Casing Failure Prevention

East Texas Gas Producer's Assoc.

9 March 2010

The Ideal Casing String

- For as long as needed, it will:
  - *Safely carry all applied loads,*

Until the next string is set…

  - *and be free from leaks.*

…to the life of the well

A breakdown in any one of these steps can result in a casing failure!

The discussion today will focus on:

- Common failure modes
- Underlying causes
- Steps to minimize the risk of failure

Casing Failures

Failure Modes

Casing Failures

PRESSURE
- Burst
- Collapse
- Connection Leaks

TENSION
- Tube Fracture
- Connection Fracture
- Connection Jump Out
- Buckling

BRITTLE FRACTURE
- Environmental Cracking
- “Naturally” Brittle Material

FATIGUE
- Connections

OTHER
- Galling
- BTC Disengagement

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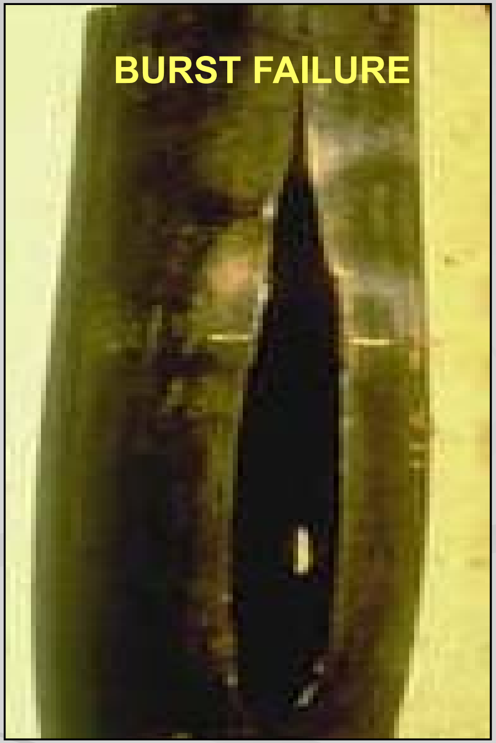
Pressure Related

Burst and Collapse

- Failure Mechanism

  Overload failures where pressure (burst or collapse) exceeds load capacity

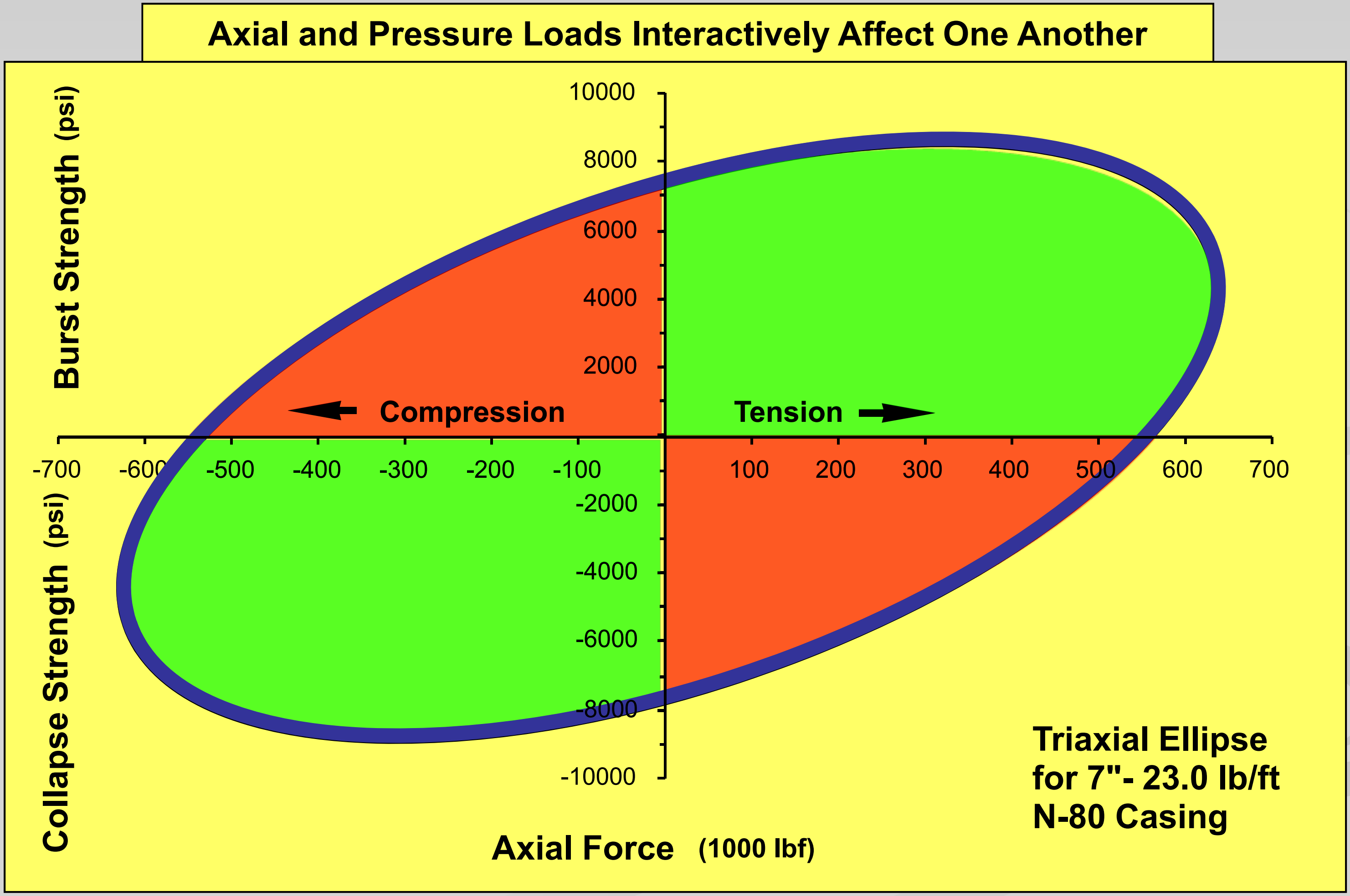
- Recognition
  - Appearance: Plastic deformation (ductile material)
  - Orientation: Longitudinal
  - Location: Sections with highest loads


BURST FAILURE

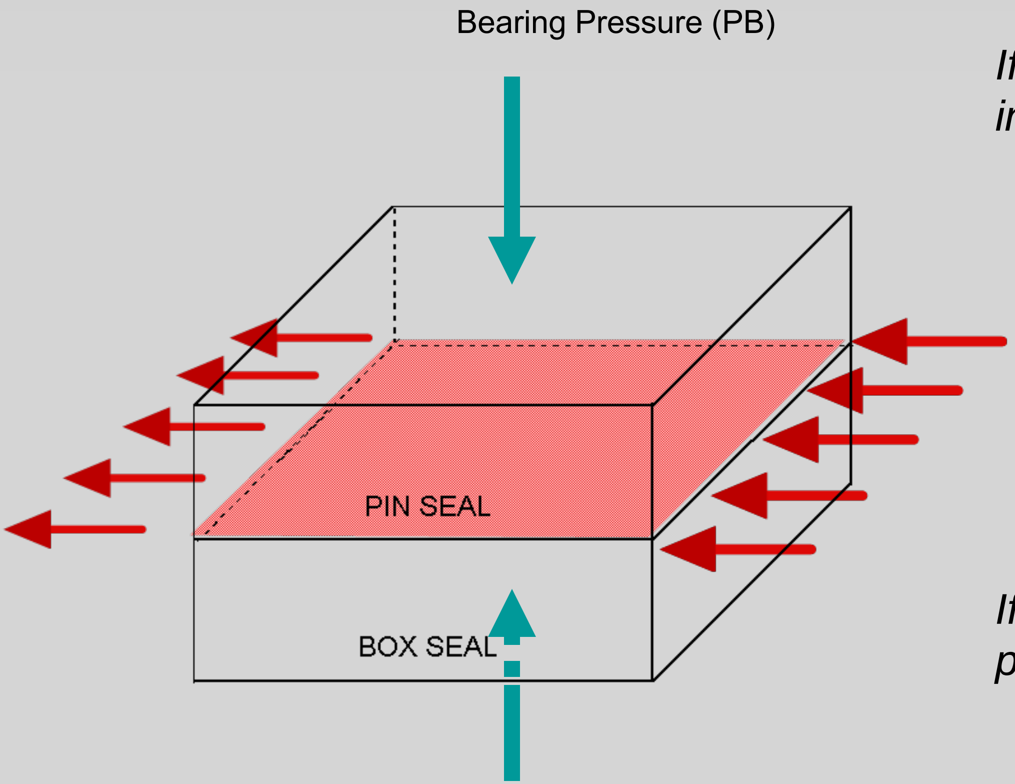

COLLAPSE FAILURE

Remember…..

Pressure and Tension are not independent.



Why Connections Leak:
1. Inadequate Bearing Pressure



If bearing pressure (PB) exceeds internal pressure (PI), then no leak.

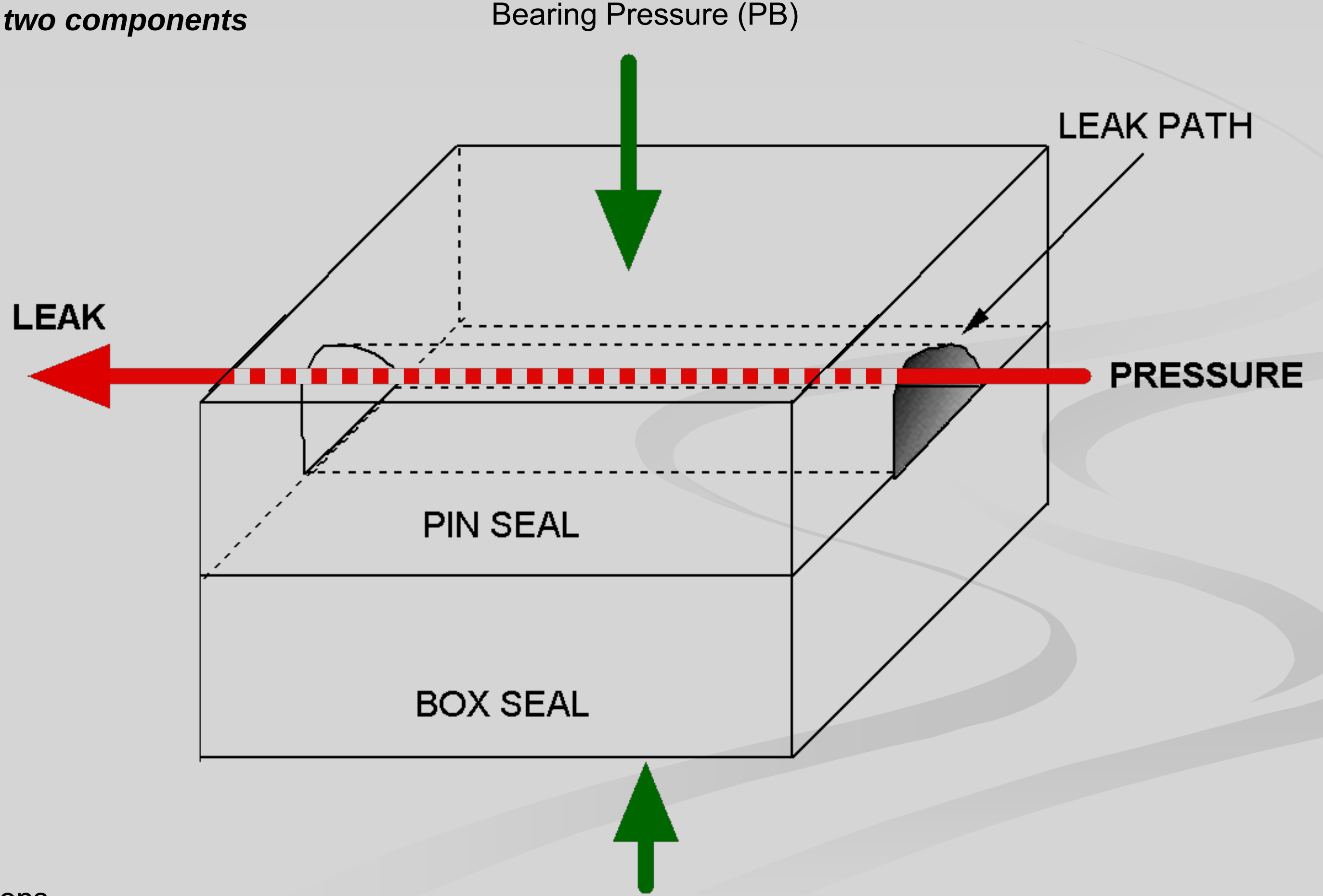
Internal Pressure (PI)

If internal pressure (PI) exceeds bearing pressure (PB), then leak.

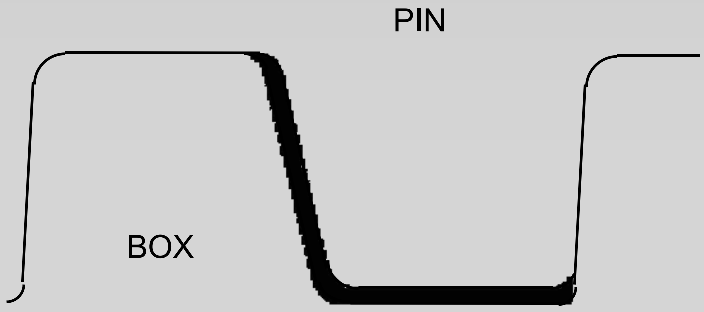
Why Connections Leak:

2. Leak Path Across Seal(s)

A leak path is present on this pin seal. The seal will leak regardless of how much bearing pressure is forcing the two components together.

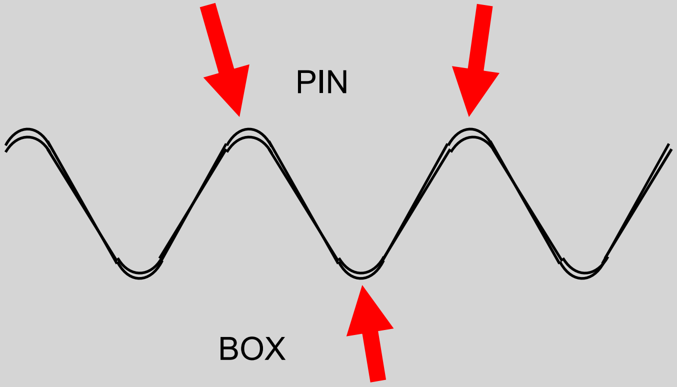


API Connections Have Built-In (Helical) Leak Paths



API BUTTRESS

These tortuous paths are plugged with the solids in thread dope during makeup.



API ROUND THREAD

Preventing Leaks

- Leak Paths (other than helical) *Found in visual inspection. Removed from the string.*

- Inadequate Bearing Pressure *Adequate Bearing Pressure is assured by:*
  - --Proper dimensions
  - --Proper makeup

Pressure Related Failures

Failure drivers

- Design error:

  Applied load > rated load capacity
- Material problem:

  Load capacity < rated load capacity
- Casing wear
- Inspection problem:
- Manufacturing flaw, thin wall joint or thread dimensions
- Improper make up

Mitigations Steps

- Use appropriate design factors to account for higher than anticipated loads.
- Inspect material for manufacturing flaws, thin wall, grade and thread dimensions.
- Minimize casing wear by: reducing side loads, use of casing friendly hardbanding and reducing rotations of drill string.
- Make up connections to generate desired bearing pressure.

Failure Modes

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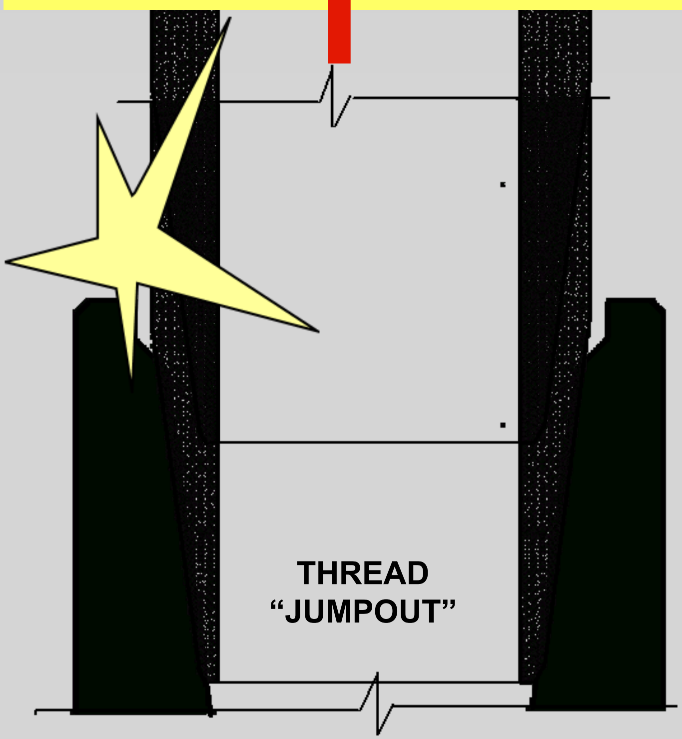
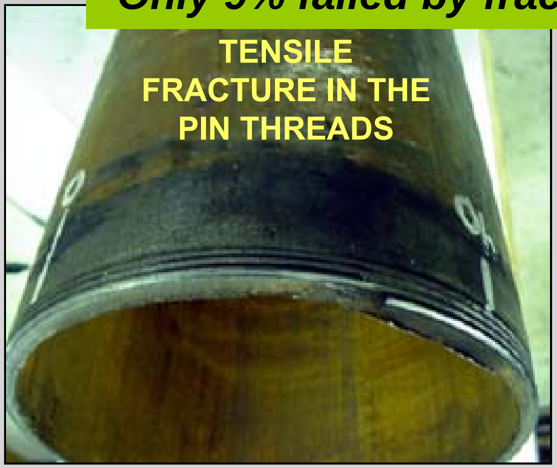
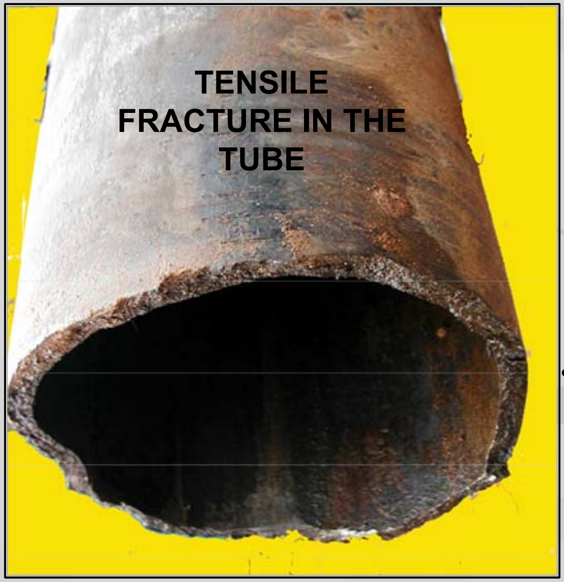
Failure Generally Associated with Tensile Loads

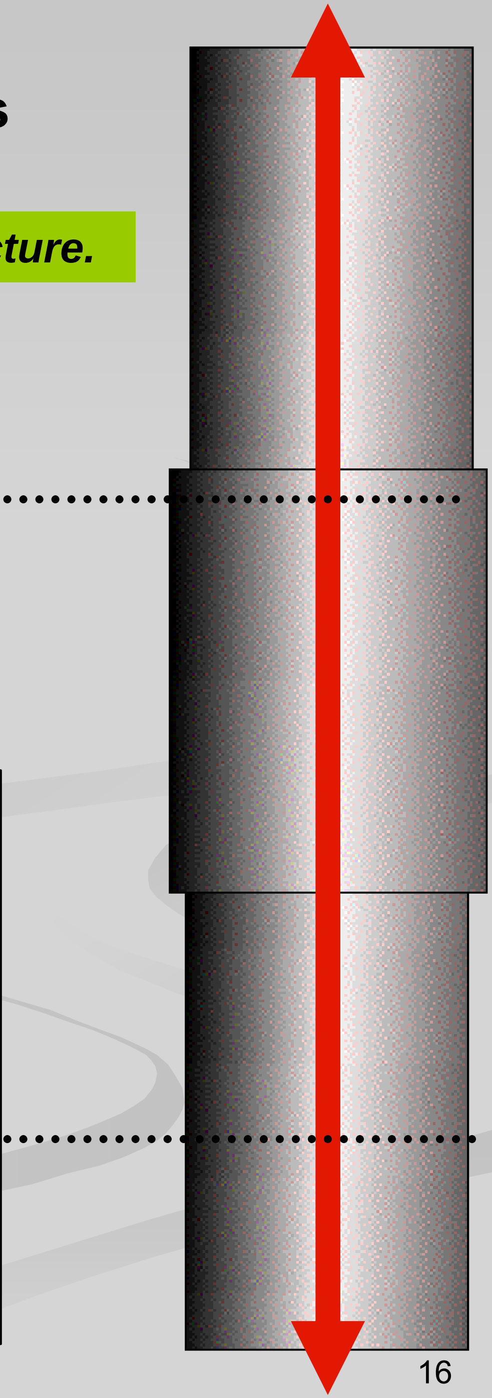
In API tensile tests to failure, 148 of 162 (91%) of round threaded connections failed by jumpout.



Only 9% failed by fracture.

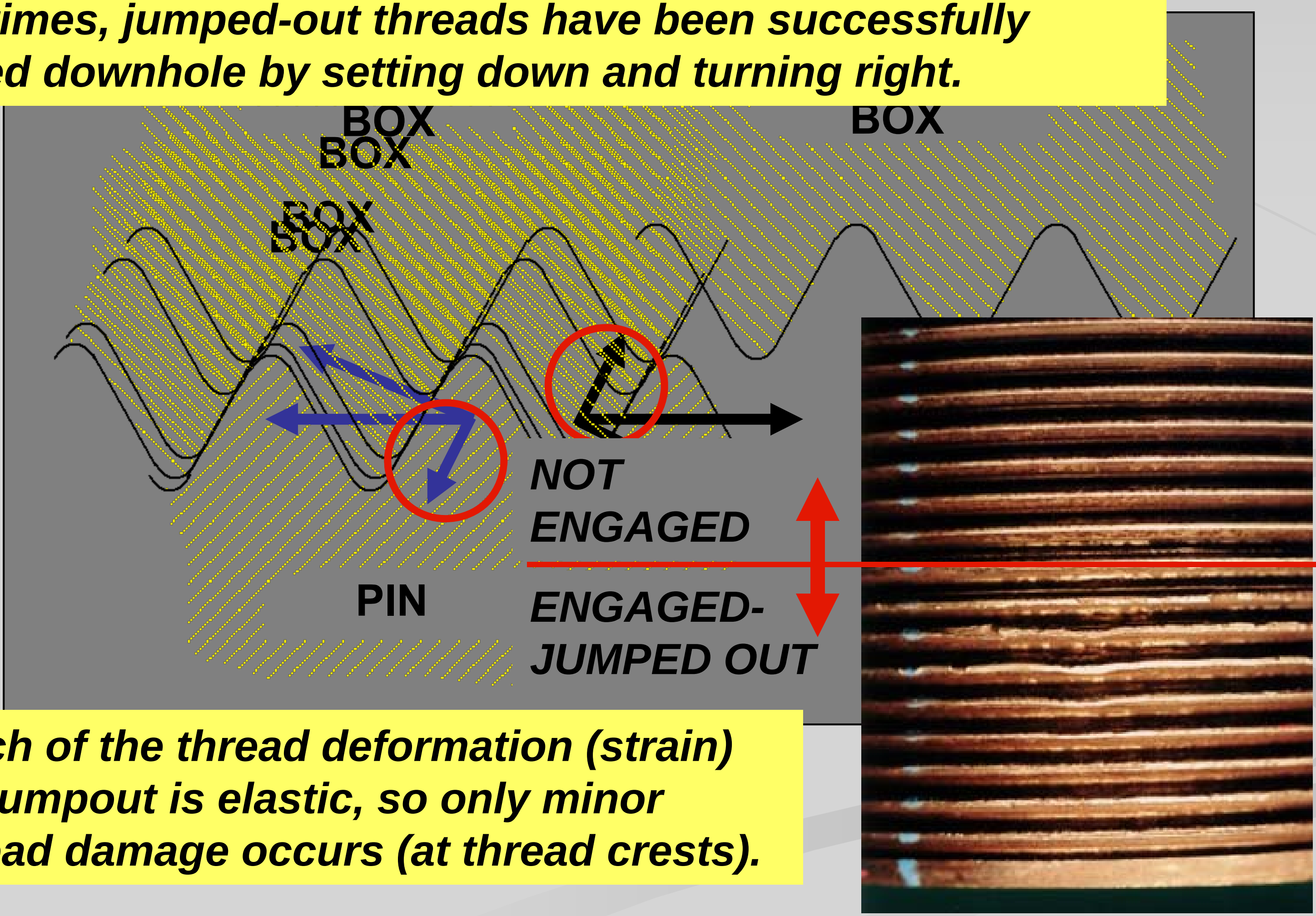






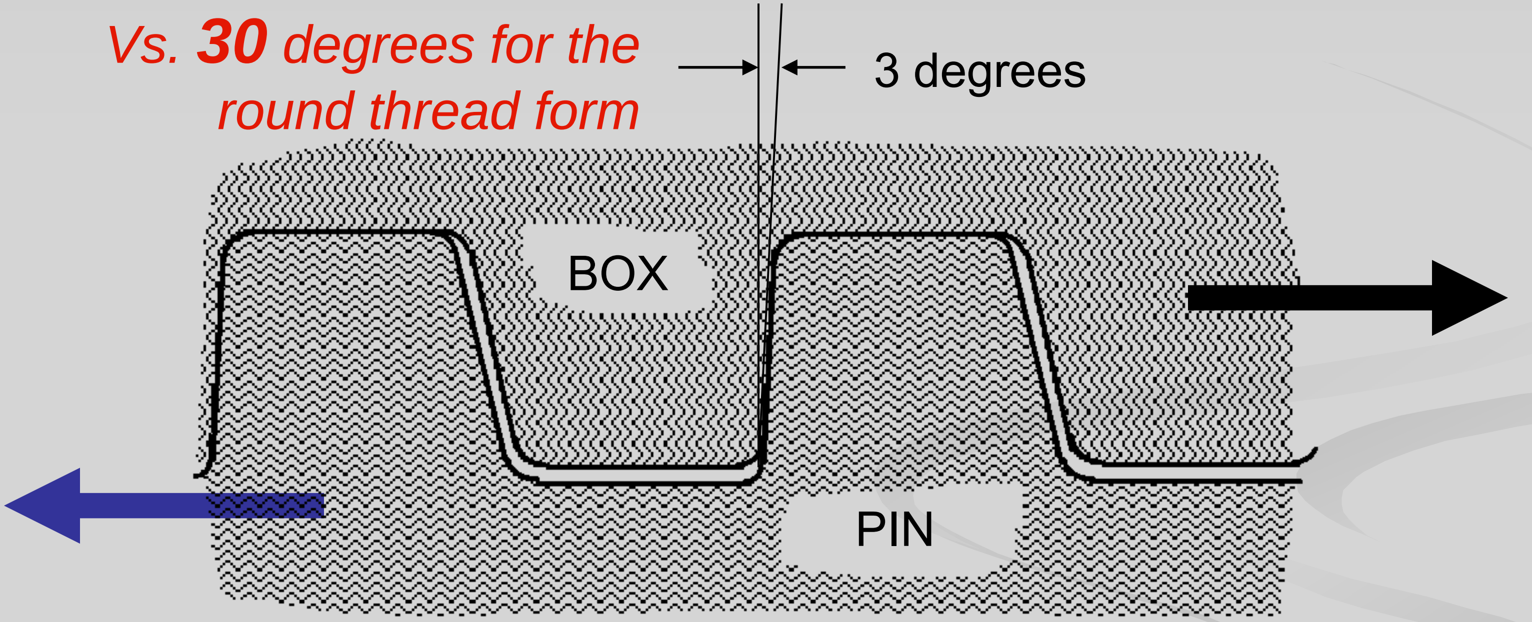
How Jumpout Happens

Many times, jumped-out threads have been successfully rejoined downhole by setting down and turning right.



Much of the thread deformation (strain) on jumpout is elastic, so only minor thread damage occurs (at thread crests).

Jumpout - The Main Reason API Adopted the Buttress Thread Form

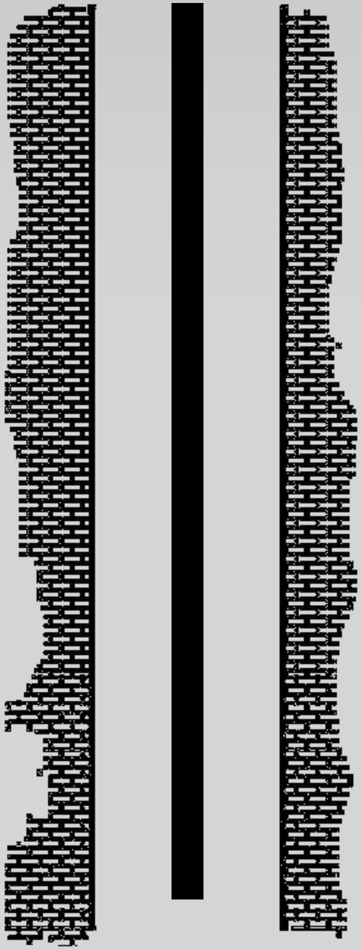


Vs. ***30*** *degrees for the round thread form*

API BUTTRESS THREAD FORM

Casing Buckling

Stable



$F > (P_I \times A_I) - (P_O \times A_O)$

- Sudden, rapid axial collapse of a casing section that occurs when forces that <u>destabilize</u> the section exceed forces that <u>stabilize</u> it.
- Factors affecting buckling:
  - State of tension or compression including temperature and pressure affects
  - Stability forces

    $(P_I \times A_I) - (P_O \times A_O)$
- Section stable if:

  $$F > (P_I \times A_I) - (P_O \times A_O)$$
- Section buckled if:

  $$F \leq (P_I \times A_I) - (P_O \times A_O)$$

where:

F is the amount of tension (+) or compression (-) (lbs)

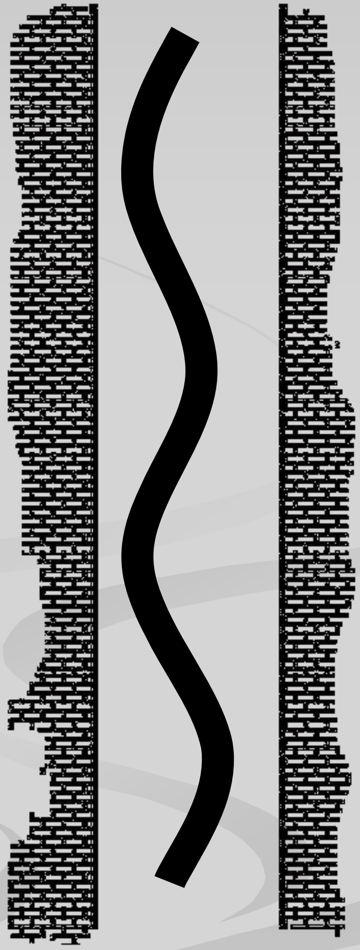
P_O is the annular pressure (psi)

A_O is the outer circumference of the casing (in)

P_I is the pressure inside the casing (psi)

A_I is the inner circumference of the casing (in)

Buckled



$F \leq (P_I \times A_I) - (P_O \times A_O)$

Tension Failures

Failure drivers

- Design error:

  Applied load > rated load capacity
- Material problem:

  Load capacity < rated load capacity
- Casing wear
- Inspection problem:

  Manufacturing flaw, thin wall joint or incorrect thread dimensions.
- Improper make up
- Casing buckling

Mitigation steps

- Use appropriate design factors to account for higher than anticipated loads
- Inspect material for manufacturing flaws, thin wall and grade.
- Minimize casing wear by reducing side loads, use of casing friendly hardbanding and reducing rotations of drill string.
- Gauge connections and make up properly.
- Adjust tension and TOC to eliminate buckling.

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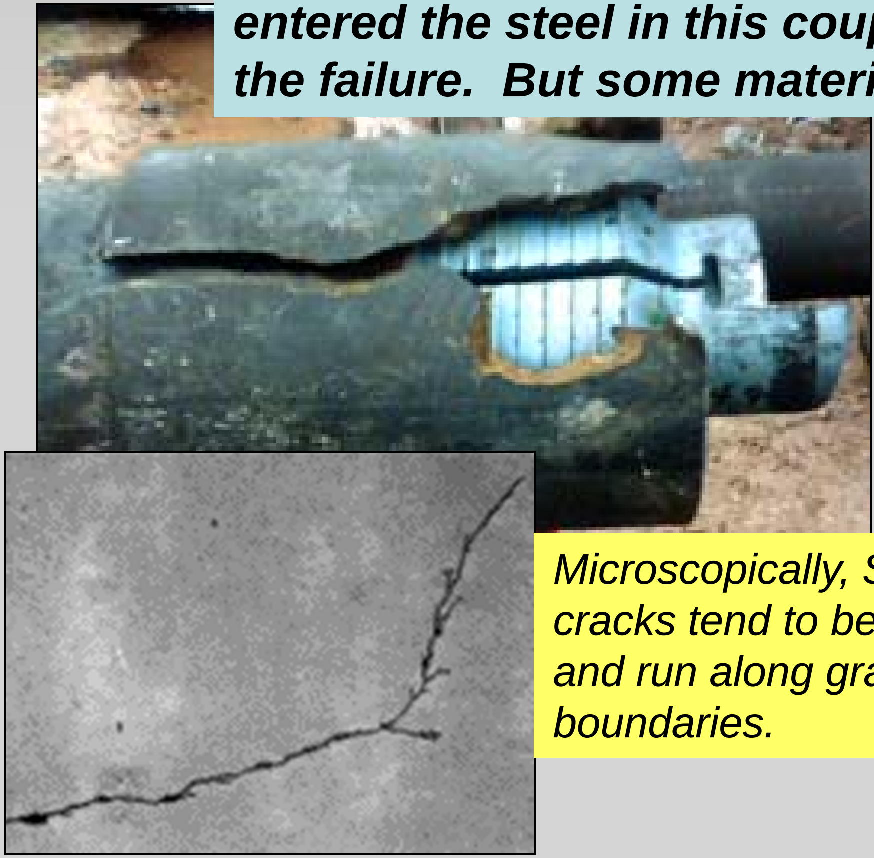
BRITTLE FRACTURE (Hydrogen Induced)

Free hydrogen ions from the chemical reaction with H_2S entered the steel in this coupling and made it brittle, leading to the failure. But some materials begin life brittle…



Microscopically, Sulfide Stress cracks tend to be branched and run along grain boundaries.

in

nt.

The mechanism is called Sulfide Stress Cracking (SSC)

Whether or not such a failure will happen depends on many factors that work together in complex interrelationships:

- **H_2S concentration**
- **Time of exposure**
- **Tensile stress level**
- **Metallurgical properties**
- **Temperature**
- **Other factors**

BRITTLE FRACTURE

(“Naturally” Induced)

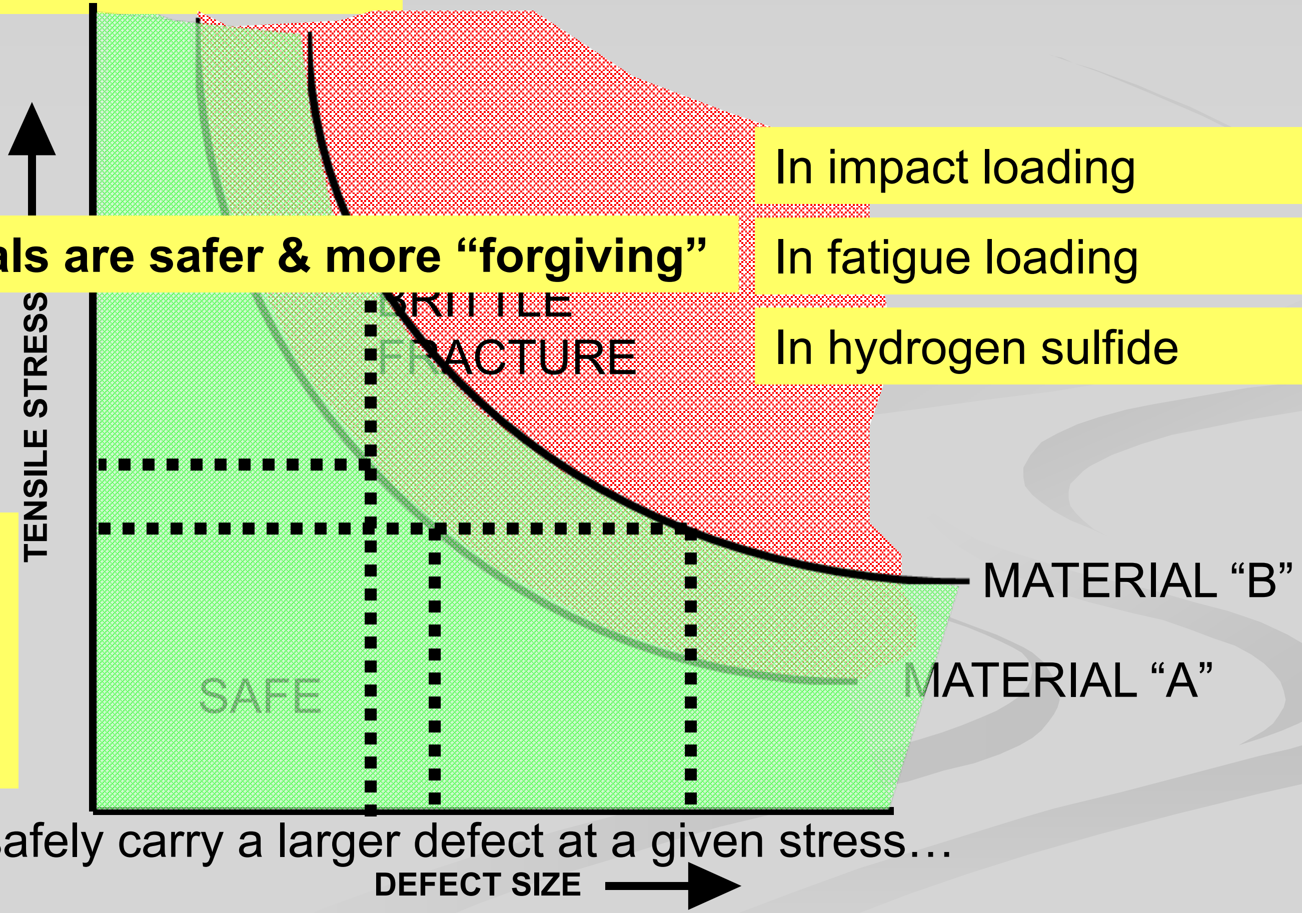
This N80 casing joint was never exposed to hydrogen sulfide. Rather, it came brittle off the production line due to improper metallurgy and/or heat treatment.

Under impact loading, the pipe cracked and parted (much like laboratory glass piping is cut) when a crack started at the bottom of a slip cut, and rapid, brittle fracture occurred. Such a material is called “NOTCH-SENSITIVE.”

Why Tough Material is Better Than Brittle

MATERIAL “A” - BRITTLE, NOTCH-SENSITIVE

MATERIAL “B” - TOUGH



Tougher materials are safer & more “forgiving”

carry a higher stress with a given defect,

Can safely carry a larger defect at a given stress…

In impact loading

In fatigue loading

In hydrogen sulfide

Will fail by tearing apart like a piece of taffy, not shattering like a piece of glass!

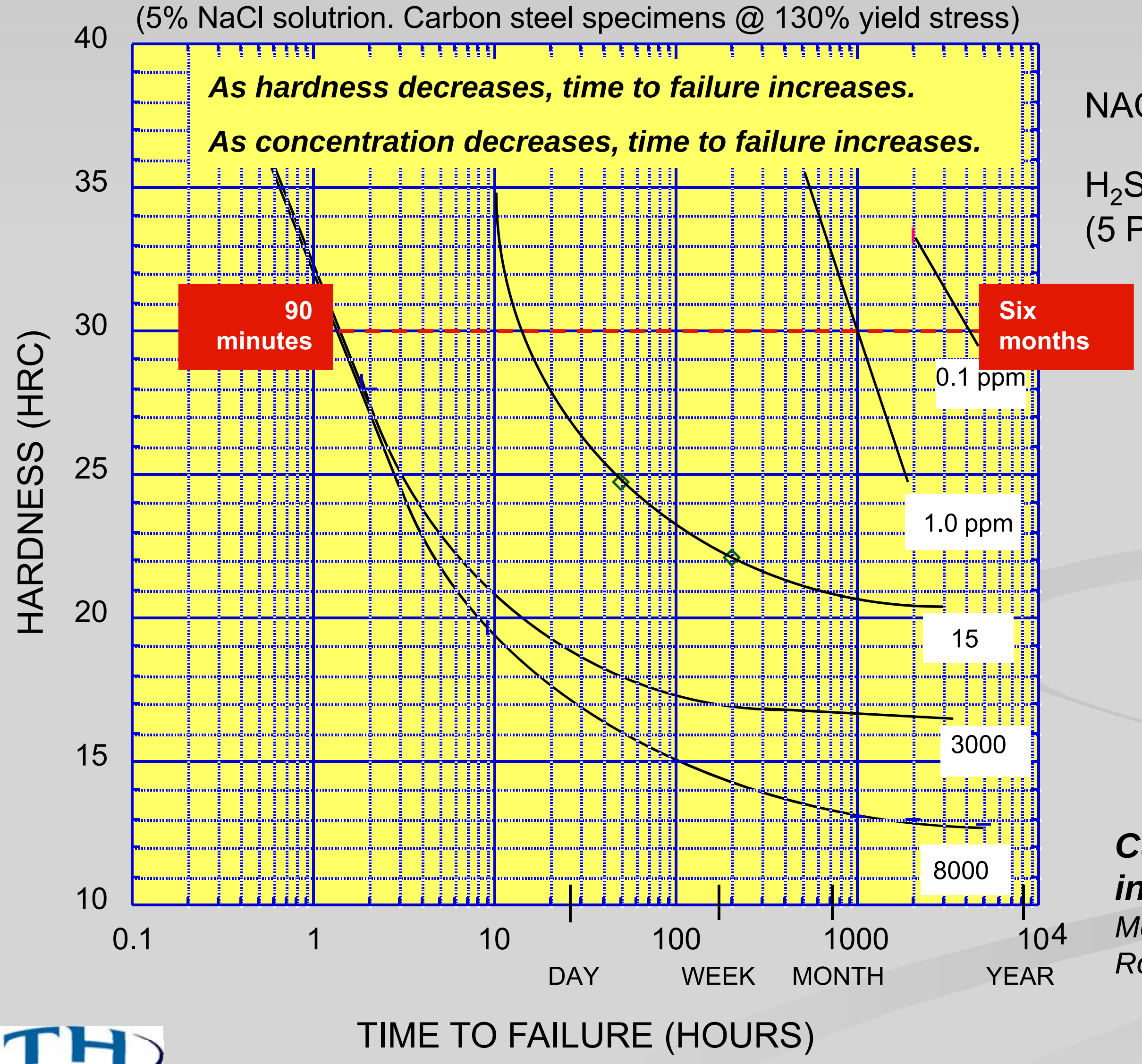
als!

aterial Selection for
e Service

Recall the failure mechanism Sulfide Stress Cracking (SSC)

Free hydrogen generated in the H_2S-Steel corrosion reaction causes otherwise ductile metal to become brittle and crack.

How Hardness and H_2S Concentration Affect SSC


(5% NaCl solutrion. Carbon steel specimens @ 130% yield stress)

As hardness decreases, time to failure increases.

As concentration decreases, time to failure increases.

90 minutes

Six months

NACE definition of “sour:”

H_2S Partial Pressure ≥ 0.05 psia.
(5 PPM @ 10,000 psi)

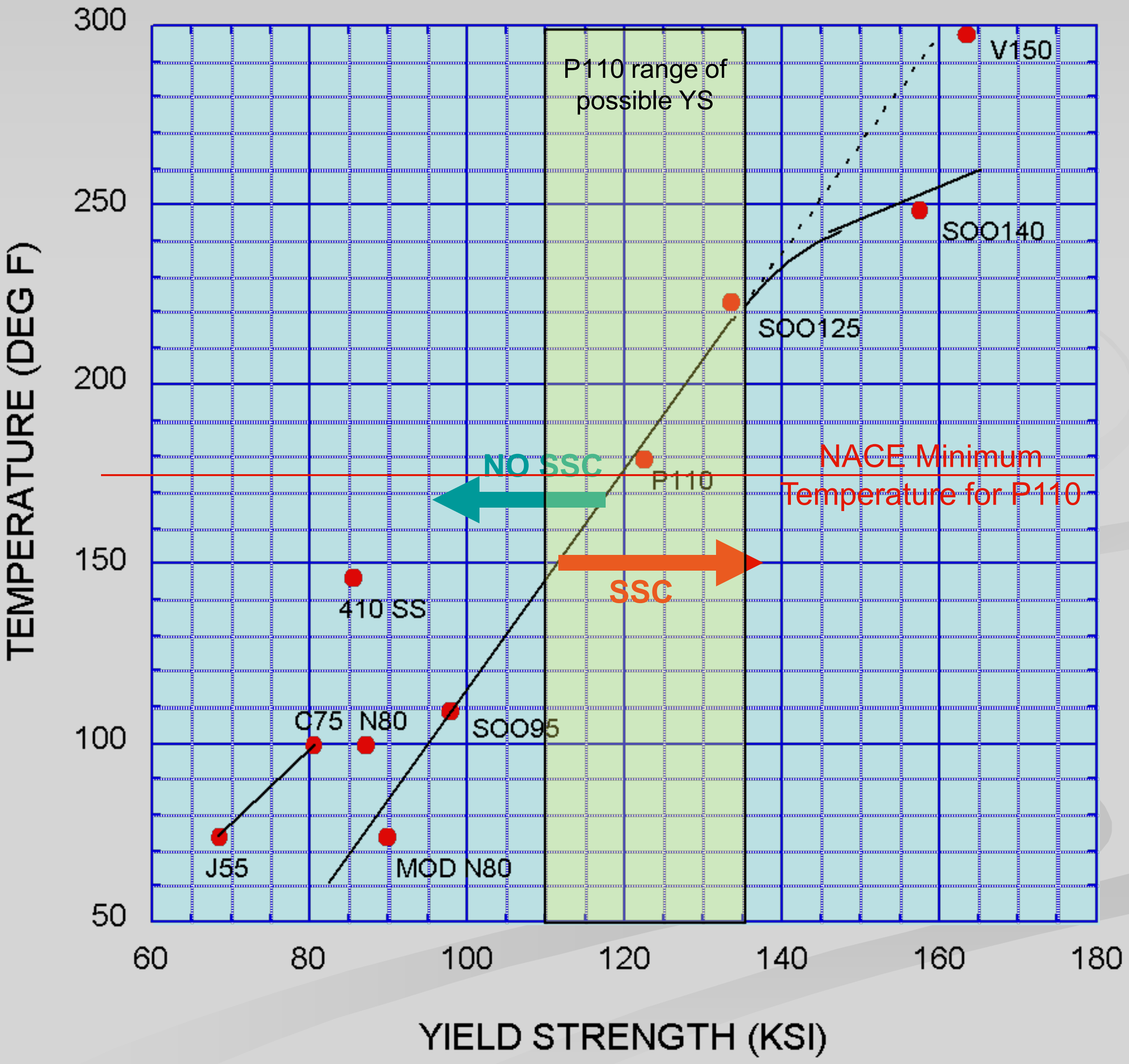
H_2S PPM	H_2S PP @ 10,000 psi
8000	80
3000	30
15	0.15
5	.05
1	.01
0.1	.001

Curves give H_2S concentration in NaCl solution. *(After Hudgins, McGlasson, Mehdizadeh, and Rosborough)*

Temperature and SSC

For a given grade, as minimum temperature increases, liklihood of SSC decreases.

This explains why P110 (for example) may be fine for a deep liner in sour service, but be unacceptable in the same hole near the surface.

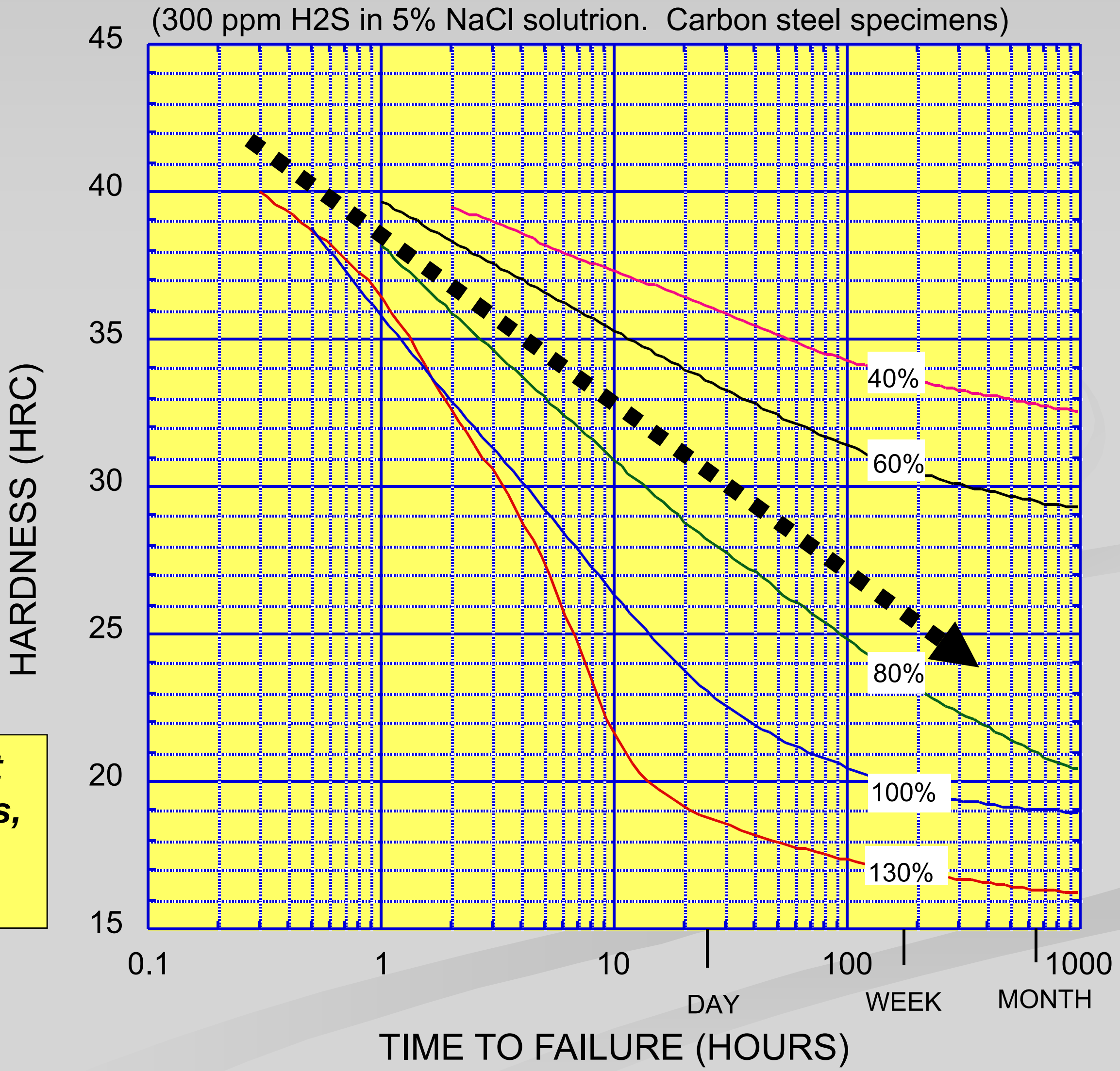


How Hardness and Tensile Stress Affect SSC

Why Group 2 sour service grades (M65,L80,C90,T95) have restricted maximum hardness

As Tensile Stress decreases, time to failure increases.

Curves give stress as a percent of yield strength. (After Hudgins, McGlasson, Mehdizadeh, and Rosborough)



A Corrosion Engineer Selecting a Sour Service Material Will Consider Many Factors:

a. H_2S concentration
b. Chloride levels
c. CO_2 concentration
d. pH
e. Temperature
f. Oxygen content of the flowstream
g. Sulfur content of the flowstream
h. Gas/Oil Ratio
i. Water content of the flowstream
j. Fluid velocity
k. Cost of alternatives
l. Anticipated life of the well

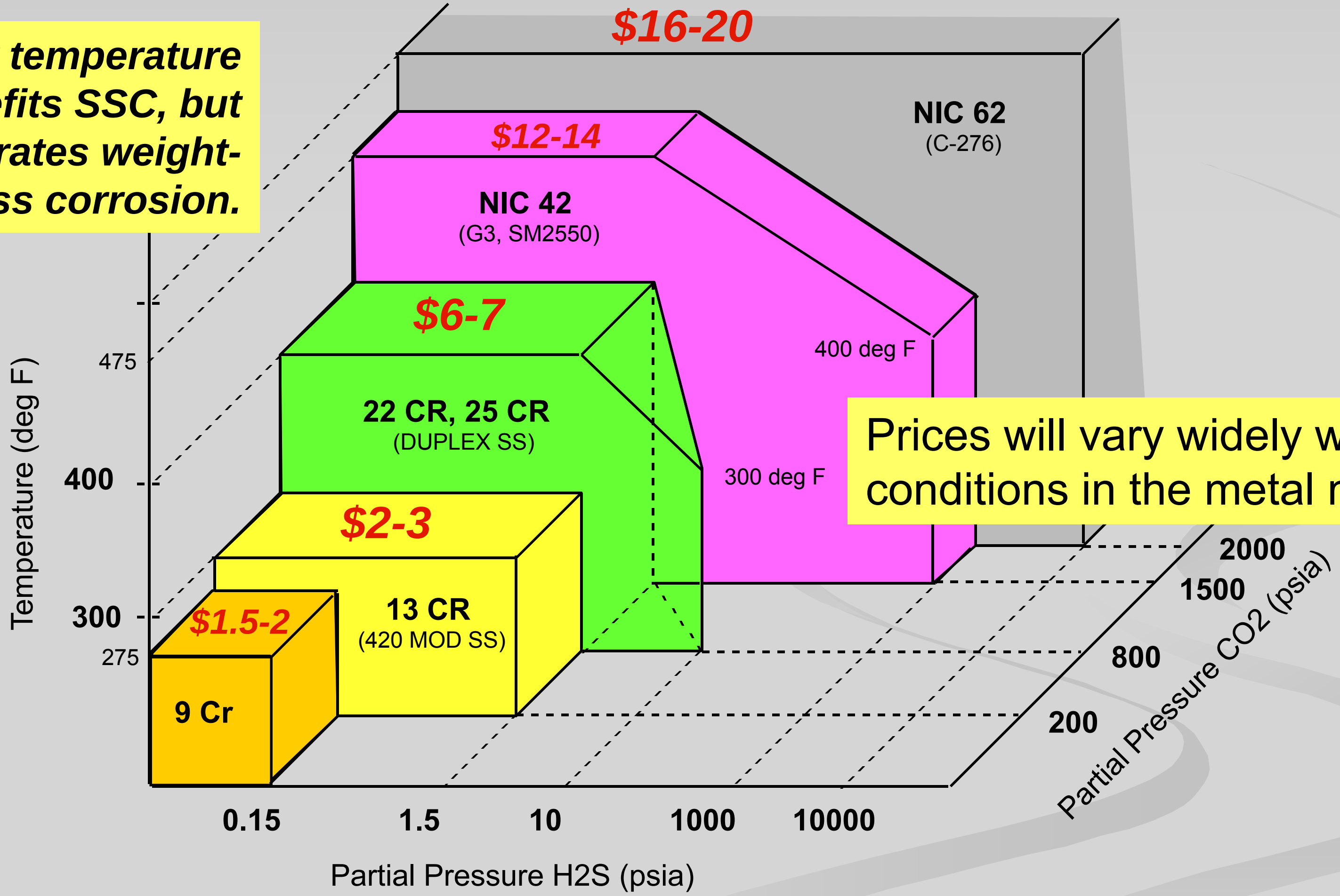
The analysis is complex and the result will be a compromise that's very dependent on "Local Conditions."

Typical Chemistry of Steels

Classification				
	Carbon Steels	**Low Alloy Steels**	**Stainless Steels**	**Nickel Based Alloys**
Element (% Wt.)				
Carbon	0.3 - 0.5	0.3 - 0.5	<0.25	<0.3
Manganese	0.5 - 2.0	<2	<2	<2
Molybdenum	----	<1	<4	<10
Chromium	----	<2	9 - 26	<25
Nickel	----	<1	<25	40 - 70
Iron	>97	>95	40 - 85	2 - 40
Typical Cost Ratios				
	1	1.5	3 - 10	$$$!

Not for Material Selection!
(talk to your corrosion engineer)

A Guide for the Application of Corrosion Resistant Alloys (CRA)



Higher temperature benefits SSC, but accelerates weight-loss corrosion.

Prices will vary widely with conditions in the metal markets.

If L80 Type 1 costs $1

Questions