatibility, failure in the service organization, and human error. Seldom can the root cause be attributed to a single factor, and often it is a combination of these factors. Overall systems improvement and better service quality can be achieved only through investigation of all failures associated with CT well interventions.

CT-string failures continue to be a recurring issue whenever the subject of

OFs is discussed. A study of operating data found human error to be a common cause, although there are other contributing factors. To mitigate the human error element, a specialized control system (CS) has been incorporated into CTUs. Statistics gathered over a 5-year period, from 2001 to 2005, are presented to determine if this CS has been effective in reducing the number of OFs attributed to human error.

CT-String Failures

Use by a major service company of a service-quality statistical database to identify problem areas was the subject of an industry paper in 2001. OF severity was determined by nonproductive time (NPT) and financial loss and is categorized as follows where NPT is total client and service-provider downtime and loss is total client and service-provider losses.

- Catastrophic operational failure (COF), where NPT is greater than 48 hours and/or loss is greater than U.S. \$1,000,000.
- Major operational failure, where NPT is greater than 12 hours and less than 48 hours and/or loss is between U.S. \$100,000 and \$1,000,000.
- Serious operational failure, where NPT is greater than 4 hours and less than 12 hours and/or loss is between U.S. \$10,000 and \$100,000.
- Light operational failure, where NPT is less than 4 hours and/or loss is less than U.S. \$10,000.

CT-string OFs from global CT operations from 2001 to 2005 show that only 7% of CT string failures are COFs, and nearly one in three of all COFs is related to a CT-string failure. Almost one-third of the COFs are attributable to human error. By addressing human error, significant service-quality improvement can be realized by minimizing losses and reducing NPT.

Modified CS

A system to moderate OF severity in CT strings involving the CT operator consists

of a CS retrofit in existing CT units that allows automatic tripping of the string. The system monitors hanging weight and CT speed to prevent overpull and kinking incidents. The system enables automated control of CT-string running speeds and loads. Practical applications include prevention of overpull when tripping out and of kinking caused by downhole obstruction while tripping in. In addition, pre-programmed slowdowns or stops (in both directions) can be set for as many as 40 critical points. The system also includes an emergency stop.

The CS operates in a way similar to cruise control in an automobile. The operator positions all CTU controls as normal, and then sets the desired speed, slowdown points, weight limits, depth limits, and target depth. When switched into auto mode, a computer controls the injector directional-control valve and injector motor-system pressure valve. These valves actuate the hydraulic system that runs the CT string in or out of the well while the computer continuously monitors the CT-string weight, depth, and speed. If string weight exceeds preset limits, the injector is stopped automatically and an alarm is triggered. This occurs if the CT string or tool string tags a downhole obstruction while tripping in or pulls against the stripper when tripping out. Because the computer also monitors the rate of change in CT-string weight and speed, system response is precise with minimal lag time.

At any time, the operator can take over CTU control by actuating the auto/manual switch. The operator also can control the injector manually while the CS is actuated. In this case, the CS also monitors CT weight and stops the injector if any preset string weight limit is exceeded.

An additional feature that facilitates more-efficient CT-string running is the depth-triggered slowdown function. From critical depth information entered (e.g., from the completion schematic),

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For a limited time, the full-length paper is available free to SPE members at www.spe.org/jpt. The paper has not been peer reviewed.

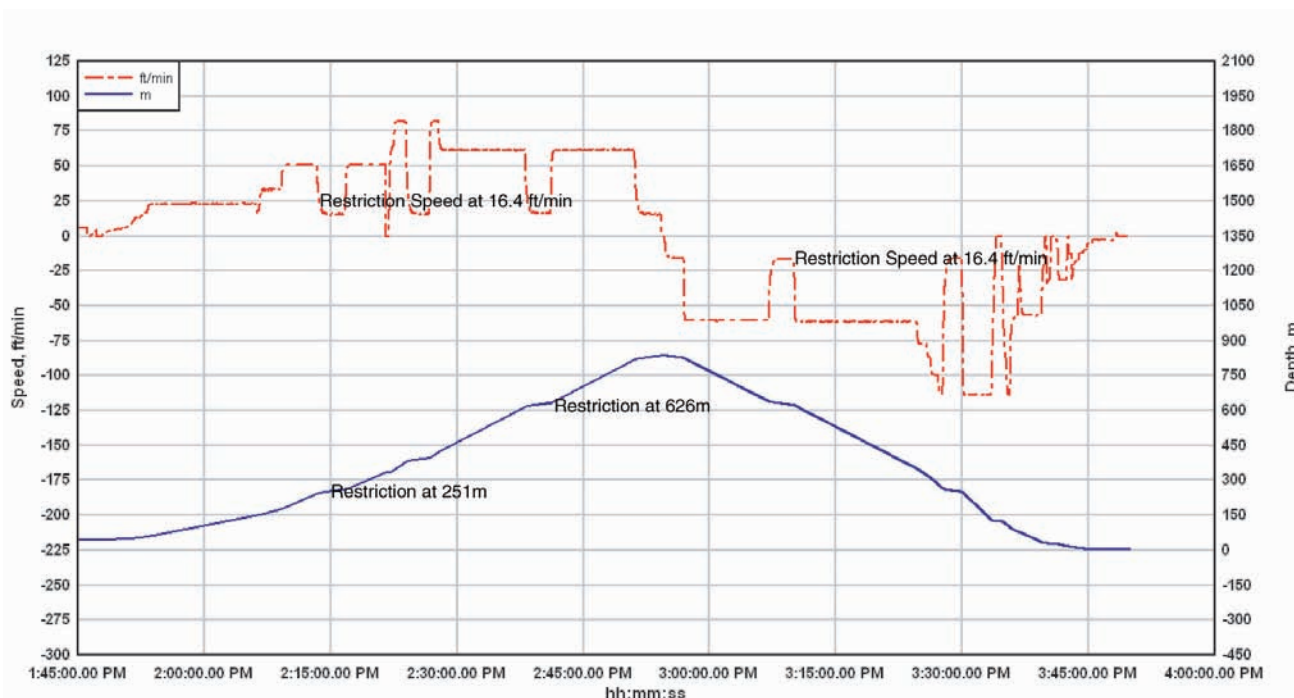


Fig. 1—CT speed during a small acid job.

the CS automatically slows CT speed when approaching a hazardous location. Similarly, automated pull tests when tripping in are another feature provided by the system that can be used to verify job design or modeling parameters with actual measured data.

Job Histories

Case History 1. The first case history is a small acid job with foam diversion performed in northern Canada. The well was 1087 m with a 27/8-in. completion that included several restrictions with different inside diameters. A 1½-in. CT string was used to place the treatment. To facilitate tripping, the completion restrictions were entered into the CS to allow automatic slowdown at the restriction locations. The plot of CT speed and depth vs. time in **Fig. 1** shows speed slowing to 16.4 ft/min as the bottomhole assembly passed by restrictions during tripping in and tripping out of the well. The programmed restriction depths were at 250 and 625 m. The system was set to moderate the running speed for 10 m above and below the restriction depth.

Case History 2. The second case history, a fill-removal job in the Sahara, demon-

strates the weight-trip feature of the system. The 3300-m-vertical-depth well was completed with 4½-in. tubing. The top of the fill was unknown before running the CT. The weight-trip functionality of the CS was set for a 7,000-lbf maximum slackoff weight at surface of during tripping in. The fill was tagged at 2900 m, with the system shutdown occurring at 6,970-lbf weight. The interval then was cleaned as normal. Once breakthrough occurred, the maximum slackoff weight at surface was readjusted to account for the additional CT-string weight. A second bridge was tagged at 3090 m. Again, the system override prevented excessive slackoff weight. The second bridge was cleaned with the CT reaching a depth of 3260 m. Three cleanout sweeps at bottom were performed before tripping out of the well.

Measuring CS Effectiveness

Nearly 2 years have passed since initial system deployment, a sufficient time period to evaluate the effect of the system. OFs in CT strings have not been eliminated completely because several failure mechanisms related to downhole and surface events that are direct causes of pipe failures cannot be addressed by simply modifying the injector CS. These include

mechanical damage resulting from poor pipe handling and the effects of downhole or storage corrosion.

Performance indicators available from a comprehensive CT failure-analysis program were used in the evaluation. Initiated in 1995, the program includes analysis of more than 690 CT-string failures. The objective of the analysis was to determine if a failure was related to one of the following three main categories.

- Material or manufacturing-process-related defects.
- Service deterioration.
- External mechanical forces.

For statistical tracking and trend monitoring, these three main categories were subdivided into nine failure mechanisms and eight failure causes.

Failure mechanism was defined as the main cause of the final failure or breakdown that rendered the CT string unserviceable. Failure mechanisms were categorized as tensile overload, buckling, rupture, collapse, fatigue, material loss, distortion, mechanical damage, and other.

The cause of failure was defined as the initial condition that triggered the CT string to eventually fail. The failure causes used in the system were overload, mechanical damage, fatigue, pitting corrosion,

general corrosion, manufacturing/processing, unknown, and other.

Other Factors. The 5-year trend of CT-string failures attributable to overloading is definitely positive. There was a marked reduction in CT-failure occurrences with overloading as an initial cause, from approximately 1.2 failures per 1,000 jobs in 2001 and 2002 to an improved rate of approximately 0.2 failures per 1,000 jobs in 2005. However, it would be inappropriate to attribute the improvement solely to introduction of the modified injector CS. Within the same time frame, the service provider adopted several corporate initiatives to address OFs in general. Key among these initiatives was senior management participation in the mandatory review of all catastrophic, major, and serious OFs. This alone has resulted in a heightened awareness among operating personnel of the negative visibility of human-error-related OF.

Another contributing factor was a companywide campaign for accountability. In 2004, a personal-accountability initiative was launched to provide a structured framework for improving behaviors in companywide operations. This also has resulted in improved quality and health, safety, and environmental performance. A key element of the initiative was establishment of fair and clear definitions for accountability in meeting operational expectations.

Nonetheless, it is clear that the introduction of the modified injector CS played a vital role in the overall result. The fact that the two CT COFs in 2005 attributed to personnel action (or lack thereof) occurred on CTUs not yet featuring the CS is a testament to this contribution.

Conclusions

1. The modified injector CS can be used effectively in everyday CT operations.
2. Indicators from a comprehensive CT failure-analysis program can be used to monitor the effect of service-quality improvement initiatives involving CT-string failures.
3. Accountability and management visibility are key elements influencing personnel behavior.
4. The modified injector CS in conjunction with personnel-behavior change has resulted in a significant reduction in CT-string failures caused by CT-string overloading during a 5-year period. **JPT**

Resources