Materials Challenges for Deep-water Oil & Gas Production

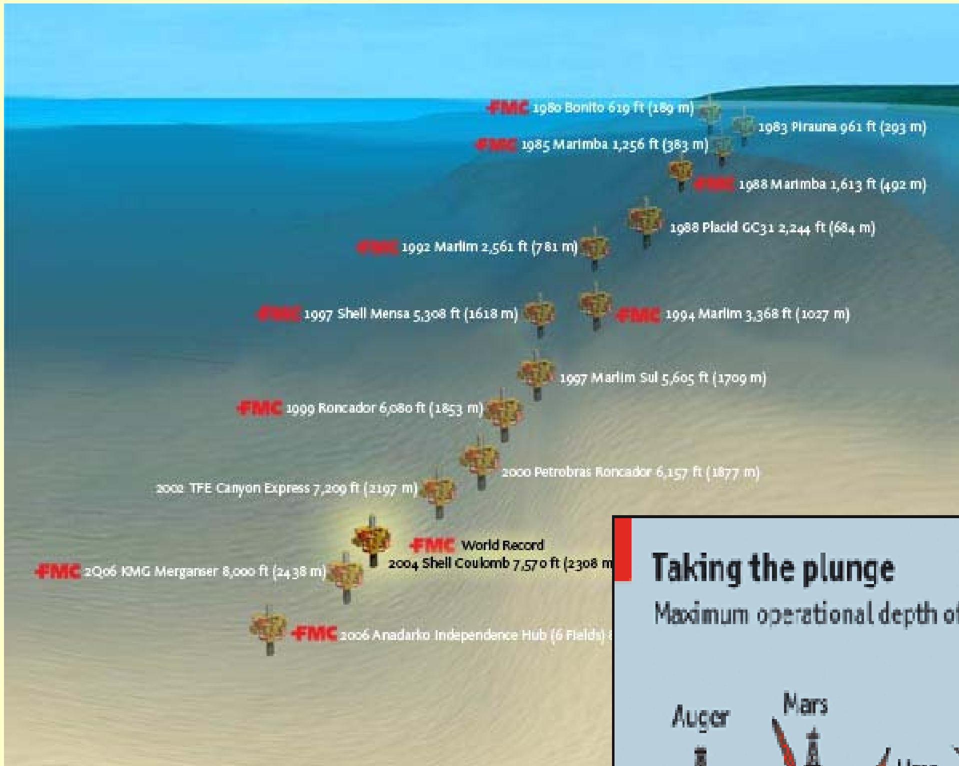
A Presentation for the NACE Houston Chapter
August 13, 2013

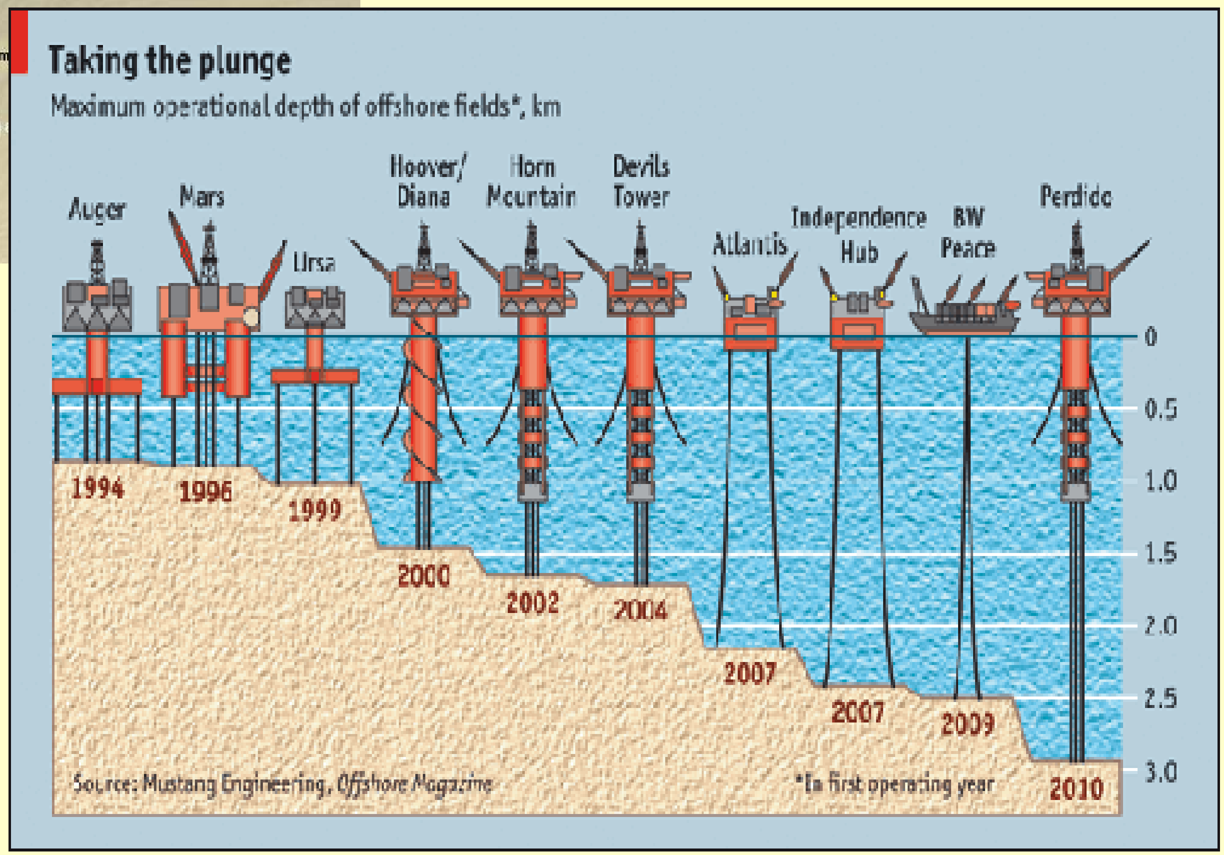
Lillian Skogsberg

&

Jim Skogsberg

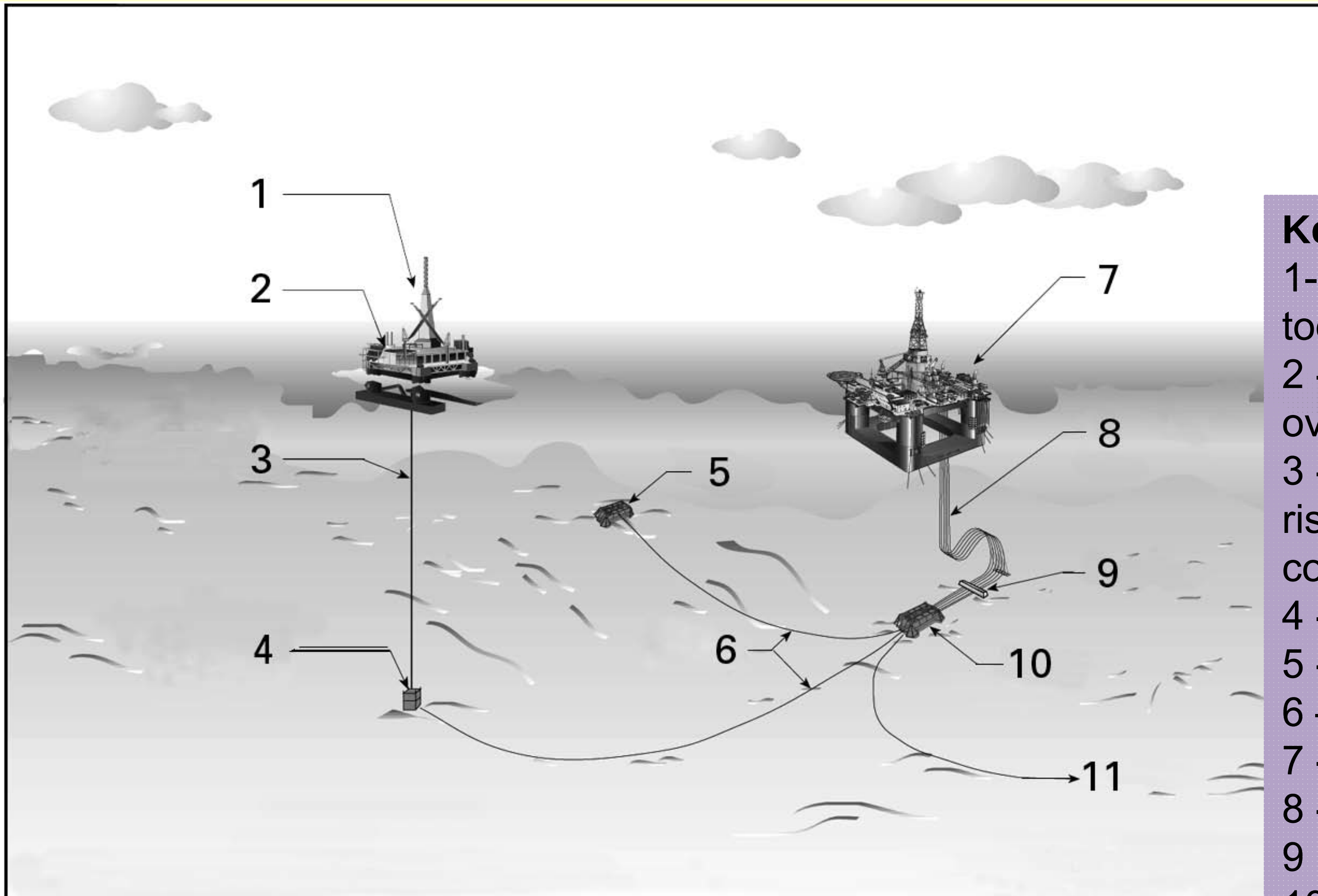
Deepwater Depth History





- Going deeper
- Complex
- Moored
- Floaters
- Subsea

Subsea Scenarios-API 17A



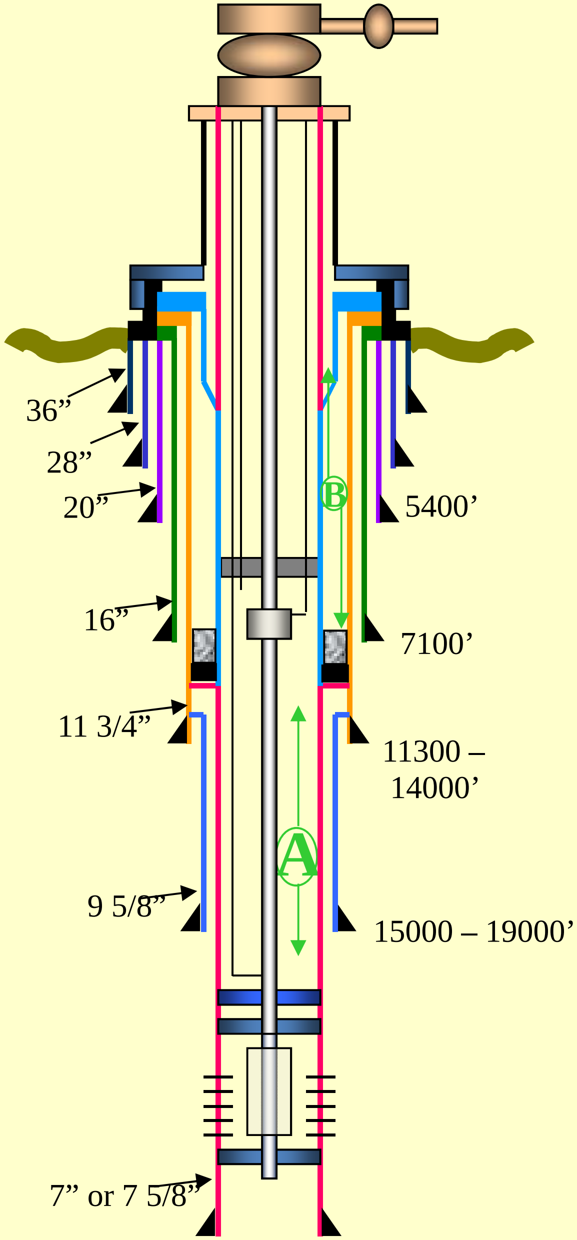
Key
1- Running and retrieving tools
2 - Installation and work over controls
3 - Completion/work over riser and work over controls umbilical
4 - Satellite well
5 - Template
6 – Flow lines
7 - Production controls
8 - Production riser
9 - Riser base/SSIV
10 - Manifold
11 - Export flow line

Subsea production system - several subsystems for HC production from one or more subsea wells and transfer HC to a processing facility located offshore (fixed, floating or subsea) or onshore, or to inject water/gas through subsea wells.

E & P Challenges

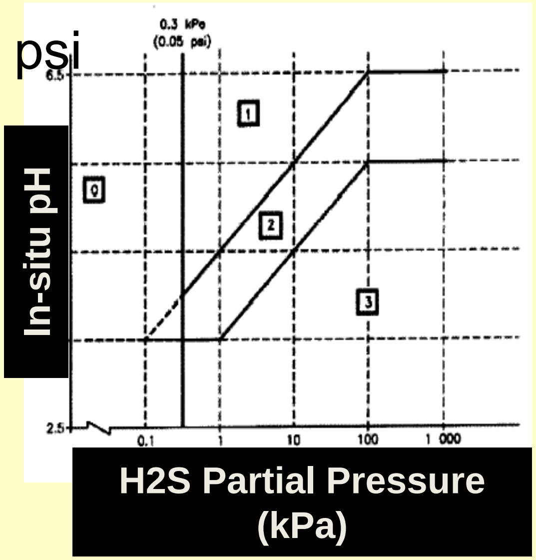
- Targets in deep water water depth > 8,000 feet
- Project Life ~ 30 years
- Mooring adjustments due to hurricanes affect fixed TLP's & subsea structures
- Weight & Space limits on floaters
- EOR
- Maybe HPHT – up to 30,000 psi & 550°F
- Subsea processing
- Well costs on TLP's or Floaters ~ $30MM (drill & complete)
- Well costs subsea ~ $80MM (drill & complete)
- Wells complex
- Commodity shortages
- Mills @ capacity
  - Increasing uncertainty in project estimates
- H_2S – a few ppm to 1,000 psi

Complex Equipment

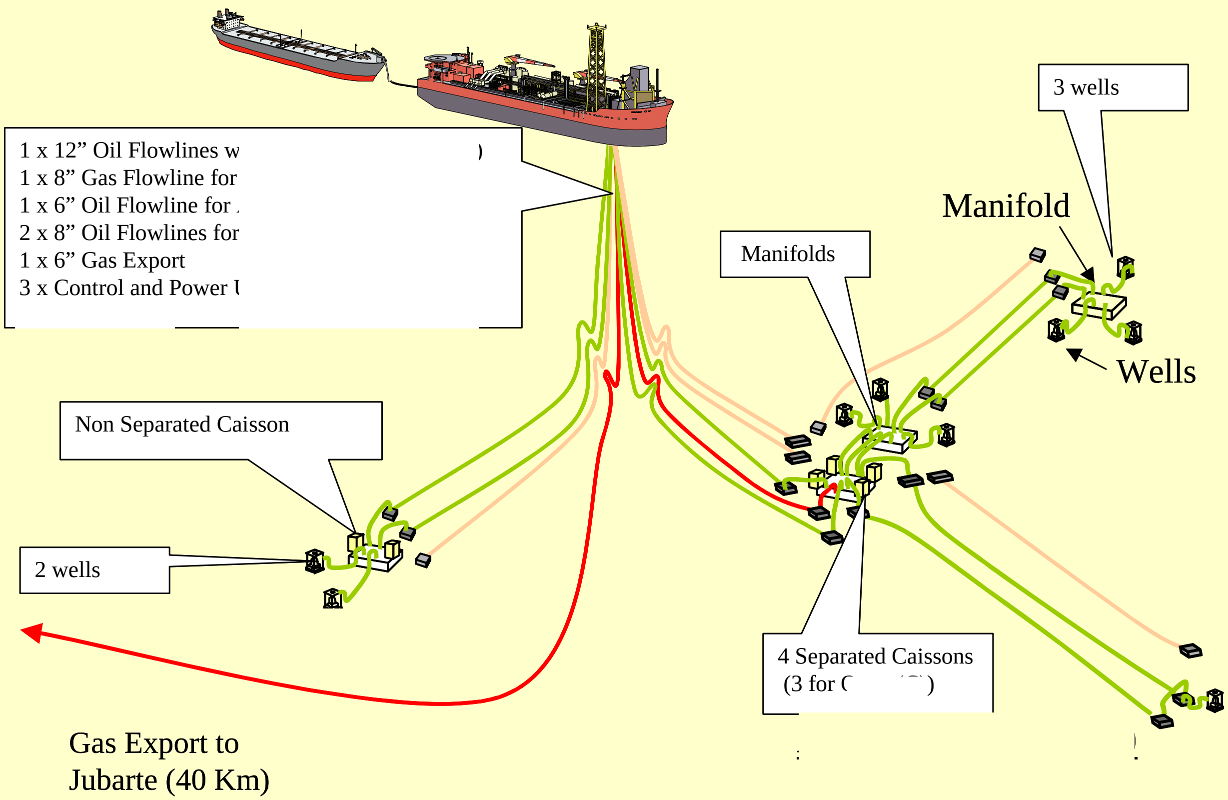


High Pressure High Temperature (HPHT)

- **Target Wells**
  - Bottom Hole Pressure > 20,000 psi – 30,000 psi
  - Temperature > 400°F – 550 F
- **Materials Needed for Completions**
  - NACE MR0175/IS015156 with pH vs H_2S
  - Steel YS > 95 ksi min to 140 – 160 ksi
  - For sour service, K_{ISSC} > 40 ksi√in
  - Long lead times
  - High Qualification Costs
- **Failures in North Sea & GOM:**
  - Tubing hangers, production valves etc.



Subsea Materials Selection



Issues:

- Well equipment
- Trees
- Manifold/ESP
- Jumpers
- Sleds
- **Flow lines-high temp CI needed**
- Umbilicals
- Subsea Control Module
- Seals
- Insulation
- CP
- HSE

Not to mention installation and Operation

Steps in Selecting CRAs

1. Define design life: 10 years, 20 years, zero tolerance for failure ?
2. Establish economic risk: HPHT, high H2S, subsea or deep water?
3. Determine alloy strength requirements based upon design.
4. Choose most economic alloy to prevent general corrosion.
   - CO2 corrosion
   - H2S corrosion
   - Organic acids
5. Consider localized corrosion resistance (pitting & under-deposit corrosion)
   - Chlorides
   - Sulfur
6. Choose alloy to resist environmental cracking.
   - Sulfide stress-cracking and
   - Stress-corrosion cracking

NACEMR0175/ISO1516

7. As needed, compliment field experience and the literature with laboratory study.

Selecting CRAs – Defining Mechanical Properties

- Define required yield strength and tensile strength for design in burst, collapse and tensile load.
- Consider the effect of temperature on yield and tensile strengths.
  - 5% to 15% decrease depending upon the alloy and the manufacturing process
- Some CRAs have non-isotropic mechanical properties.
  - A factor for cold-worked alloys NOT for the 13 % Cr alloys or the age-hardenable alloys (alloy 825, 28% Cr etc.)
  - 5% to 15% decrease depending upon the alloy and the manufacturing process

XHPHT wells –limited design data.

No recognized industry data base for design.

Selecting CRAs: Define All Environments That May Cause Corrosion & Cracking

- **Production Environment: short-term & long-term**
  - Water cut, bubble point, velocity, pH, & chlorides.
  - Partial Pressures of H_2S & CO_2
    - Reservoir souring?
  - BHT & surface or mud-line temperatures
  - BHP & FTP
  - Contaminants – organic acids
  - Desired project life: 5 yrs, 10 yrs, or 20 yrs?
- **Annular Environment: short-term & long-term**
  - Chlorides – types of clear brines – NaCl, $NaBr_2$, $ZnBr_2$
    - pH, oxygen scavenger, corrosion inhibitor, & biocide
  - Effect of acid gas leaks up the annulus
- **Workover:**
  - Acidizing, clear brines without inhibitor & oxygen scavenger, & mixing with sour gases during flow back.
  - Flow back through subsea equipment
  - Shut in conditions (weeks, months to years)

Both production and annular environments must be documented for changing conditions.

Challenges for Selection of Low Alloy Steels

- **Forgings**:
  - Thicker-walls
  - Higher strengths >80 ksi SMYS
  - Weldability : <250 HVN hardness in sour service & < 350 HVN hardness in sea water with CP
- **Casing and Tubing:**
  - Strength grades of 110 ksi to 140 ksi with good notch toughness
  - In sour service, grades >95 ksi with cracking resistance down to +40°F.
  - Reliable industry data base for effect of temperature on mechanical properties
- **For all equipment:** lead time for delivery

Tubing and Casing Part 2 Table A.3 uses Designations in API Spec 5CT/ISO

	Operating Temperatures[B]		
All Temperatures[A]	>66°C (150°F)	>79°C (175°F)	≥107°C (≥225°F)
Tubing and Casing Grades	Tubing, Casing Grades	Tubing, Casing Grades	Tubing, Casing Grades
H-40,[C] J-55, K-55, M-65, L-80 (type 1), C-90 type 1, T-95 type 1	N-80 (Q & T), C-95	N-80, P-110	Q-125[G]
Proprietary[H] grades as described in A.2.2.3.3	Proprietary Q&T to 700 MPa (110 ksi) max. YS	Proprietary Q&T to 965 MPa (140 ksi) max. YS	
Pipe now in Table A.2.			

No major changes in 2003.

Challenges for Selection of CRAs

- Alloys must be evaluated for resistance to SCC at 450°F>T> 550°F.
  - Most wells in the world are at <350°F.
  - NACEMR0175 limits alloys to 450°F except for C-276 and C-22HS.
- Alloys must be evaluated with 160 ksi min SMYS
  - Except for alloy C-276, NACEMR0175 limits alloys to 150 KSI max YS.
- Evaluation of age-hardenable nickel-base alloys for hydrogen embrittlement service
  - Failures of tubing hangers and packers
  - Clear brine packer fluids, galvanic coupling, acidizing, & cathodic protection
  - Not covered in NACEMR0175.
- Need a reliable industry data base for effect of temperature on mechanical properties
  - Transverse vs. longitudinal
- Lead time for delivery
  - Major issue for large diameter and range 3 pipe.

Table A.14: Cold Worked Ni-Based Alloys

Ni-based alloys are grouped by composition.

Type 4C: Alloys 825, 28Cr, & 2535.

Type 4D: Alloys G-3, 2550 & G-50

Type 4E: Alloy C-276

Alloy Type Compositions Defined in Table A.12

Table A.14 —Environmental and materials limits for annealed and cold-worked, solid-solution nickel-based alloys used as any equipment or component

Materials type	Temperature max. °C (°F)	Partial pressure H_2S p_{H_2S} max. kPa (psi)	Chloride conc. max. mg/L	pH	Sulfur-resistant?	Remarks
Cold-worked alloys of types 4c, 4d and 4e	232 (450)	200 (30)	See "Remarks" column	See "Remarks" column	No	Any combination of chloride concentration and *in situ* pH occurring in production environments is acceptable.
	218 (425)	700 (100)	See "Remarks" column	See "Remarks" column	No	
	204 (400)	1 000 (150)	See "Remarks" column	See "Remarks" column	No	
	177 (350)	1 400 (200)	See "Remarks" column	See "Remarks" column	No	
	132 (270)	See "Remarks" column	See "Remarks" column	See "Remarks" column	Yes	Any combination of hydrogen sulfide, chloride concentration and *in situ* pH in production environments is acceptable.
Cold-worked alloys of types 4d and 4e	218 (425)	2 000 (300)	See "Remarks" column	See "Remarks" column	No	Any combination of chloride concentration and *in situ* pH occurring in production environments is acceptable.
	149 (300)	See "Remarks" column	See "Remarks" column	See "Remarks" column	Yes	Any combinations of hydrogen sulfide, chloride concentration and *in situ* pH in production environments are acceptable.
Cold-worked alloys of type 4e	232 (450)	7 000 (1 000)	See "Remarks" column	See "Remarks" column	Yes	Any combination of chloride concentration, *in situ* pH occurring in production environments is acceptable.
	204 (400)	See "Remarks" column	See "Remarks" column	See "Remarks" column	Yes	Any combination of hydrogen sulfide, chloride concentration and *in situ* pH in production environments is acceptable.

Wrought or cast solid-solution nickel-based products in these applications shall be in the annealed and cold-worked condition and shall meet all of the following.

a) The maximum hardness value for alloys in these applications shall be 40 HRC.

b) The maximum yield strength of the alloys achieved by cold work shall be

— Type 4c: 1 034 MPa (150 ksi);

— Type 4d: 1 034 MPa (150 ksi);

— Type 4e: 1 240 MPa (180 ksi).

c) UNS N10276 (Type 4e) when used at a minimum temperature of 121°C (250°F) shall have a maximum hardness of 45 HRC.

NOTE The limits of application of the materials types 4c, 4d and 4e in this table overlap.

Metallurgical properties.

Summary

- The production of oil and gas from deep water wells provides technical challenges in the development of materials to provide safe and reliable service at reasonable cost.
- Materials technology continues to evolve to meet this challenge.

Thank you for your attention and the opportunity to present this talk. Are there any questions?