

Case Study of Drillstring Failure Analysis

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AADE Mid-Continent Symposium
January 20, 2010

Summary

- Three drillstring fatigue failures occurred while drilling two deep wells.
- Shallow doglegs in conjunction with high tension and slow penetration rates were root causes.
- Seemingly insignificant doglegs can cause problems in deep wells.
- New deep-well drilling guidelines were developed and implemented successfully.



Presentation Outline

- Project Objectives
- Case studies
- Survey spacing
- Pipe failure analysis
- Cumulative fatigue model
- Deep-drilling guidelines



Project Objectives

- Study failures to understand why these wells experienced failure.
- Review data and perform analysis.
- Determine root cause of failures.
- Develop deep-well drilling guidelines which are applicable worldwide.



Well A: 1st Drillpipe Failure

- A heat related tensile failure in crossover left fish in hole.
- Well was sidetracked around the fish.
- Sidetrack created 1-3°/100 ft dogleg severities (DLS) in drop section of wellbore from 6,550 to 6,800 ft.
- Drilled to 16,525 ft.
- Rotated pipe without circulation at 16,525 ft for 11 hours while replacing service loop.

Well A: 1st Drillpipe Failure

- Pipe parted at 6,787 ft while pulling out of hole.
- Lower string assembly fell to bottom.
- Fish was recovered except 3 bit cones.
- Unsuccessful recovering bit cones at 16,525 ft.



Well A: 2nd Drillpipe Failure

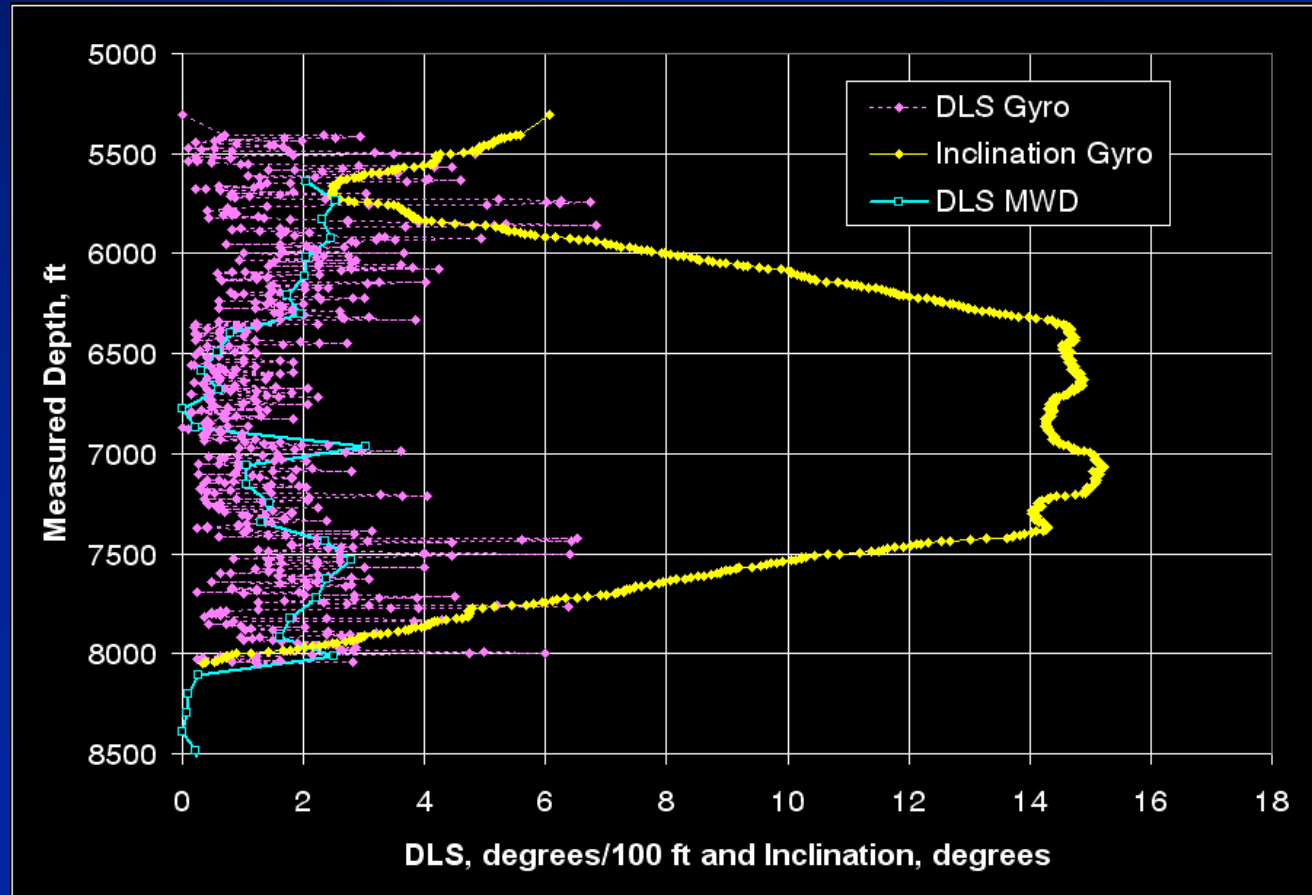
- While milling bit cones at zero ROP for 4.5 hours, pipe failed at 6,756 ft.
- Both drillpipe failures occurred across the highest DLS of 2.9°/100 ft.



Well B: Drillpipe Failure

- Surface hole walk led to an S-shaped directional correction from 5,500 ft to 8,000 ft.
- Correction run created 1-3°/100 ft DLS in wellbore.
- Drilled to 16,628 ft.
- Last 375 ft drilled at 3 ft/hr ROP.
- Pipe parted at 7,756 ft while pulling out of hole.
- Drillpipe failure occurred across the highest DLS of 2.4°/100 ft.

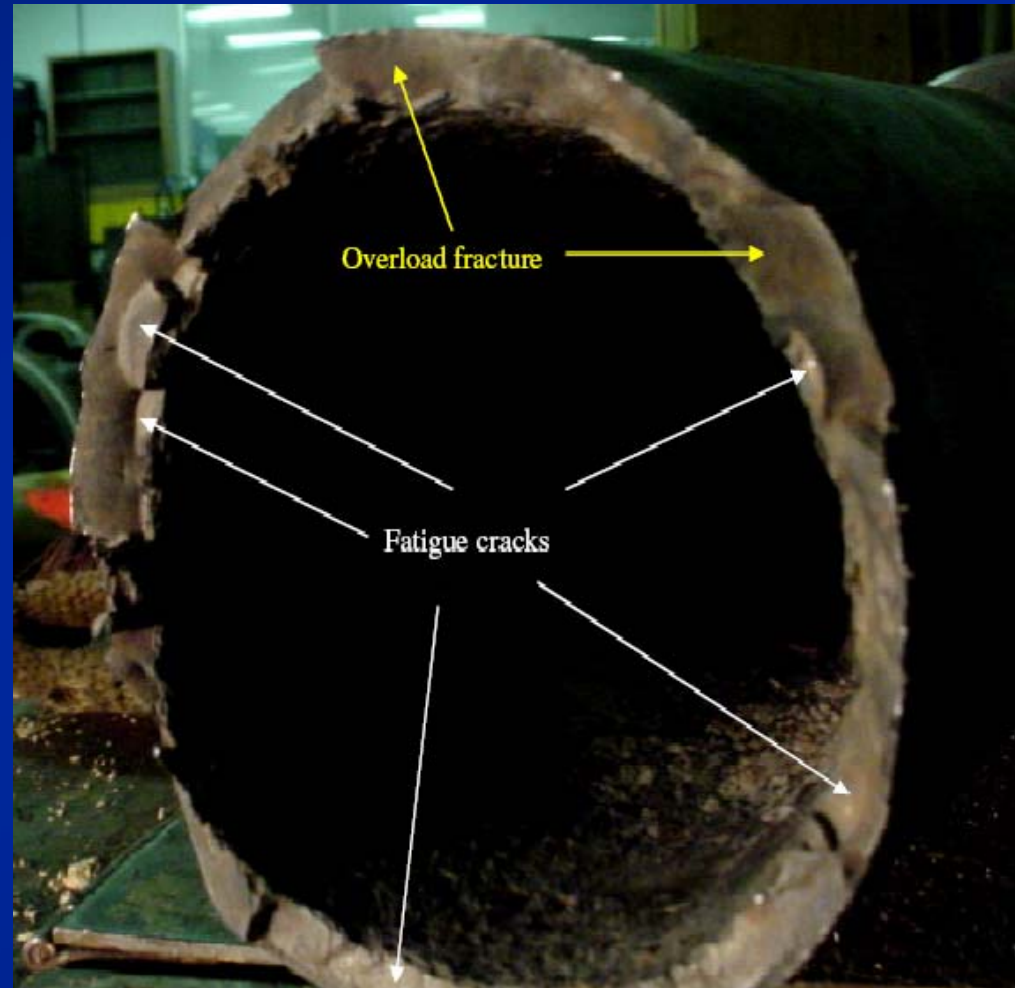
Survey Spacing: 90 ft vs. 5 ft



- Well A: DLS at 6,768 ft = 8.8°/100 ft vs. 2.9°/100 ft
- Well B: DLS at 7,765 ft = 6.4 °/100 ft vs. 2.4°/100 ft

Well B: Fatigue Cracks

- Multiple fatigue cracks initiated on pipe OD



Well B: Corrosion Pitting on Pipe ID



ID Corrosion pitting.



Close-up image.

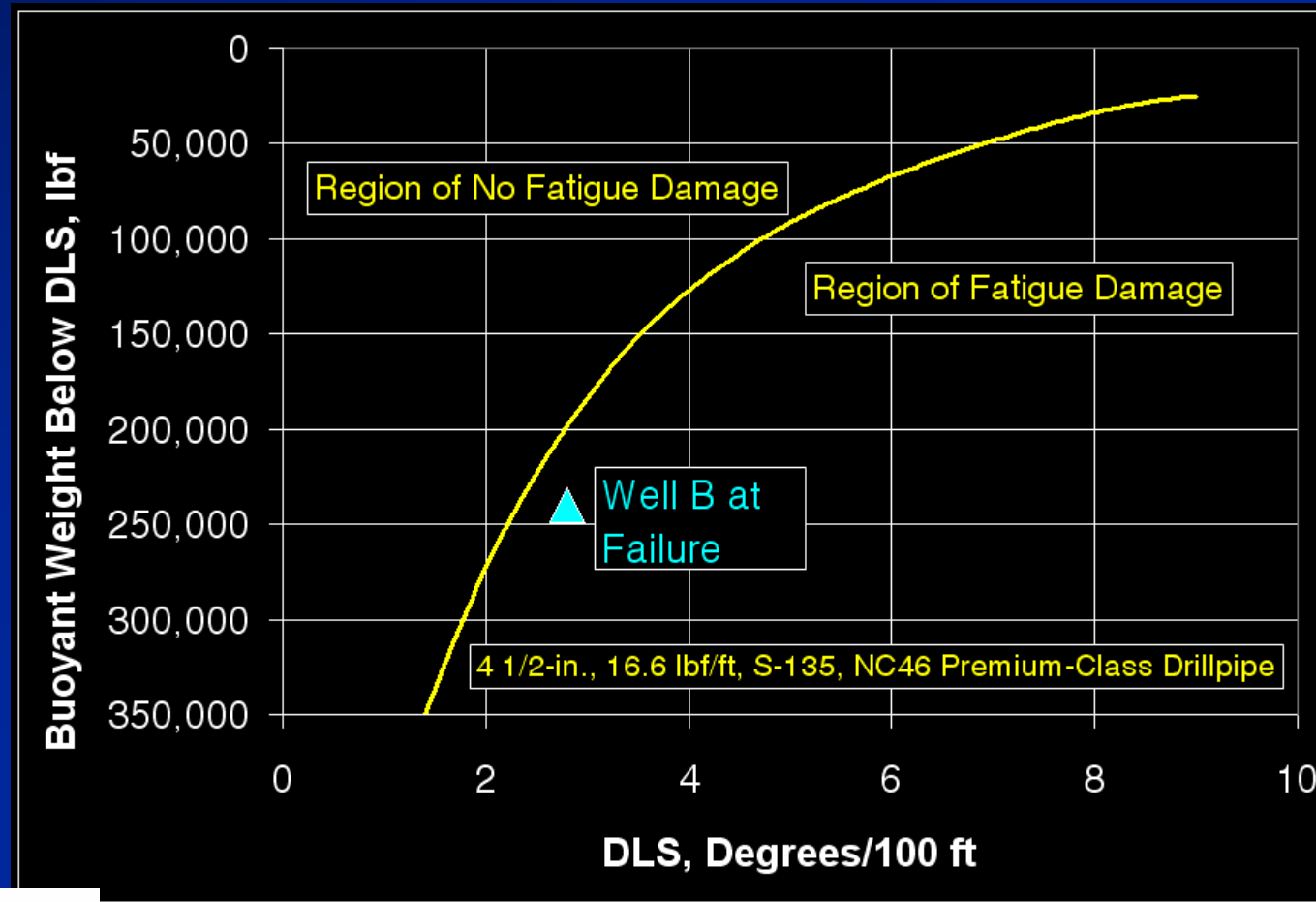
- Well B had 0.09-in. deep pitting (25% of wall thickness).
- Pits were not related to failure mechanism.

Drillpipe Inspection

- Pipe inspection was not the root cause of the failures.
- Failed drillstrings were originally inspected with a mid-level inspection (UT Wall and EMI).
- Slip/upset areas were not inspected.
- For wells with TD >15,000 ft, MPI and UT Slip/Upset inspection is recommended to identify ID corrosion pitting and potential crack initiation sites.



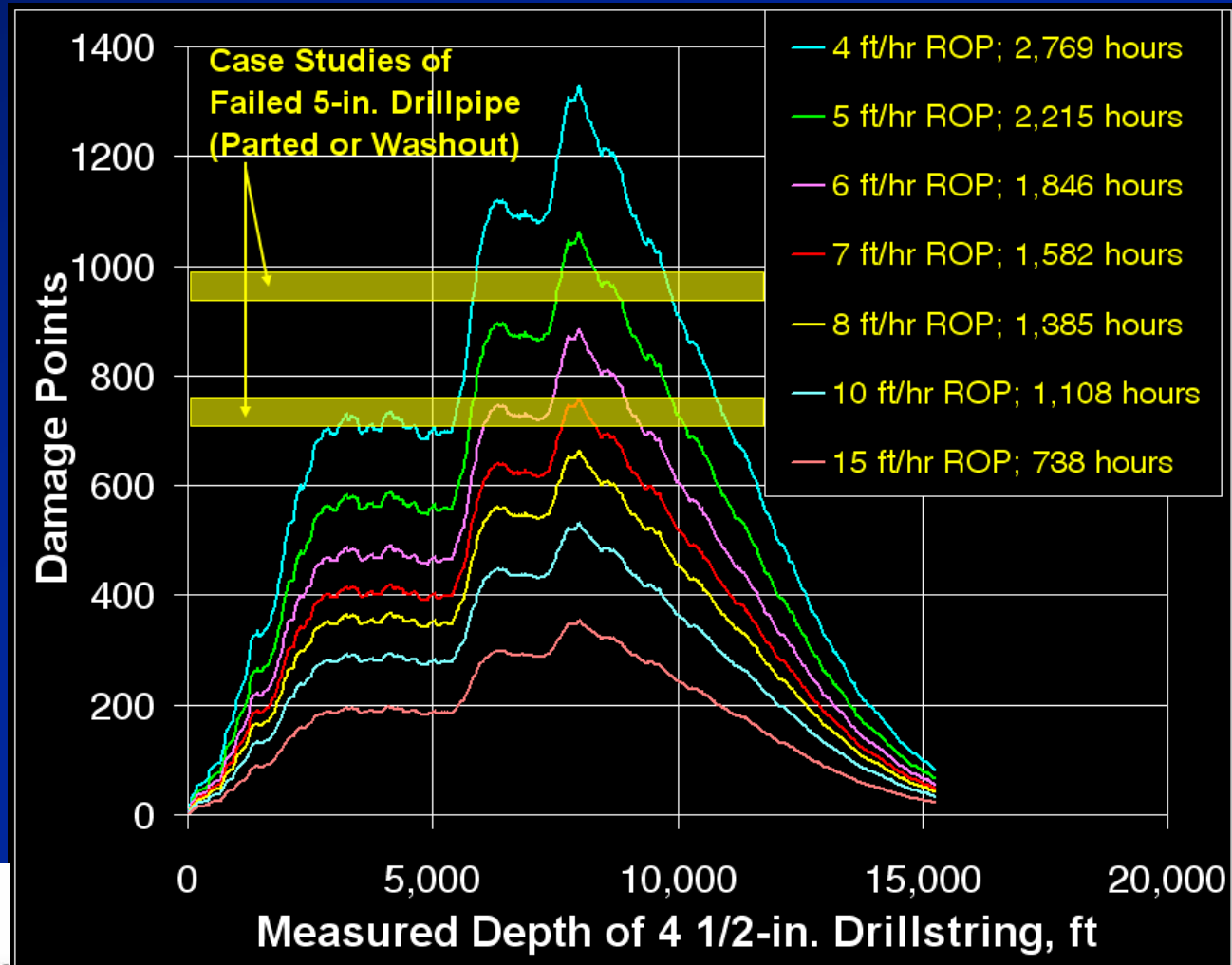
Lubinski's DLS Limit Curve



Cumulative Fatigue Analysis

- CFA model combines Lubinski's maximum bending stress in a drillpipe while rotating in a dogleg under tension with the Forman Crack Growth Model to calculate remaining fatigue life.
- Used CFA to model the 3 drillstring failures along with 2 control wells.
- Model is calibrated with actual case studies where failures occurred and uses dimensionless indices to compare the combined effects of hole curvature, axial tension in the tube, and pipe properties.

Well B: Result of CFA Modeling



Deep-Well Drilling Guidelines

- Minimize DLS in hole sections above 10,000 ft.
- A short spacing (between 5 ft and 20 ft) survey should be run across suspected problem intervals as localized ledges may change over time, especially across unstable formations or in angle-drop sections.
- Lubinski's DLS Limits curves should be used for initial assessment of DLS and to determine if additional actions are required.
- Forward-looking CFA is recommended if the drillstring is expected to operate outside the endurance limit to develop a failure mitigation plan.

Deep-Well Drilling Guidelines

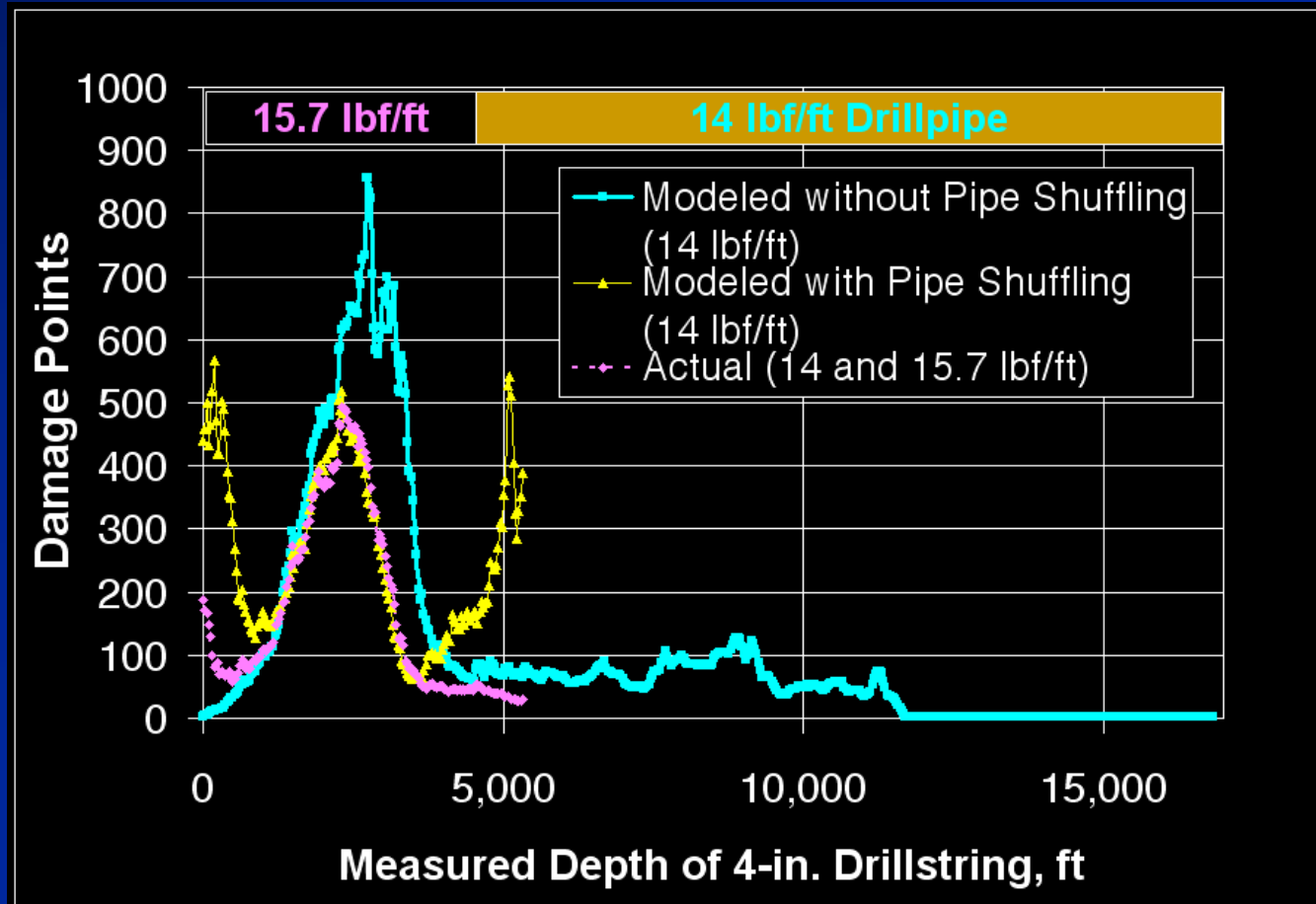
- Any pipe sections which are predicted to accumulate more than 500 damage points should be laid down and inspected.
- A higher-level inspection which includes MPI and UT Slip/Upset inspection is recommended prior to spud.
- Mean cyclic stress in the drillpipe can be minimized by positioning heavy-wall pipe across the DLS, shuffling drillpipe, using a tapered drillstring, reducing off-bottom rotation, increasing ROP, etc.
- DLS and fatigue must be managed for successful deep-well drilling, or else $\text{DLS} + \text{Tension} + \text{Slow ROP} = \text{Fatigue Failure}$.

Well C: Results

- Planned TD of 18,000 ft.
- Shallow deviation problem created 2.74°/100 ft DLS at 1520 ft.
- Expected to operate outside endurance limit at TD.
- Ran CFA model and developed pipe failure prevention plan by placing heavy wall drill pipe across DLS and shuffling pipe.
- Successfully drilled to TD of 18,000 ft.



Well C: Forward-Looking CFA



Questions?

Oil Well Exhibit Captures Prize

Two metro area residents won an exhibit competition conducted during the recent 72nd annual open house at the University of Oklahoma College of Engineering.

David Bert of Norman and Mark Williamson of Purcell placed first for their exhibit of an oil well blowout simulator.

Victim vs. Player and the Golden Gate Bridge

Dave Bert, Chesapeake Energy



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Definitions

Victim:

- It's not my fault or my problem
- There is nothing I can do about it
- Somebody else is to blame
- I have no control; I am powerless to change it
- I can't do it any better
- I can't change my crew's behavior
- I am not responsible

Victim vs. Player

Player:

- Engaged in the game
- I can do something; I can make it better
- Has hope for the future
- Power, Control, Ownership
- Can influence the outcome
- I am responsible
- Players create possibilities...

Our industry needs players (not victims).

Let's all strive to put a team of players in the field.*

- That's the one who looks out for the other guy.
- The one who raises the standard of performance.
- The one who encourages others to do their best.
- The one who won't settle for second best.
- The one who accepts responsibility.
- The one who makes no excuses.

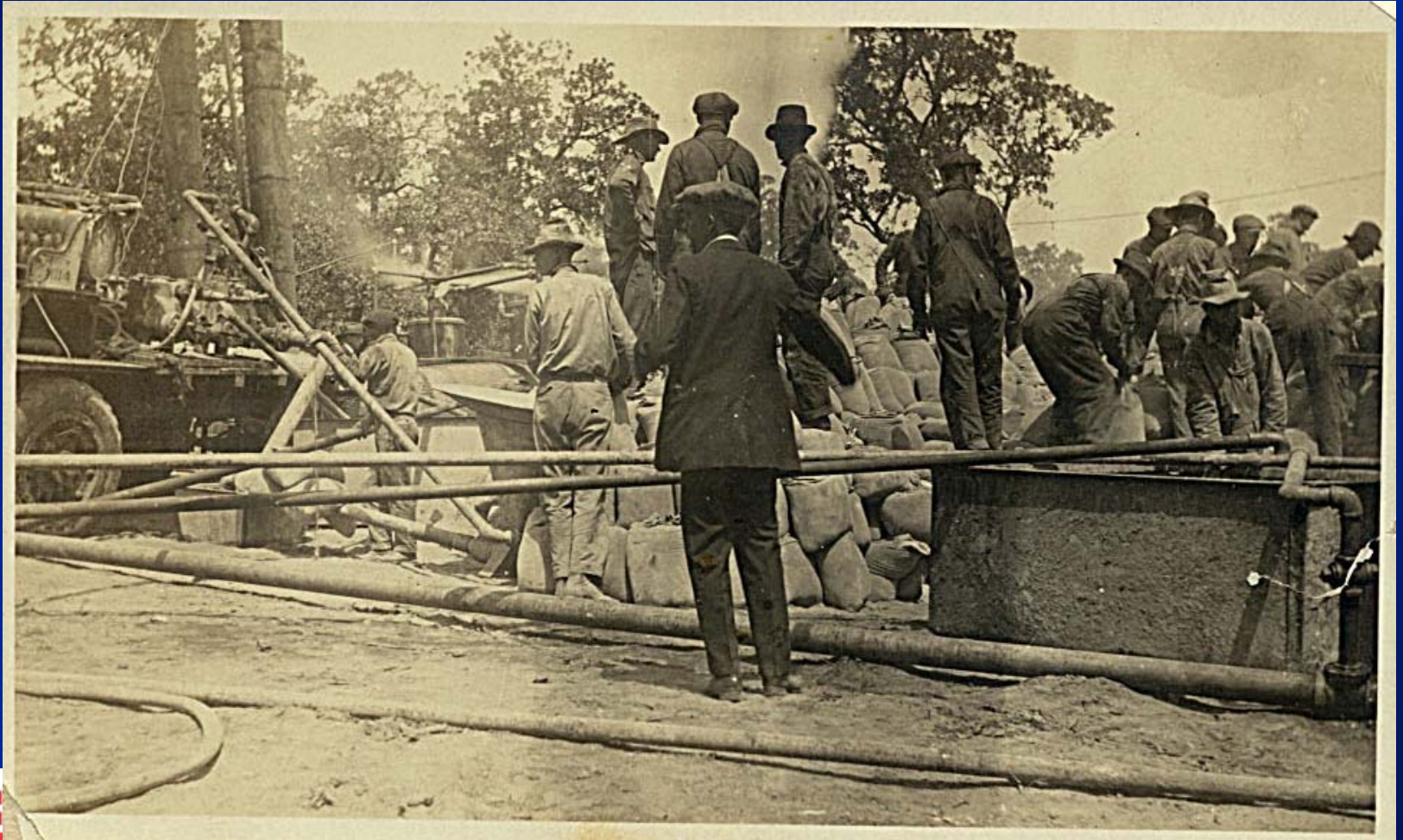


*Adapted from Nabors Drilling, 2005

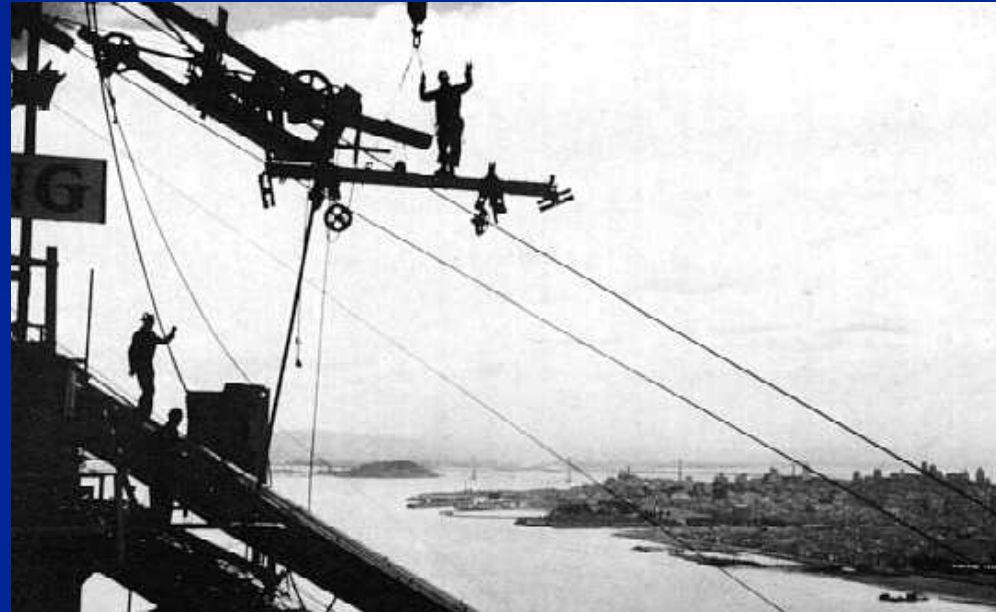


Rockefeller Center, 1932

E. P. Halliburton cementing in 1924.



Bridge Construction in 1930's



Golden Gate Bridge

- Opened in 1937, it is considered the most spectacular bridge in the world. The bridge was the most eminent structural feat in history up to that time. The engineers defied the known laws of physics.
- The bridge is the tallest suspension bridge in the world (764 ft towers) with each cable over a yard thick. The bridge spans 8,981 feet.
- It has affected the lives of millions of people, providing expanded job opportunities in the area.
- The bridge construction also changed the thinking of civil engineers and industrial construction throughout the world.

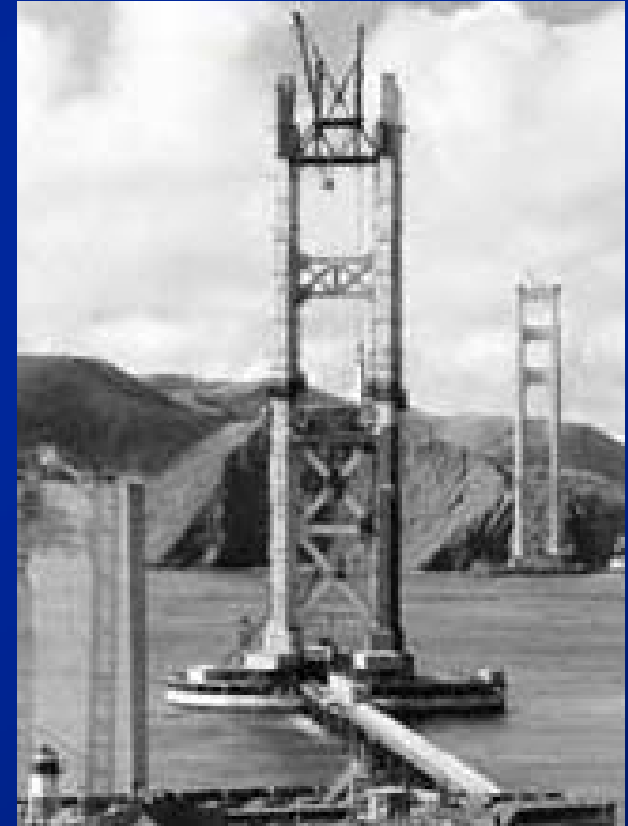
Golden Gate Bridge

- The Golden Gate Bridge in San Francisco was debated and contemplated for over 20 years before it was built.
- 11 engineering construction firms submitted bid proposals to build the bridge (all were around \$35-million).
- The industry standard was one worker fatality for every \$1-million dollars in project cost.
- The City Council held a critical vote. The swing-vote Councilman could not vote for a project which was going to kill 35 people during construction, many who would be from his ward. He continued to ask why 35 people had to die, and if anything could be done to reduce the number.
- Joseph Strauss was a Bridge Engineer who wanted to improve worker safety. His bid was \$300,000 higher to account for new ideas.

Joseph Strauss & Golden Gate Bridge

- The Councilman agreed to vote for the project if the contract was given to Strauss's firm, along with a promise to reduce fatalities.
- Mr. Strauss invented safety nets, fall protection harnesses with lanyards, hard hats, and non-glare goggles. He developed special hand and face cream to protect workers from the wind and sun exposure.
- For the first 4 years of construction, there was only one fatality (drunk worker fell off of crew boat during the journey to the work site). As a corrective action, Mr. Strauss implemented sobriety testing prior to embarking on the crew boat.
- Near the end of the project, there was an incident which killed 10 people. A scaffold collapsed, and fell through the safety net.
- 11 fatalities was the best safety record anywhere, up to that time.
- A club was formed by 19 survivors of Golden Gate construction falls, dropped objects, etc. which was called the "Halfway-to-Hell" club.

Workers with 1st hard hats and fall protection.



What will be your legacy? Be a player!



Joseph Strauss,
Bridge Engineer

