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Safe Coiled-Tubing Operations

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ABSTRACT

Safe coiled tubing operations require quality control of the coiled tubing, wellsite safety standards for coiled tubing operations, and the safe deployment of long tool strings in and out of the well. The quality of coiled tubing is monitored by a patent pending real-time inspection device, fatigue cycle tracking, data acquisition of critical job parameters, and inputting all the coiled tubing history data into a model to get predicted coiled tubing life. Coiled tubing operational safety standards detail coiled tubing issues with emergency contingency procedures and the use of a downhole force model to predict the force when running coiled tubing in deviated wells. The safe deployment of long tool strings, both fluid and electrical, requires special procedures and equipment to get in and out of the well. The operational methods and standards provide improved safety during coiled tubing operations at the wellsite, whether onshore or offshore.

INTRODUCTION

Coiled tubing (CT) has been used since the 1960s for pumping operations such as nitrogen kickoffs, sand cleanouts and matrix acidizing. During the early development, CT suffered a poor service quality image due to tubing failures at the wellsite. In the mid 1980s, there was a dramatic improvement in the quality of the CT with the availability of improved materials and the manufacturing processes (fewer butt welds). In recent years, the understanding and monitoring of CT has increased significantly,[1] to the point that CT has become a very reliable means of well workover.

As the reliability of CT increased, new CT applications have developed which are more demanding on CT than the simple pumping operations mentioned above.[2] Instead of being considered as a simple pipe for conveying of fluids, CT applications now take advantage of the CT mechanical strength. New applications include running longer tool strings, having wireline inside to power and transmit data from downhole tools, perforating and conveying various tools strings into a highly deviated holes.

This paper details recently developed systems which ensure safe coiled tubing operations. CT quality control, CT safety standards and safe deployment techniques are discussed.

References and illustrations at end of paper.

Quality in Coiled Tubing

It is well understood in the industry that CT has a limited life. The working life of CT is governed by the loads and resulting stresses to which it is subjected. The industry standard unit of measure for CT life, since the introduction of CT, has been "running feet." This old "running feet" measurement was not adequate because it was not indicative of the damage accumulating in specific sections along the length of the CT.

During the past few years, full-scale fatigue tests, using actual well service equipment, were conducted while monitoring the multiaxial strains. These tests indicated that the life of CT is more dependant upon the surface parameters[1]. The primary damage is caused by repeated bending of the CT at the gooseneck and reel, with internal pressure in the CT. This damage mechanism is called "low cycle fatigue."

A new pressure/fatigue cycle tracking measurement has been developed to replace the "running feet" measurement. The pressure/ fatigue cycle tracking provides the information necessary to calculate the actual low cycle fatigue damage accumulation along the length of CT.

The following observations were made.

- Fatigue damage due to combined pressure and bending cycles is the primary consideration in CT life modelling.
- The life of the CT increases with a thicker CT wall.
- The life of CT increases with larger radius goosenecks and reels.
- The life of CT decreases as the CT diameter increases (see Fig. 1).
- Initial cracking starts on the inside surface of the CT.
- The sequence of pressure and bending cycles must be considered to determine CT life.
- Fatigue modelling alone is not sufficient to prevent CT failures. Real-time geometry monitoring of CT is required to locate mechanical damage, necking and/or ballooning of the CT material.
- There is some static fatigue damage done to CT by pressure cycles alone. This damage is insignificant compared to the damage caused by combined pressure and bending cycles.
- CT cycling at butt welds should be avoided (see Fig. 2).
- The outside CT diameter grows; the tubing wall thins; and CT life decreases when the tubing is cycled at high pressure.

The knowledge gained from these fatigue tests has enabled the development of the CT quality accessment and control system. This system includes the following:

- A data acquisition system to monitor and record critical job parameters, produce post job plots and prints for permanent record of the operation and input the CT model.
- A computerized fatigue-cycle tracking system that is used to maintain a record of the work that each element of the reel has performed.
- A real-time inspection device of the CT geometry that correlates the diametrical behavior to the fatigue life and continuously inspects (see Fig. 3) the CT for mechanical damage, such as dents and ovality changes.[3]
- Inputting the CT history data (items above) into a CT model to obtain a plot of CT life along sections of the CT. (When a job is being planned, the

proposed pumping schedule can be used in the CT model to predict changes in CT life during the job.)

- Maintaining a CT life file for each reel of CT

This CT quality control system forms a package with the objective of minimizing the possibility of a wellsite tubing failure.

Job Design and Evaluation

Safe CT operations can only be assured when there are careful considerations given to safety in the pre-job design. After the job, the job design should be evaluated based on the actual job results. This will improve the job design process. The following are critical steps in the prejob design process which help to ensure a safe operation.

- A job procedure must be prepared, especially for complex jobs involving several operations.

- The pressure/fatigue cycle damage that will occur during the job should be calculated by simulating the job based on job procedure. This will ensure that the CT will not reach the end of it's life before the job is complete.

- The job should be simulated using a tubing forces calculation model.[4] The purpose of this simulation is to ensure that the CT will not be stressed beyond it's limits during the job.

During the job evaluation process, the actual weight indicator measurements should be compared to the predictions from the tubing forces calculations, to validate the model's design calculations.

Safety Standards for Coiled Tubing

Each CT service company should have a set of safety standards for CT operations. The following is a partial list of items which should be considered.

- Responsibility - covers the authority and responsibility of personnel on location

- Job review - a pre-job safety meeting is defined which the CT operation guidelines and limits are discussed

- Personal protective equipment

- Safe crane operations

- Spotting equipment for land and offshore operations

- Equipment rig up for land operations and offshore operations

- Safe vehicle transportation

- Pressure testing procedures for CT and BOP

- Pumping and flowing through CT

- Emergency BOP operations

- Emergency contingency procedures

Safe Deployment

It is not unusual for a string of logging tools, perforating tools and/or selective treatment tools to be over 30 ft in length.[5] These tools are usually deployed into a well by placing them inside a lubricator on top of the wellhead. If the conventional deployment method were used for coiled tubing logging and/or selective treatment tools, the CT injector would need to be placed on top of the lubricator as shown in Fig. 4. The CT injector weighs over 7000 lb. Holding it steady at this height for a job is logistically difficult and a considerable safety hazard for the following reasons:

- A large crane is needed to hold the injector.

- The injector cannot easily be seen from the control cabin. If a problem occurs with the CT or with the injector, it may not be noticed. Any repair or service to the injector or stripper would require working at that height.

To avoid placing the injector at an unsafe height; a patented method[6] referred to as "deployment" was developed. It uses a deployment bar that is placed on top of the logging tool or selective treatment tool string. The deployment bar has a reduced diameter section that is the same outside diameter as the coiled tubing. Figure 5 shows the sequence of events to deploy the tools into the well. This is outlined below:

1. The tools are lowered into the well using the wireline lubricator method until the deployment bar is across the CT BOP rams.

2. The pipe rams and slips are closed around the deployment bar, holding it from moving up or down, and sealing off the wellhead pressure.

3. The wireline lubricator and connector are removed, leaving the end of the deployment bar accessible. If a selective treatment tool is being run, then tandem kelly ball valves in the tool string (just above the deployment bar) need to be closed prior to removing the connector.

4. The injector, with a short riser and a wireline or fluid connector made up to the CT, is picked up over the wellhead. The wireline or fluid connector is made up to the deployment bar. If a selective treatment tool is run, then the tandem kelly valve will need to be opened after making up the connector.

5. The injector is then lowered until the short riser is made up.

6. Once pressure testing is complete, the rams are opened and the tool string is ready to run in the hole.

The benefits to the deployment system is that the injector head is put at a workable, safe height and the unsupported length of CT from the reel to the injector is shortened. The deployment system may also be pressure tested at every step before proceeding with the next step.

CONCLUSIONS

Safe coiled tubing operations should meet these requirements:

- Pre-job design calculations to ensure there will be no tubing problems during the job.
- The critical job parameters monitoring and recording system
- A pressure/fatigue cycle tracking database
- A CT life prediction model which calculates the fatigue damage along the length of the CT
- A downhole forces model to determine the stresses in the CT
- A real-time inspection device to check the CT for mechanical damage
- If long tool strings are being run, a method of deploying the tools must be used which keeps the injector head at a reasonable height

ACKNOWLEDGMENTS

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REFERENCES

1. Newman, K., Newburn, D.: "Coiled Tubing Life Modeling," SPE paper 22820, SPE Fall meeting 1991.

2. Ackert, D, Beardsal, M., Corrigan, M. and Newman, K.: "The Coiled Tubing Revolution," *Schlumberger Oilfield Review*, October 1989

3. Anom, "New System Measures Coiled Tubing String Working Life" Technology at Work, Ocean Industry, February 1991.

4. Newman, K., Corrigan, M.: "Safely Exceeding the Critical Buckling Load in Highly Deviated Holes," SPE paper 19229, Offshore Europe, 1989.

5. Newman, K., Corrigan, M., Kehoe, G., Douglas, A., Torre, A.: "Assisted Lift Production Logging with Coiled Tubing," Offshore Southeast Asia paper 90142, 1990.

6. Newman, K.R.: "Deployment/Retrieval Method and Apparatus for Well Tools used with Coiled Tubing" U.S. Patent No. 4,940,095 (July 10,1990).

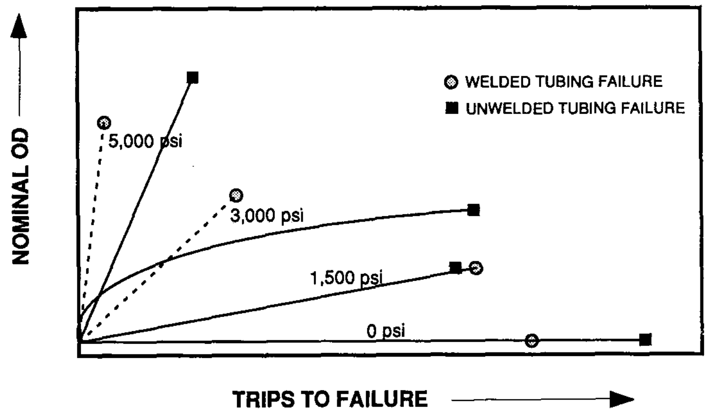

Fig. 1—Coiled tubing OD vs trips to failure.

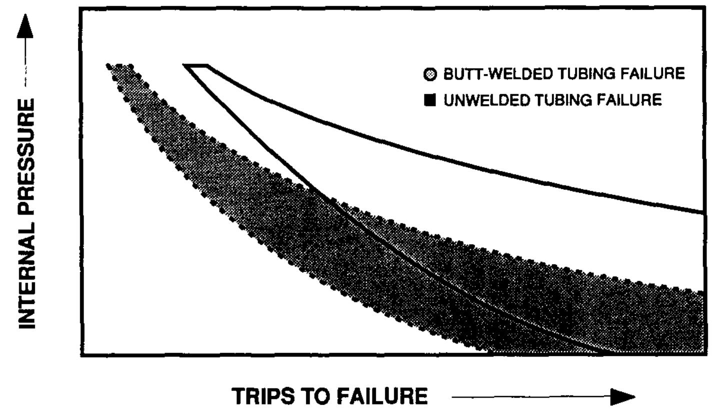

Fig. 2—Internal pressure vs trips to failure.

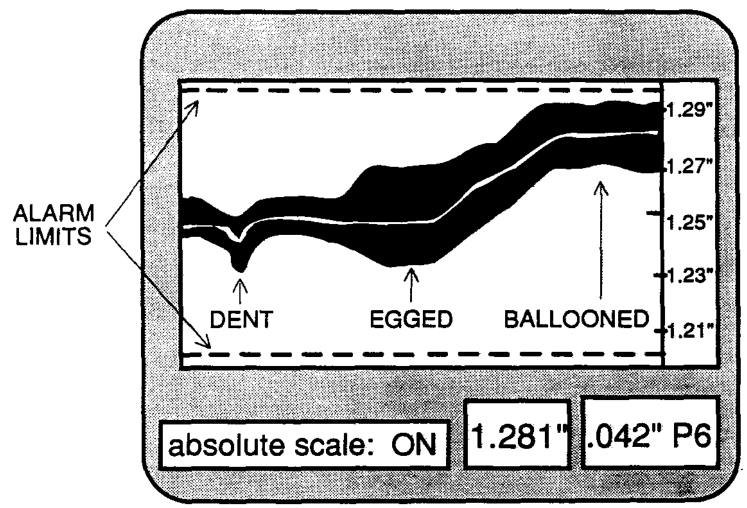

Fig. 3—Tubing integrity monitor screen.

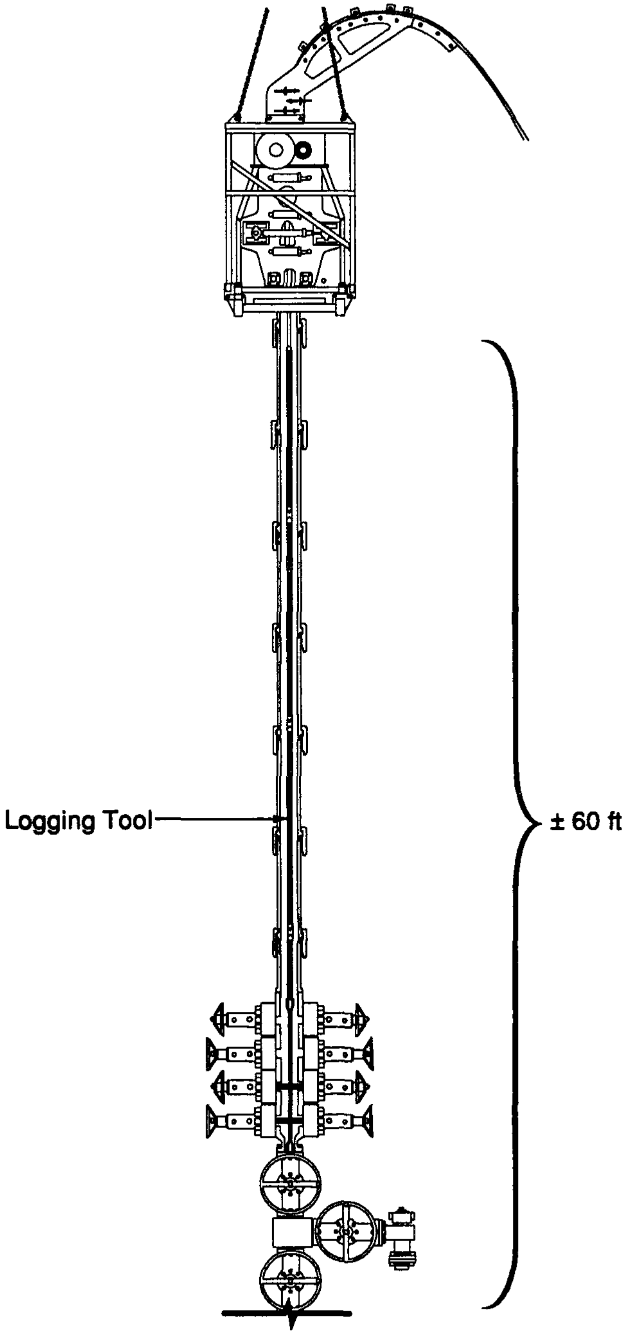

Fig. 4—Conventional depolyment schematic.

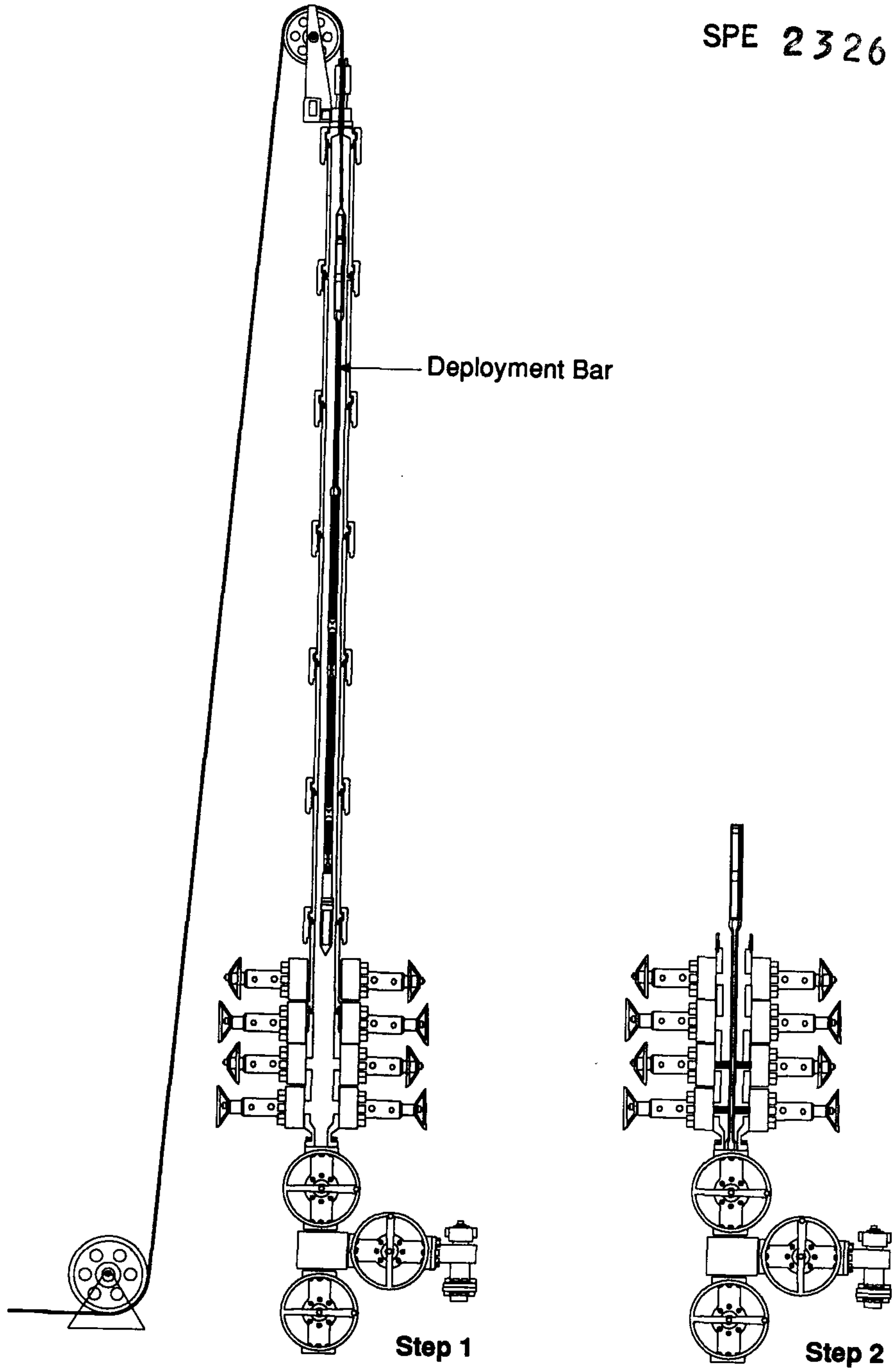

Fig. 5.1—Deployment schematic.

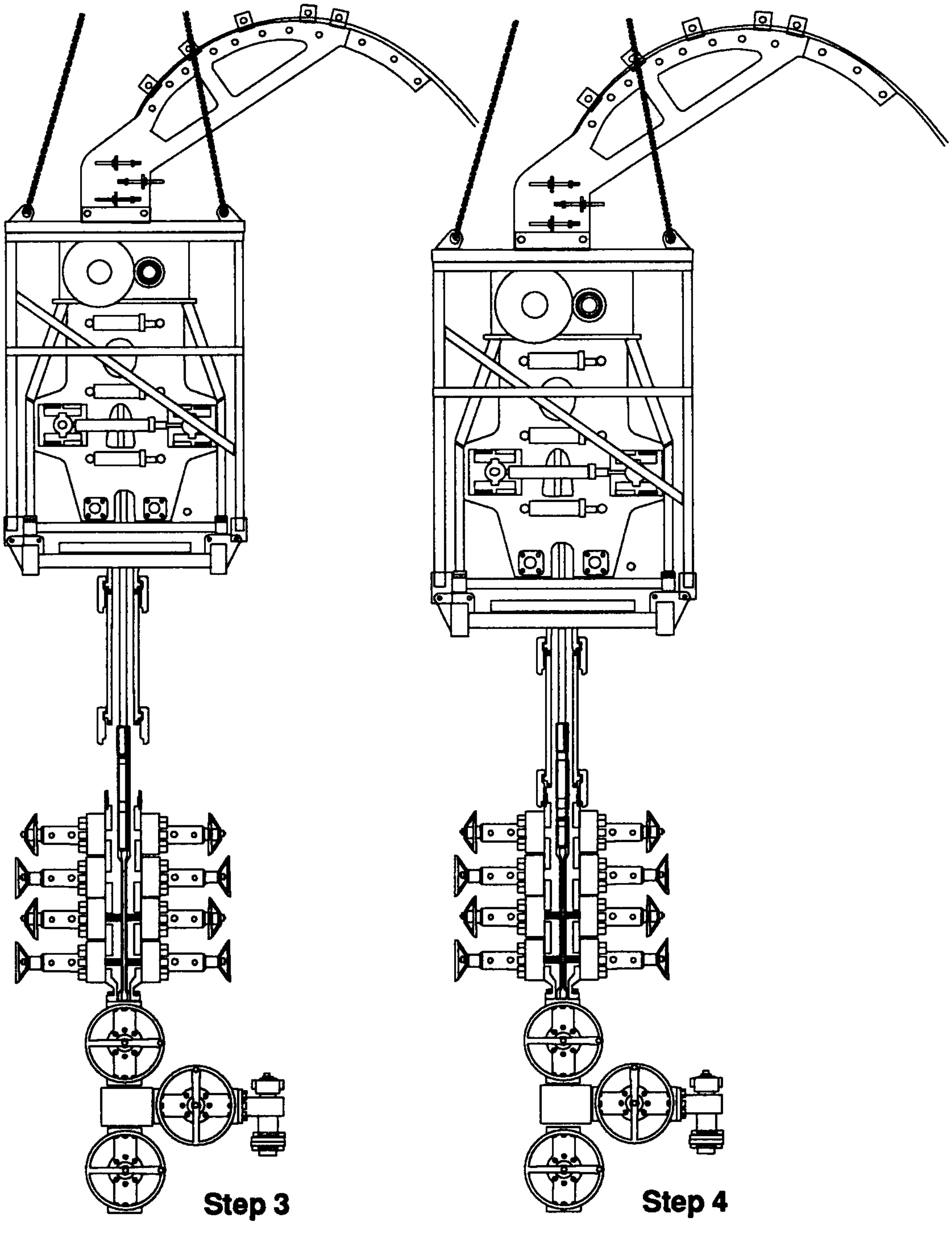

Fig. 5.2—Depolyment schematic.