

Developments in Materials and Design of Casing Connections for Fracking Operations

Prepared for: DEC Technology Forum

Date: 21 March 2016

Prepared by: Michael G. Burns, PE

Patrick McDonald, PE



Taking on your toughest technical challenges.

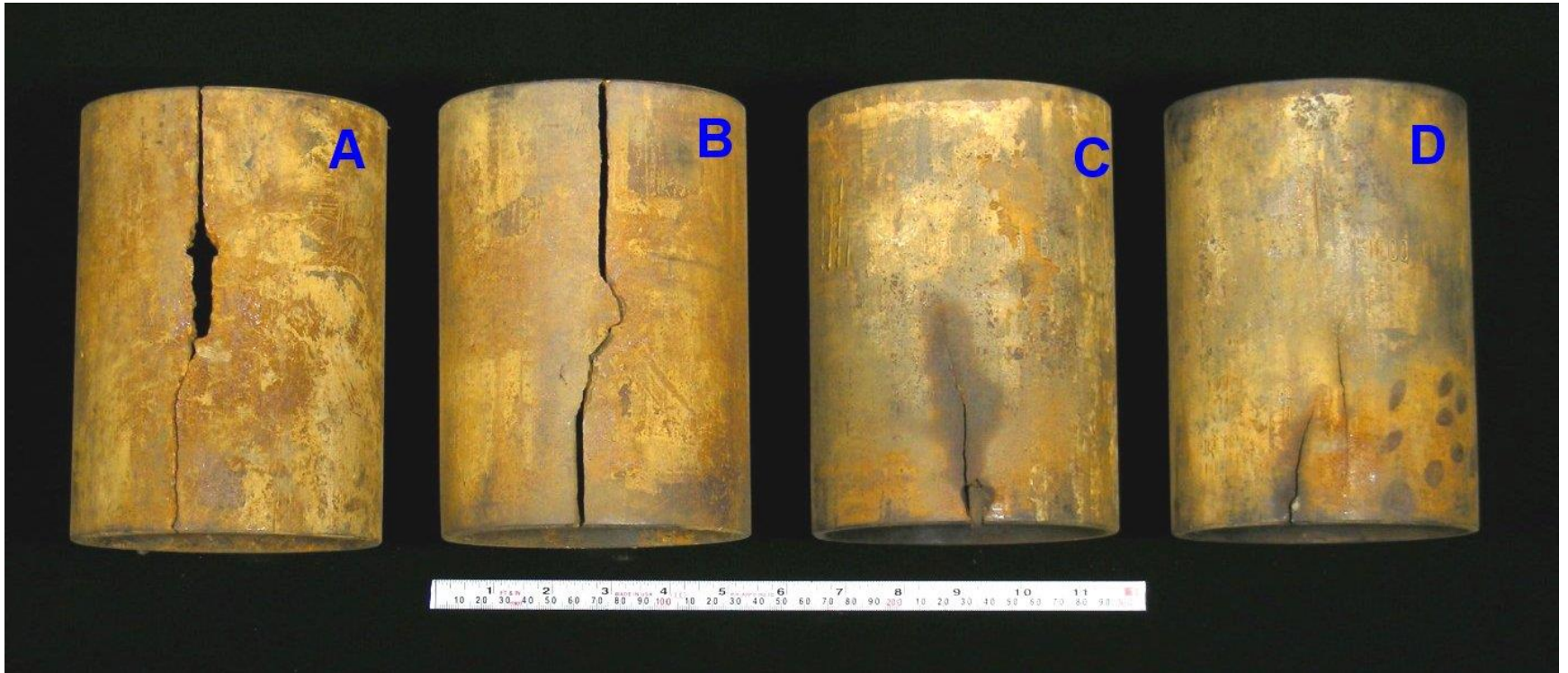


an employee-owned company

In the early days . . .

- Connections were mostly API 8rd.
- Casing and coupling stock were high collapse P110, for the improved performance.
- Shale formations in Texas were understood to be free of H₂S.
- A lot of fracking was performed through 4-1/2 11.60.
- 10-15 frack stages was a complex completion.

And so, in the early days . . .

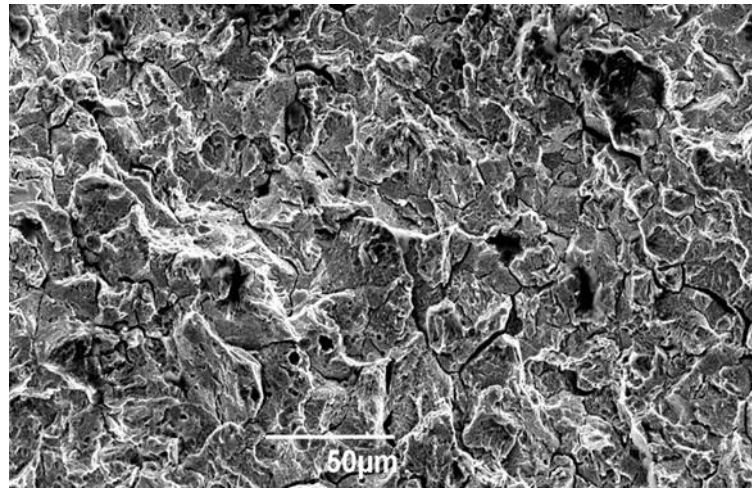
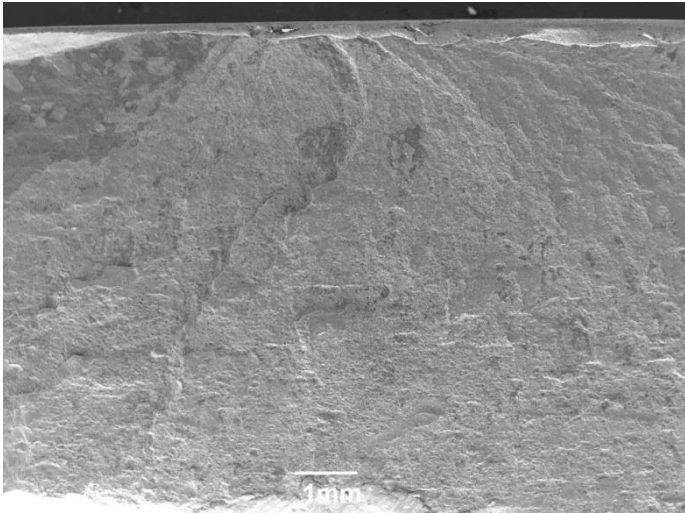
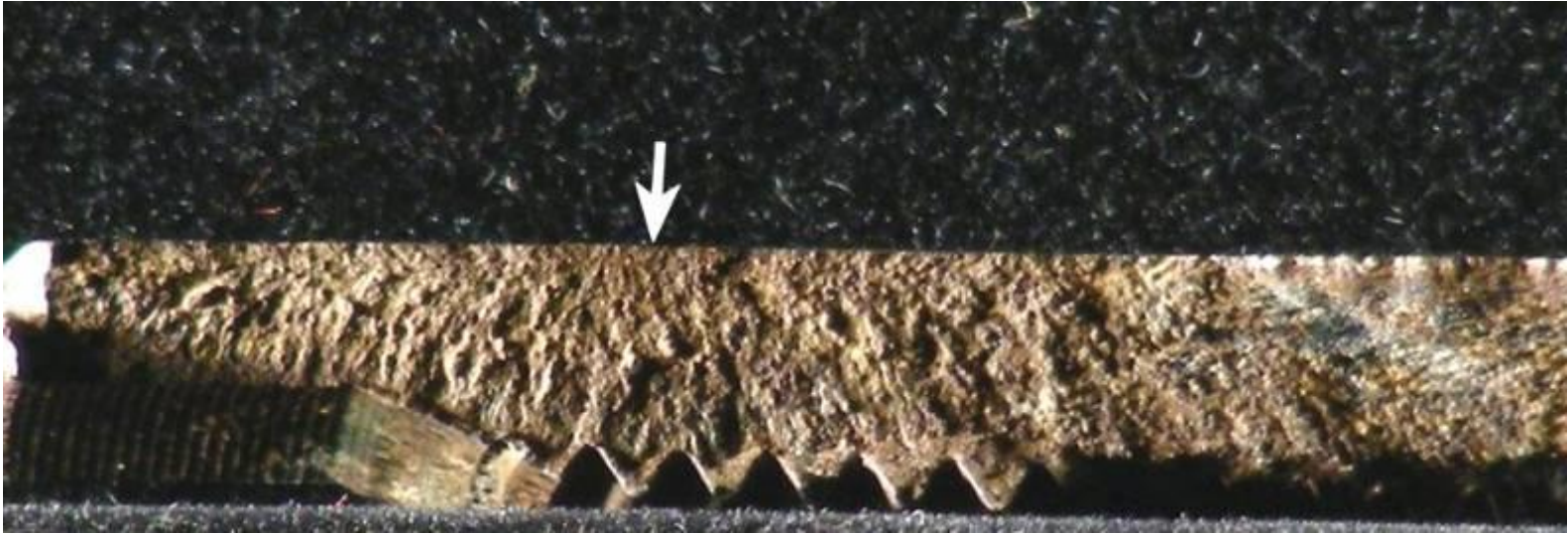


“High Collapse” P110

- Due, in part, to a large variation in collapse resistance test results, API 5C3 estimates of collapse resistance have historically been relatively conservative compared to the “average” performance of P110 casing.
- Individual test results often exceeded proprietary “high collapse” standards.
- Measures to improve collapse resistance vary in cost:
 - Reduce ovality
 - Improve uniformity of wall thickness in seamless casing
 - Eliminate cold straightening (warm straightening only)
 - Increase yield strength to the high end of the specified range (110-140 ksi)

High Collapse P110

- This combination of factors has created a situation in which casing manufacturers could reduce the temperature in their tempering furnaces by a few degrees and market casing as “high collapse” with little or no increase in processing cost.
- Operators, in turn, often had little need for improved collapse resistance specifically, but nonetheless sought the improved performance of a “better than standard” grade of P110 for demanding fracking operations.
- Unfortunately, coupling manufacturers initially ordered matching “high collapse” coupling stock . . .



Hydrogen stress cracking

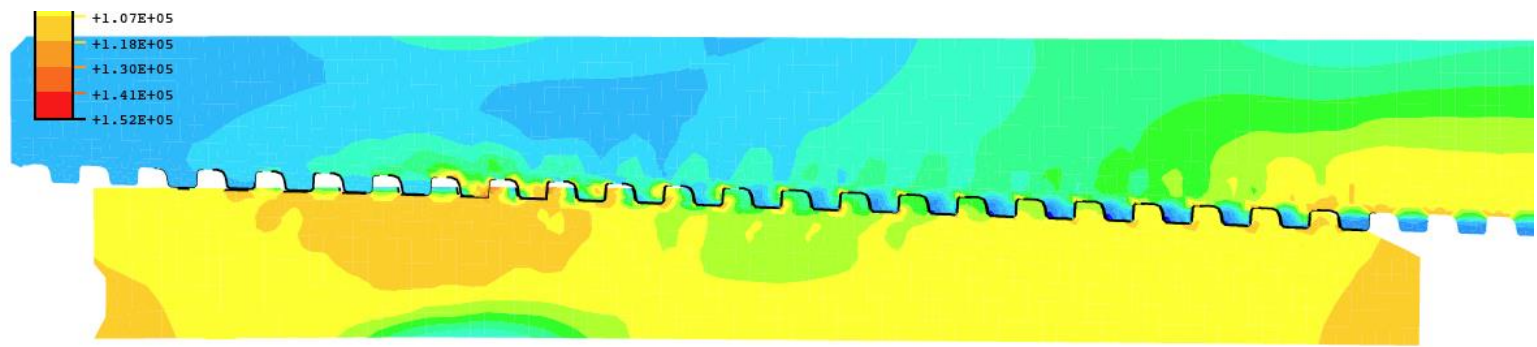
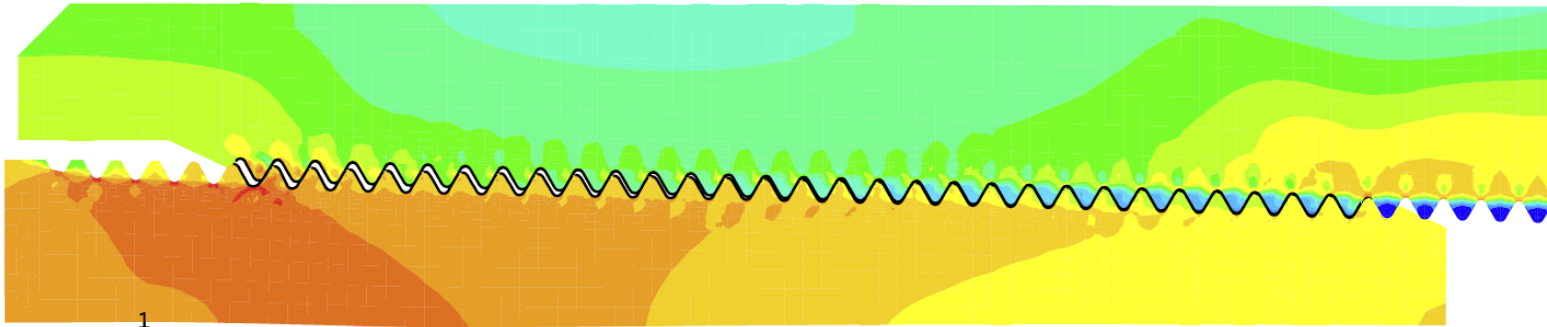
- Hydrogen, usually generated by corrosion, enters the steel and causes the grain boundaries to come apart under stress.
- API 8rd connections have high hoop stresses.
- Susceptibility of steel increases with hardness and strength.
- Although small amounts of H₂S can greatly enhance the absorption of hydrogen (greatly increasing the susceptibility of steels), hydrogen generated by corrosion in sweet wells or during acid treatments can cause cracking, too, if the hardness and strength are high enough.
- Characteristic features include multiple crack origins, often in multiple couplings, and intergranular or mixed intergranular/cleavage fracture.

Coupling Failures

- API 8rd coupling failures overwhelmingly occurred in steels with yield strength greater than about 133 ksi—high collapse coupling stock. High stresses and high strength made them very susceptible to hydrogen stress cracking, even in the (presumed) absence of H₂S.
- Ironically, the use of “high collapse” coupling stock did nothing to improve the collapse resistance of the casing strings—the coupling was never the weak link in collapse—but did increase the likelihood of hydrogen stress cracking.

Industry response

- Coupling manufacturers adopted “restricted yield” specifications for coupling stock (typically 110-125 ksi, rather than the 110-140 ksi permitted for P110).
- Operators moved away from 8rd connections to buttress, semi-premium (shouldered or pin-to-pin buttress, often with increased OD) or premium connections.
- By 2010, the incidence of failures had dropped precipitously (long before the oil-price-driven drop in fracking operations)



Connection Developments

- Rule of thumb for early horizontal wells (Austin chalk)
 - Up to 10°/100 ft API 8rd
 - Up to 16°/100 ft Buttress
 - Greater than 16°/100 ft Premium
- Fracking pressures increased
 - Barnett shale 6-8 ksi
 - Haynesville >10 ksi
- Old rules of thumb based on bend radius alone insufficient
- Casing rotated in tighter holes—more fatigue
- Laterals reaching 3-4 miles

Progression in connections

- Increasing demands for improved performance of connections (within cost constraints) have led to an evolution in connection designs:
 - API 8rd
 - API Buttress
 - Buttress with torque rings
 - Shouldered buttress connections
 - Pin-to-pin buttress (with or without seal ring)
 - Proprietary semi-premium (premium thread form, without metal-to-metal seals)
 - Premium with metal to metal seals

Recent Developments

- Fractures in the improved buttress and semi-premium connections currently being used are much rarer, but still occur.
 - In some shouldered connections, failures tend to be circumferential rather than axial because of a change in the orientation of make-up stresses.
- Recently, operators have reported an increase in leaks through the threads during fracking operations. Failures have been reported in semi-premium connections in the kickoff area. High pressures and severe bending loads are clearly factors—the failures appear to be mechanical rather than metallurgical.
- Engineers continue design work and testing of semi-premium and premium connections for increasingly demanding fracking operations.

A Final Word: Manners at the Rotary Table

- Materials and connections cannot solve all the issues
- Manners – Running procedures still matter
- Follow manufacturer's or API recommended practices
- Haste makes waste – A little extra time and care in running of the string will pay for itself many times over

Thank You!



Disclaimer

- This presentation is prepared for information purposes for the audience, and the scope is limited to matters expressly covered within the text. SES is not able to direct or control operation or maintenance of the audience's equipment or processes, and is not responsible for any use or misuse of the information contained in this presentation.