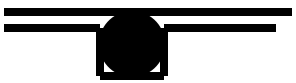
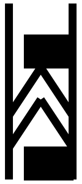
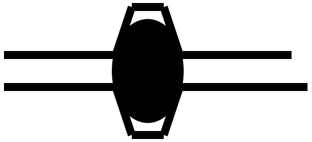
Seals – Performance and Selection

- Seal Types
- Mechanical Considerations
- Chemical Factors
- Time Stability

Common Seal Types

- “O”-ring

- Chevron Seals

- Seal Packs

- Metal-to-metal


O-Rings

- Fundamentals
  - good static or dynamic seal
  - best where clearances are close and consistent
  - seal abrasion must be minimal: smooth sealing surfaces
  - can stand high pressure differential, may need back-up rings in some cases
  - needs only small amount of compression to activate
- Problems
  - gas permeation and rapid depressurizing of system
  - softening and swelling in fluids – may lead to failure
  - one small scratch in “O”-ring or seal bore ruins seal

Chevron Packing

- Fundamentals
  - good static seal, decent dynamic seal in some cases
  - works with more varied clearances than O-rings
  - can stand some seal abrasion, solids and rougher surfaces
  - can stand high pressure differential
  - needs compression to activate
- Problems
  - gas permeation and rapid depressurizing of system may temporarily swell seal – causes drag in a few cases
  - softening and swelling in fluids – may lead to failure

Seal Types

- Chevron seals offer the highest differential pressure compared with Bullet & Molded type seals, the seal assembly mandrel retains high burst and collapse ratings
- Bullet type seals are more robust than Chevron seals. Problems – poor memory (rebound after cooling may not occur).
- Molded Type Seals are most robust (Elastomer molded on metal seal ring and an O-ring that seals between the mandrel and the metal back-up ring).

Seal Packs

- Fundamentals
  - good static or dynamic seal
  - can mix seals to work over broad temperature
  - can stand some seal abrasion
  - can stand moderate to moderate pressure differential
  - needs compression to activate
  - some seal materials less affected by gas permeation
- Problems
  - larger seal area needed, often multiple seal packs used
  - potential for bonding softer seals to steel in long term set seals.

Metal-to-metal Seals

- Fundamentals
  - excellent static seal
  - can stably hold high pressure at high temperature
  - needs compression or deformation to activate
  - not affected by gas permeation
- Problems
  - often used only once (if deformation needed for the set)
  - high energy seal areas subject to corrosion and hardening

Where used?

- O-rings: internally in tools and equipment where protected from wellbore fluids and solids
- Chevron seals: plugs, dynamic seals, re-settable tools, stingers
- Seal Packs: stingers, some plugs, packers
- Metal-to-metal: flanges (single use recommended), packers, and SSSVs (resealable)

Halliburton Energy Services
General Guidelines For Seals [1]

Compound	PEEK[2], [4]	Ryton[2], [4]	Fluorel[3] Filled	Aflas[3] Unfilled	Chemraz[3] Unfilled	Viton[3] Filled	Viton[3] Unfilled	Neoprene[3] Filled	Nitrile[3] Filled	Kalrez[3] Filled	Teflon[3] Filled	Teflon[3] Unfilled
Service °F (°C)			350 (177)	350 (177)	450 (232)	350 (177)	325 (163)	300 (149)	275 (135)	450 (232)	400 (204)	325 (163)
Pressure[2], [4] psi (MPa)			15,000 (103)	10,000 (68.9)	15,000 (103)	Above 5000 (34.4)	Below 5000 (34.4)	5000 (34.4)	3000 (20.7)	15,000 (103)	15,000 (103)	5000 (34.4)
Environments H_2S	A	A	A	A	A	B	B	NR	NR	A	A	A
CO_2	A	A	B	B	A	B	B	C	A	A	A	A
CH_4 (Methane)	A	A	A	A	A	A	A	B	B	A	A	A
Hydrocarbons (Sweet Crude)	A	A	A	A	A	A	A	B	A	A	A	A
Xylene	A	A	A	C	A	A	A	NR	NR	A	A	A
Alcohols	A	A	C	B	A			B	A	A	A	A
Zinc Bromide	A	A	A	A	A	A	A	NR	NR	A	A	A
Inhibitors	A	A	NR	A	A	NR	NR	NR	B	A	A	A
Salt Water	A	A	A	A	A	A	A		A	B	A	A
Steam	A	A	NR	A	A	NR	NR	NR	NR	NR	B	B
Diesel	A	A	A	NR	A	A	A	B	B	A	A	A

A-Satisfactory | B - Little or no effect | C - Swells | D - Attacks | NR - Not recommended | NT - Not tested

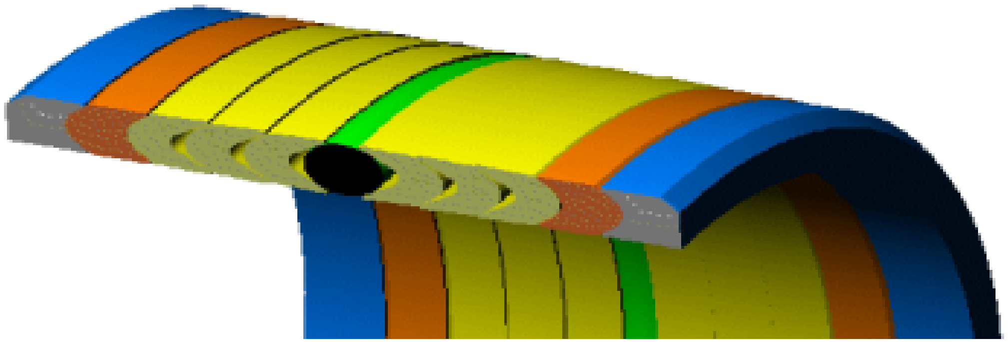
NOTE: (1) This information provides general guidelines for the selection of seal materials and is provided for informational purposes only. Seal Specialists with Halliburton Energy Services should be consulted for the actual selection of seals for use in specific applications. Halliburton Energy Services will not be liable for any damage resulting from the use of this information without consultation with Halliburton Seal Specialists.

(2) Contact Technical Services at Halliburton Energy Services - Dallas for service temperature and pressure.

(3) Back-Up Rings must be used.

(4) There could be a slight variation in both temperature and pressure rating depending on specific equipment and seal designs.

Halliburton Energy Services
General Guidelines For V-Packing[1]



Typical V-Packing Cross Section

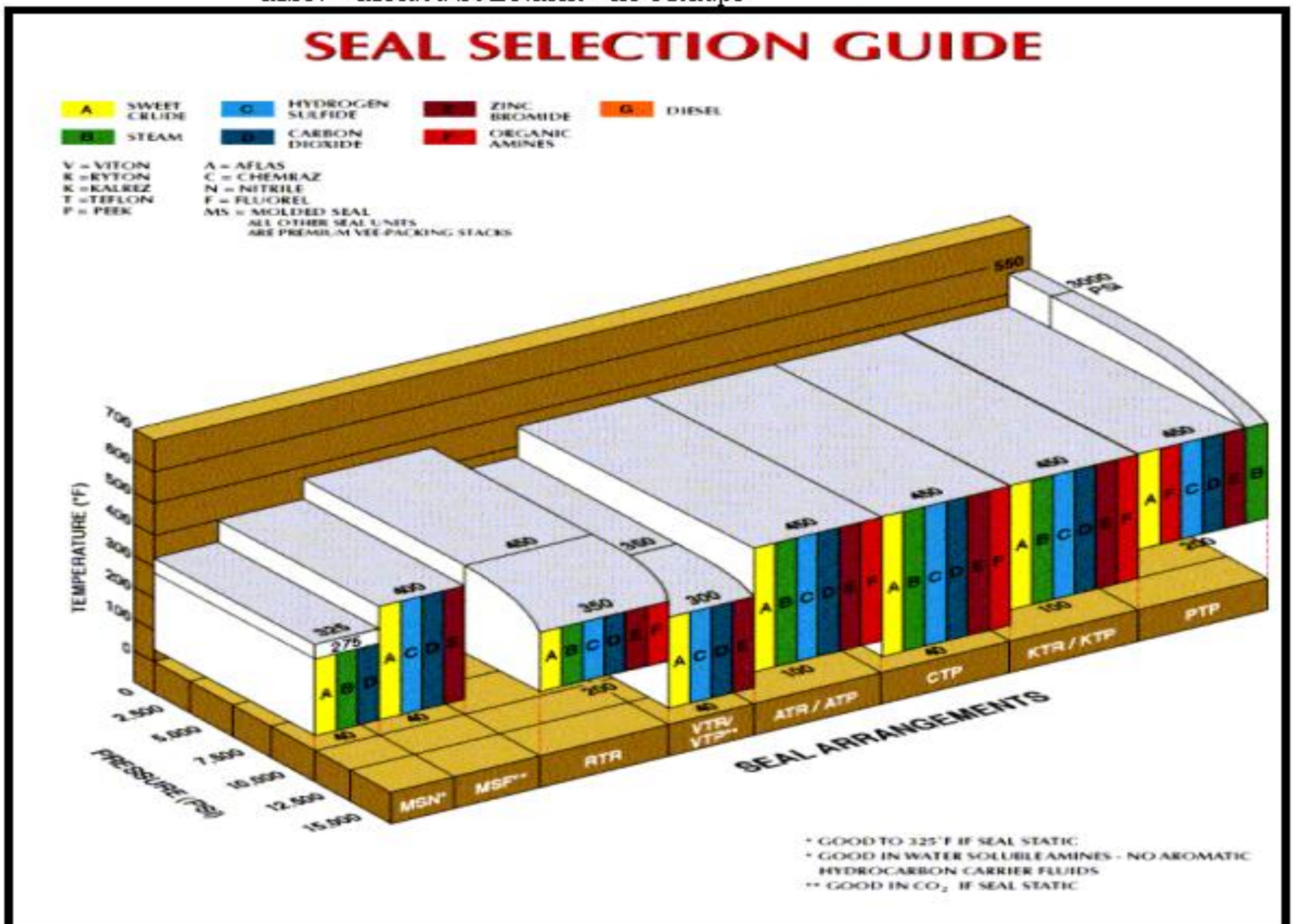
Compound	PEEK(1)	Ryton(1)	Fluorel(2) Filled	Aflas(2) Unfilled	Chemraz(2) Unfilled	Viton(2) Filled	Viton(2) Unfilled	Neoprene(2) Filled	Nitrile(2) Filled	Kalrez(2) Filled	Teflon(2) Filled	Teflon(2) Unfilled
Maximum Temperature °F (°C)			350 (177)	350 (177)	450 (232)	350 (177)	325 (163)	300 (149)	275 (135)	450 (232)	400 (204)	325 (163)
Maximum Pressure (2) psi (Mpa)			15,000 (103)	10,000 (68.9)	15,000 (103)	≥ 5,000 (34.4)	<5,000 (34.4)	5,000 (34.4)	3,000 (20.7)	15,000 (103)	15,000 (103)	5,000 (34.4)
Environments H_2S	A	A	A	A	A	B	B	NR	NR	A	A	A
CO_2	A	A	B	B	A	B	B	C	A	A	A	A
CH_4 (Methane)	A	A	A	A	A	A	A	B	B	A	A	A
Hydrocarbons (Sweet Crude)	A	A	A	A	A	A	A	B C	A	A	A	A
Xylene	A	A	A	B	A	A	A	NR	NR	A	A	A
Alcohols	A	A	C	B	A	C	C	B	A	A	A	A
Zinc Bromide	A	A	A	A	A	A	A	NR	NR	A	A	A
Inhibitors	A	A	NR	A	A	NR	NR	NR	B	A	A	A
Salt Water	A	A	A	A	A	A	A	C	A	B	A	A
Steam	A	A	NR	A	A	NR	NR	NR	NR	NR	B	B
Diesel	A	A	A	NR	A	A	A	B	B	A	A	A

A-SATISFACTORY | B-LITTLE OR NO EFFECT | C-SWELLS | D-ATTACKS | NR-NOT RECOMMENDED | NT-NOT TESTED

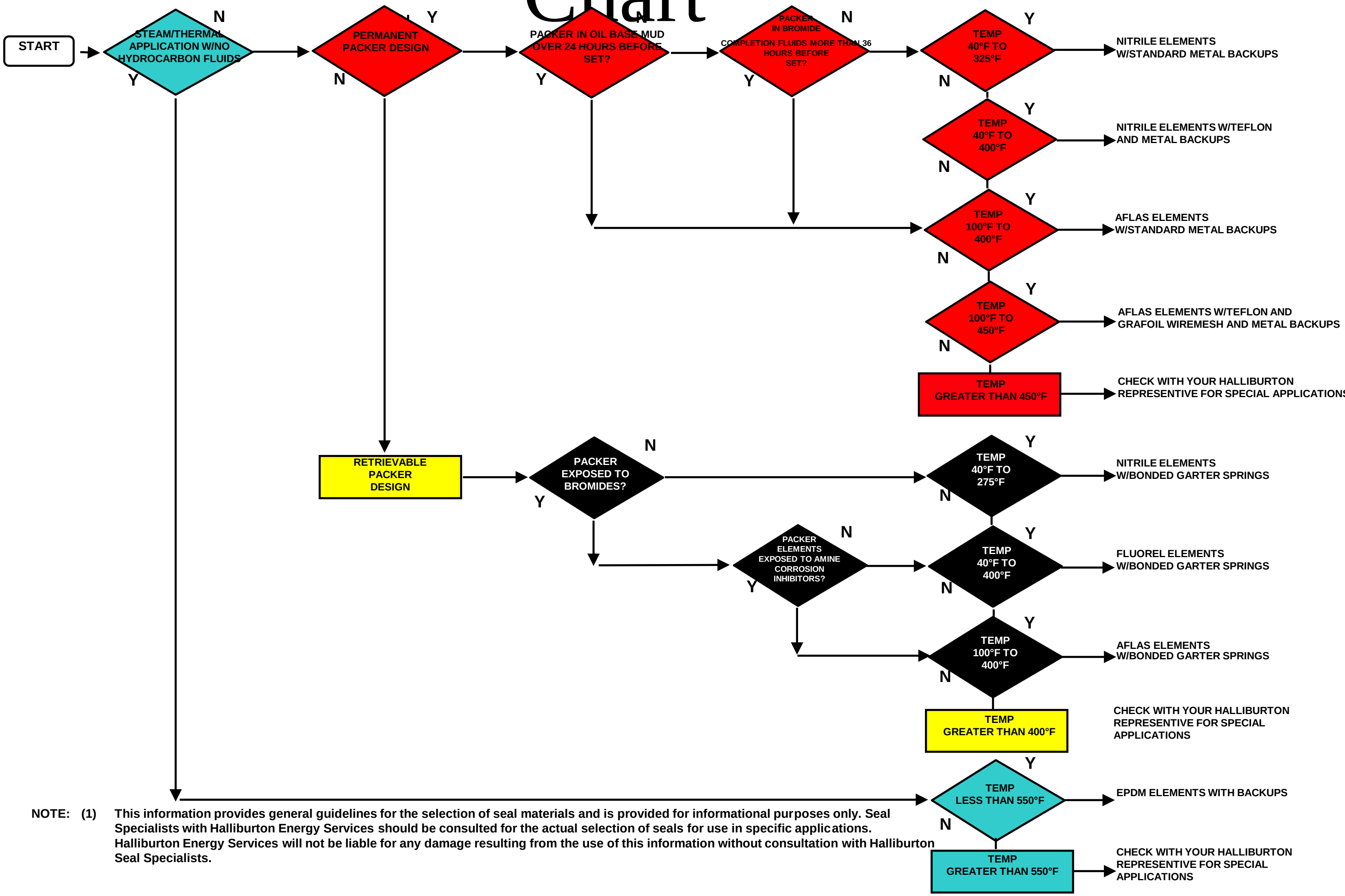
Halliburton Energy Services
General Guidelines For V-Packing (1)

Examples:

KTR = **K**alrez with **T**eflon and **R**yton backups
VTP = **V**iton with **T**eflon and **P**eek backups
MSN = **M**olded **S**eal **N**itrile - no backups



Packer Element Selection Chart (1)



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Seal Material Concerns

- Elastomers
  - contacting fluids – more from chemical compatability and gas permeation
  - dynamic or static – can be either, but movement will eventually fail any seal.
  - temperature – how does temperature affect seal hardness and are chemical resistances changed.
  - time – can be a real problem since elastomer seals can become hard with time or even bond to another surface.
  - pressure – depends on several other issues, mostly associated with chemical stability at a particular temperature.
  - stabbing – the act of stabbing when metal or rock debris is in the area can cut seals and ruin them.
  - activation – many elastomer seals require some load (physical deformation) to seal.

Seal Material Concerns

- Metal-to-metal
  - contacting fluids and erosion and corrosion – must be cautious of metal surface finish preservation.
  - dynamic or static – almost always static seal – movement and friction are killers.
  - pressure differential – can hold very high pressure and stable for long periods without degradation of seal.
  - temperature effects (concern about expansion/contraction)
  - activation issues – is deformation required
  - re-sealing issues – only good for once? – depends on how they are used and what effect deformation plays in sealing.

Gas Permeation – Part 1

- Gas permeation of elastomers is a simple migration of gas or gasses through the structure of elastomers in response to a pressure differential.
- The amount of gas invasion of an elastomer depends upon the type and structure of the material, time of exposure, differential pressure, area of the material surface exposed, type of gas, and the gas viscosity.
- Almost all elastomers are permeable to some small degree and therefore are vulnerable to gas invasion. Most are not permanently damaged.

Gas Permeation, Part 2

- Permeation of any material by gas does not, in itself, typically present a problem. The problem arises when the pressure is <u>suddenly</u> lost; a condition known as explosive decompression.
- If the surface of the material has less strength than the differential pressure applied from the trapped gas trying to escape from the pores of the structure; the gas can overcome the tensile strength of the material, forming bubbles or blisters on the surface.

Gas Permeation/Explosive Decompression Problems

- Upon pressure loss, the gas may vent through the pores of the material, create temporary bubbles and vent through the skin of the bubble or form bubbles in the elastomer structure and burst.
- Whether a bubble forms depends on the strength of the material, the differential pressure, how much time is allowed for the pressure to equalize, the permeability of the elastomer and how much gas has penetrated it.

Bubbles, Blisters and Sealability

- If bubbles form at sealing sites (surface blisters), the seal can be temporarily or permanently lost.
- Formation of surface blisters along the non-sealing part of the material's body usually do not seriously compromise the strength of the material.

Bubbles, Blisters and Sealability

- “O”-rings (with extremely small contact areas and large surface to mass ratios, may exhibit severe swelling of the entire body, followed by a slow return to normal size and shape as the gas is lost.
- If the “O”-ring seal assembly does not move during gas exposure (static seal), the sealing ability may not be lost. If the assembly is forced to move (dynamic seal), the seal may be lost and/or the “O”-ring may be destroyed.

Bubbles, Blisters and Sealability

- Blistering may or may not occur, depending upon the material. The difference is in the strength of the material at its surface, the pressure differential, the permeability of the seal and individual conditions encountered in the well.

Sources of Information on Seals

- BP experts (Steve Groves, etc.)
- Vendor specialists (be careful)
- Seal charts (must examine test conditions, times and what is defined as a failure)
- Qualification Tests

Seal Selection Tests

- Short-duration, static, immersion, pressure?
- ASTM and NACE TM0187-87
  - mechanical properties by tensile testing
  - swelling and shrinkage information
  - gas permeation and explosive decompression

<u>These data are very hard to translate to seal performance in the downhole environment</u>

- Better Way? - test fixture like downhole or use data base for seal failures

Seal Qualification

- degradation prediction
  - can be estimated through test performance - SPE 19351, SPEPE, Aug 1990.
  - look at seal requirements and seal behavior to the entire environment

Other Seals - Pack-off Seal and Efficiency

- Increasing pack-off pressure beyond what is needed causes excessive wear during movement of wire or CT.
- No lubrication may increase friction and damage to rubber and/or steel.

Solvent and Seals

- Chemical effects, like that of xylene, toluene, alcohols and amines, etc., depends on time of exposure, temperature and the material involved (Recommended Contact: Steve Groves – BP).

Solvent and Seals

- RTR stack should have no problems with the xylene - Ryton and Teflon are very resistant to chemical attack in most oilfield circumstances.
  - Only use such a stack in a HT well - all the materials are plastic rather than elastomers, and so will have problems energizing below 200F, eg during thermal transients.
  - Secondly, in dynamic applications, Ryton tends to not have as high an upper limit as the suppliers recommend - if you're above 300F, recommend changing the Ryton to PEEK if possible.

Solvents and Seals

- Viton should have no problems with short term exposure to xylene.
- However, small section seals, ie O-rings, T-seals and V-rings, made from either nitrile or Aflas may have problems due to excessive swell, particularly at high temperature.
  - not recommend use above 200F max in xylene
  - we had bad experience with Aflas PBR seals in xylene on Clyde (BHT = 300F).
  - packers should not be affected at all.

Pack-off Seal and Efficiency

- Increasing packoff pressure beyond what is needed causes excessive wear.
- No lubrication may increase friction and damage to rubber and/or steel.

Seals

- Metal-to-metal
- Elastomers
  - contacting fluids
  - dynamic or static
  - temperature
  - time
  - pressure
  - stabbing
  - activation

Seal Selection Tests

- Short-duration, static, immersion, pressure?
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Ram Requirements for a Job

SPE 27503

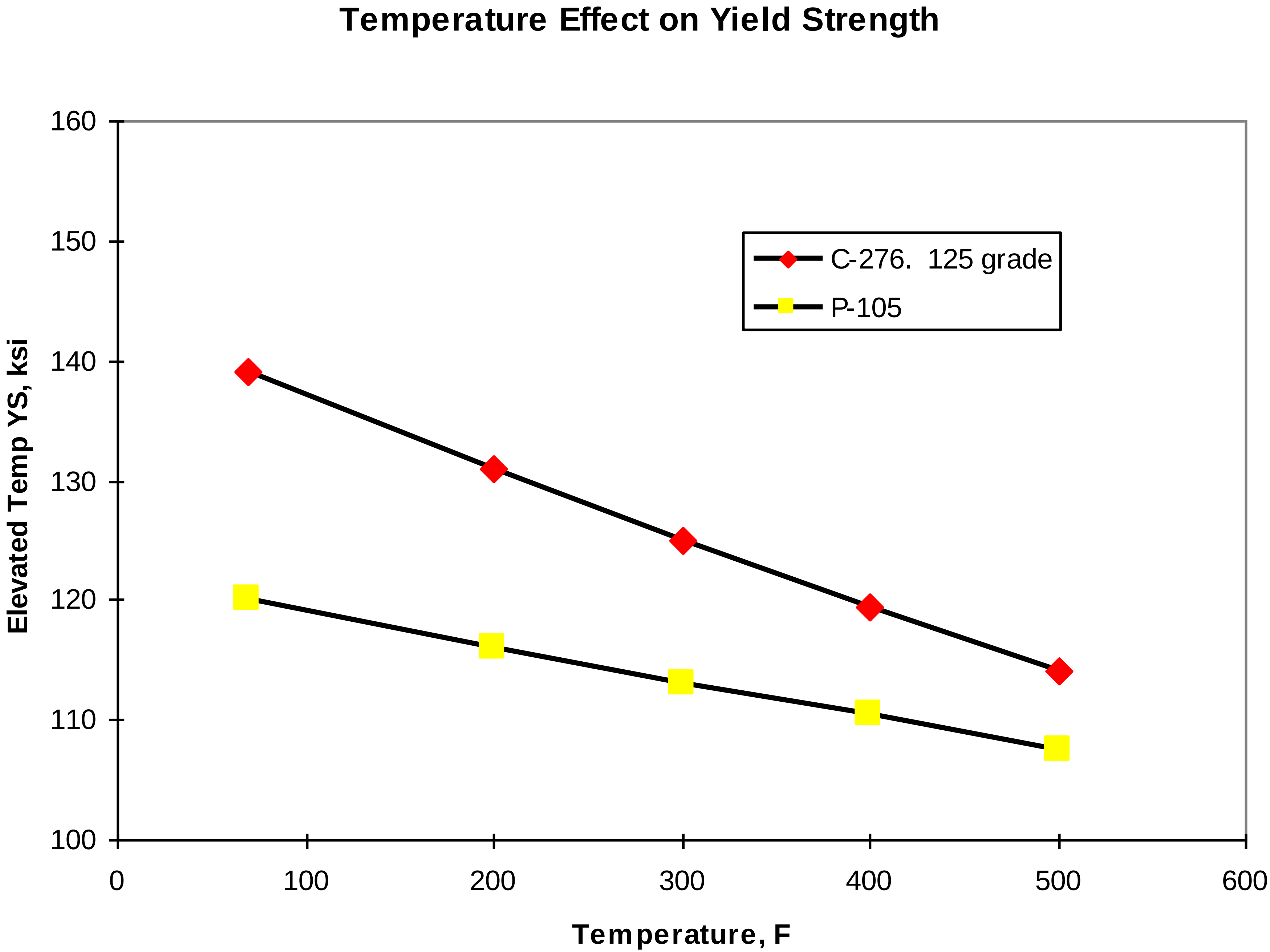
1. Are shears required to seal? Gate valve above BOPs?
2. Are shears required to cut all tubing sizes?
3. Are shears required to shear WL and cable?
4. Are shears required to cut sucker rods or sinker bar?
5. Does sheared string need to be suspended?
6. Will rams be needed for stripping or snubbing?
7. How many different tube diameters are to be run?
8. Can ram packers (seals) be changed out between string changes?

Corrosion Resistant Alloys

		Nominal Chemistries					
		Fe	Ni	Cr	Mo	Other*	Example Alloys
Class I	Martensitic SS	87		13			410, 420 13% Cr
Class II	Duplex SS	70	5	22	3		2205, 2507, duplex
Class III	Ni-Fe-Cr-Mo	33	37	25	3	3	Incaloy 825
Class IV	Ni-Fe-Cr-Mo	16	50	25	6	3	Hasteloy G-3
Class V	Ni-Cr-Mo	5	60	15	15	5	Hasteloy C-276
							Inconel 625

* cobalt, columbium, tungsten, titanium

SPE 19727


Temperature Effect on Yield Strength
C-276. 125 grade
P-105
Elevated Temp YS, ksi
160
150
140
130
120
110
100
0
100
200
300
400
500
600
Temperature, F