RAPTOR™
NYLON PIPE

# Overcoming Challenges Associated With Matching Wellhead Pressure Throughout The Well Operation Through New Thermoplastic Pipe Applications

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# OVERVIEW

- About INVISTA
- Flow line material challenges
- Flow line landscape
- Overcoming contradictions of nylon 6,6
  - Advantages
  - Challenges
- Short-term pressure ratings
  - Development process
  - Determining value and practicality

# Raptor™ Nylon Pipe – Made of Tough.™

## INVISTA

- 75+ years in nylon 6,6 technology
- Expertise in high-temperature, highly corrosive environments
- A Koch company

## Koch Industries

- Oil and gas connections include:
  - Koch Supply & Trading
  - Koch Exploration
  - Koch Pipeline
  - Koch Minerals
- Koch Energy Services
- John Zink Hamworthy Combustion
- Frac-Chem
- Raptor™ nylon pipe

INVISTA™

KOCH™

# COLLECTION AND RETURN LINES – MATERIALS CHALLENGES

- **Fluid environment**
  - Hydrocarbons
  - Natural gas
  - Produced & flowback water  pH 6-8
    - Water, salts, metals, radionuclides, production chemicals.
    - Benzene, naphthalene, toluene, phenanthrene, pentachlorophenol, glycols, alcohols, halogens, amides, aromatic hydrocarbons
  - Solids
- **Service environment**
  - Oilpatch pressures (<400 PSI) and temperatures (up to 200°F)
  - Toughness factor
- **Practical considerations**
  - Ability to be coiled
  - Needs to be joinable/weldable (low cost option)
  - No special tools for installation

# MATERIALS AVAILABLE TO THE MARKET

| | HDPE | Composites | Fiberglass | Steel | Standard nylon 6,6 |
|---|---|---|---|---|---|
| Temperature | 140°F | 140-180°F | 140-200°F | >200°F | 180-200°F |
| Pressure | - | ++ | ++ | +++ | + |
| Hydrolysis | + | + | + | + | - |
| Hydrocarbon compatibility | - | + | ++ | + | + |
| UV stable | + | + | + | + | - |
| Coilable | + | + | - | - | + |
| Simple bonding | + | - | - | - | - |
| Abrasion resistant | - | - | - | + | + |
| Toughness factor | + | - | - | + | + |
| % of steel installed cost | 40-60% | 50-80% | 60% | 100% | NA |

# OVERCOMING CONTRADICTIONS WITH NYLON 6,6

# NYLON 6,6 – ESTABLISHED ADVANTAGES

- **Hydrocarbons**
  - "Resistant to most solvents, insoluble in esters, ketones, aromatic hydrocarbons, chlorinated hydrocarbons, alkalis…excellent resistance to oils, fuels, greases, fats."[1]
  - Commonly used in auto oil pans
  - Raptor™ nylon pipe is compatible with hydrocarbons (no derate required; sour service performance equivalent to water)

- **Abrasion resistance**
  - Used in high abrasion/high energy absorption applications in fiber form such as military uniforms, parachutes, paper maker felts, timing belt cover fabrics and airbags[2]

- **Properties at temperature**
  - Melting temperature 505°F, Tg 149°F, Deflection temperature under load 118°F

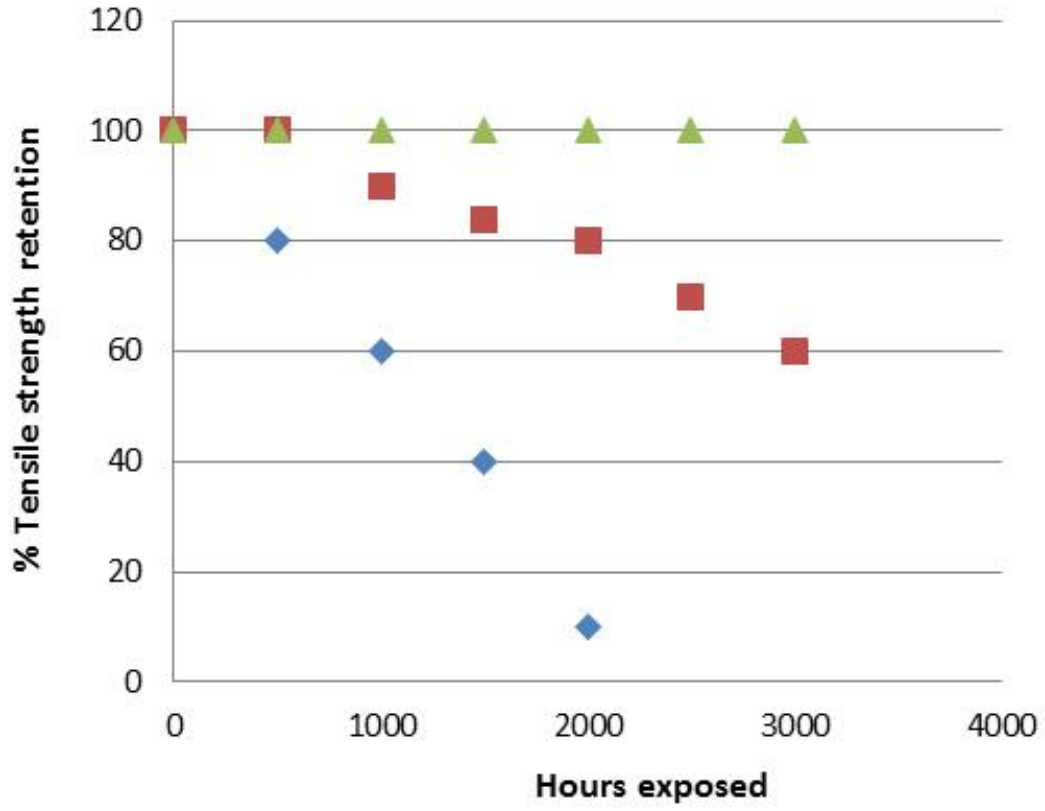
1 – Polymer Technology Dictionary, T. Whelan, Chapman and Hall, 1994
2 – Handbook of Tensile Properties of Textile and Technical Fibres, AR. Bunsell, Elsevier, 2009

# NYLON 6,6 – PREVIOUS GENERATIONS

- **UV stability**
  - General issue with polymers
  - Raptor™ nylon pipe has >2% carbon black additive to improve property retention
- **Hydrolysis**
- **Practical considerations**
  - Needs to be joinable/weldable
  - Ability to be coiled
  - Easily transported

# HYDROLYSIS AGING

## Hydrolysis resistance of Raptor™ nylon pipe




Standard PA66 at pH7, 171°F;
Kohan – Nylon Handbook, 1995, pg 339

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Raptor™ nylon pipe hydrostable at pH6.5, 178°F

# ENGINEERING PRESSURE AND FUSION

- Goal: ~400 psi and ability to be butt-fused
- In unmodified nylons, as reinforcement content is increased to improve burst strength, the tensile strength of a butt-fused joint decreases
  - Melt flow reduced during fusion as viscosity increases
  - Rapid re-crystallization rate of nylon 6,6 in cooling exacerbates the issue

| | 30% glass filled nylon 6,6 | Raptor™ nylon pipe |
|---|---|---|
| Original Yield Strength | 100% | 100% |
| Fusion Strength | 50% | 100% |

# ENGINEERING STRENGTH AND FLEXIBILITY

- Goal: 7,000+ PSI quick burst stress and inside coil diameter <100”
  - Achieved through tailored stiffness characteristics
- Standard transportation logistics required coiling and high pipe flexibility
  - Self-contained coils without the hassle of reels at the job site

# POLYMER DEVELOPMENT

## Advantages of nylon

- 4x better abrasion resistance than HDPE
- ~6x better impact resistance than HDPE, 20x better than composite
- >2x pressure ratings than HDPE in hydrocarbon service
- Utilizes off-the-shelf fusion equipment and can be installed with operator's preferred crews
- 1,000-foot coils; 6 coils per truckload

# MATERIALS AVAILABLE TO THE MARKET

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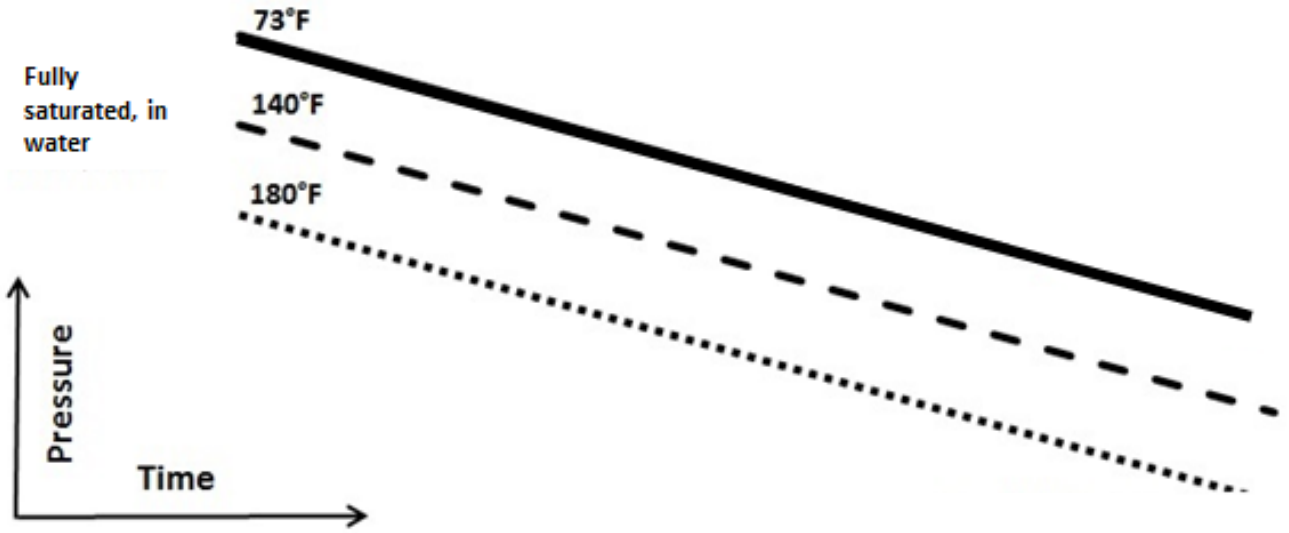
|---|---|---|---|---|---|
| Temperature | 140°F | 140-180°F | 140-200°F | >200°F | 180-200°F |
| Pressure | - | ++ | ++ | +++ | + |
| Hydrolysis | + | + | + | + | + |
| Hydrocarbon compatibility | - | + | ++ | + | ++ |
| UV stable | + | + | + | + | + |
| Coilable | + | + | - | - | + |
| Simple bonding | + | - | - | - | + |
| Abrasion resistant | - | - | - | + | ++ |
| Toughness factor | + | - | - | + | ++ |
| % of steel installed cost | 40-60% | 50-80% | 60% | 100% | 40-60% |

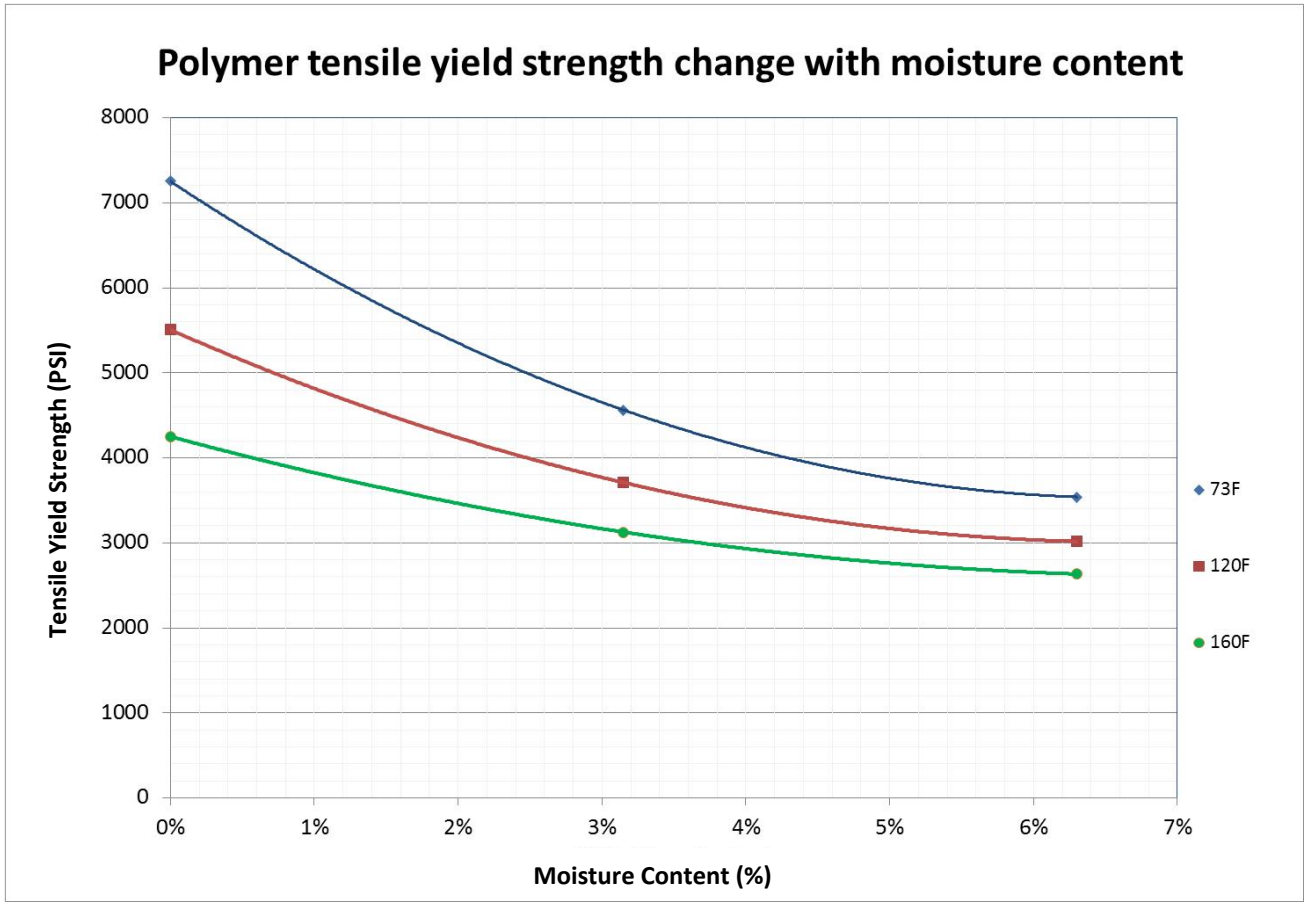
# DEVELOPMENT OF SHORT-TERM PRESSURES – A PHENOMENON TO NYLON 6,6

# MATERIAL BEHAVIOR OVER TIME & PRESSURE

**Raptor™ nylon pipe – long-term hydrostatic performance with temperature and moisture**

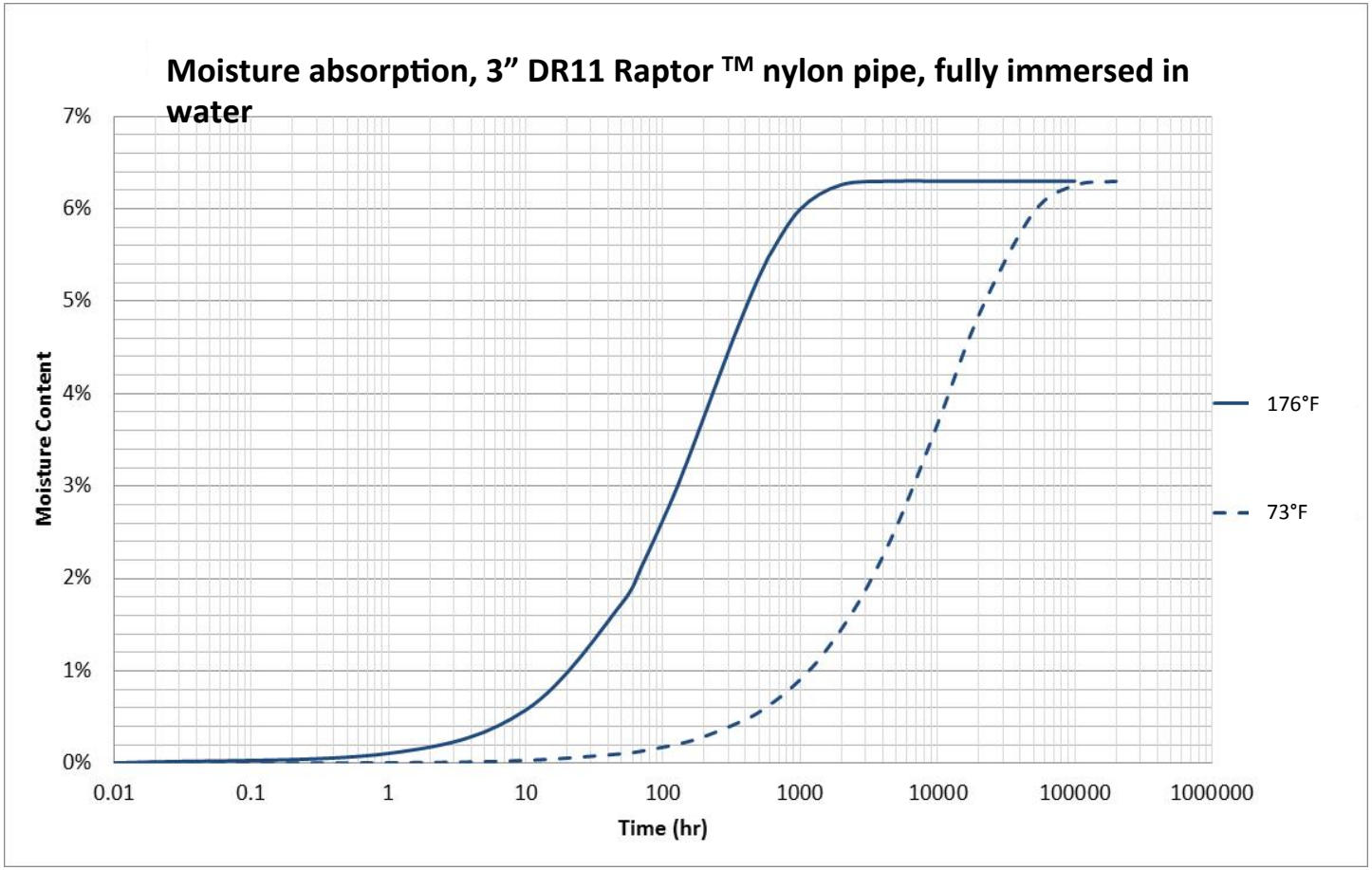


# DEVELOPMENT OF SHORT-TERM PRESSURE MODELS



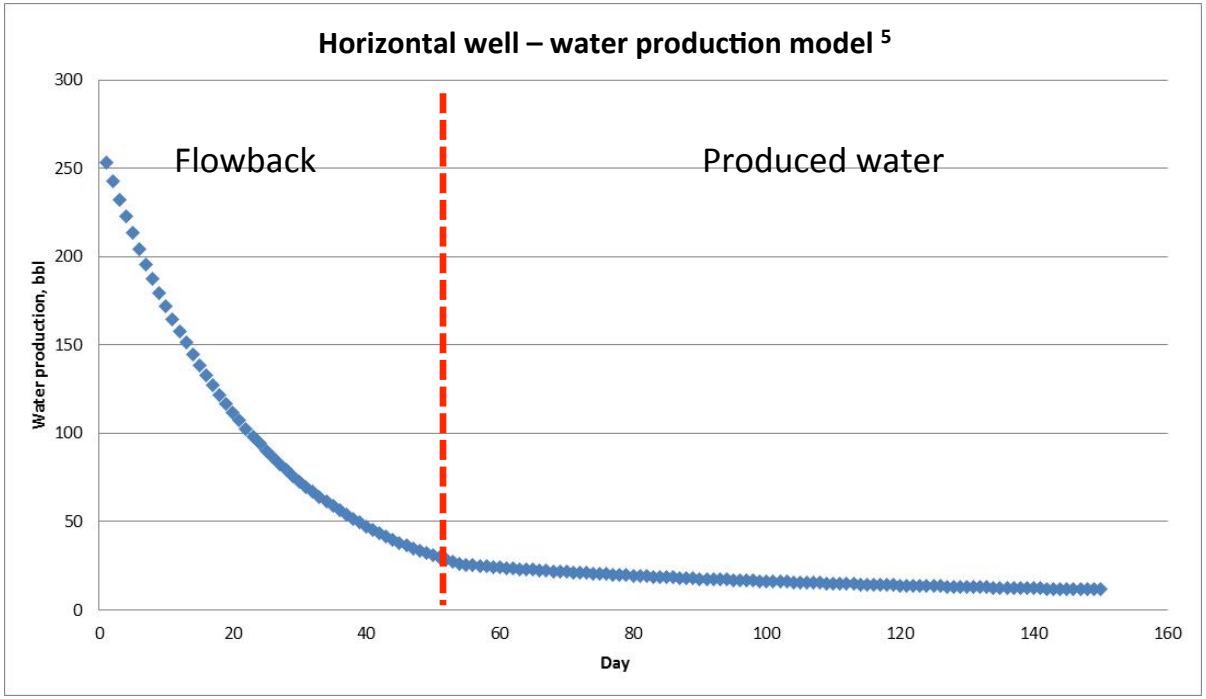

Reduction in yield and tensile strength is accompanied with an increase in strain at break, and a resulting increase in toughness

# DEVELOPMENT OF SHORT-TERM PRESSURE MODELS



# DEVELOPMENT OF SHORT-TERM PRESSURE MODELS

- Goal: Leverage well-head pressure declines during first year of operation with strength of unsaturated Raptor™ nylon pipe




5 - DEVELOPMENT OF FRAMEWORK FOR PREDICTING WATER PRODUCTION FROM OIL AND GAS WELLS IN WATTENBERG FIELD, COLORADO, Bing Bai, Department of Civil and Environmental Engineering, MSc thesis, Colorado State University 2012

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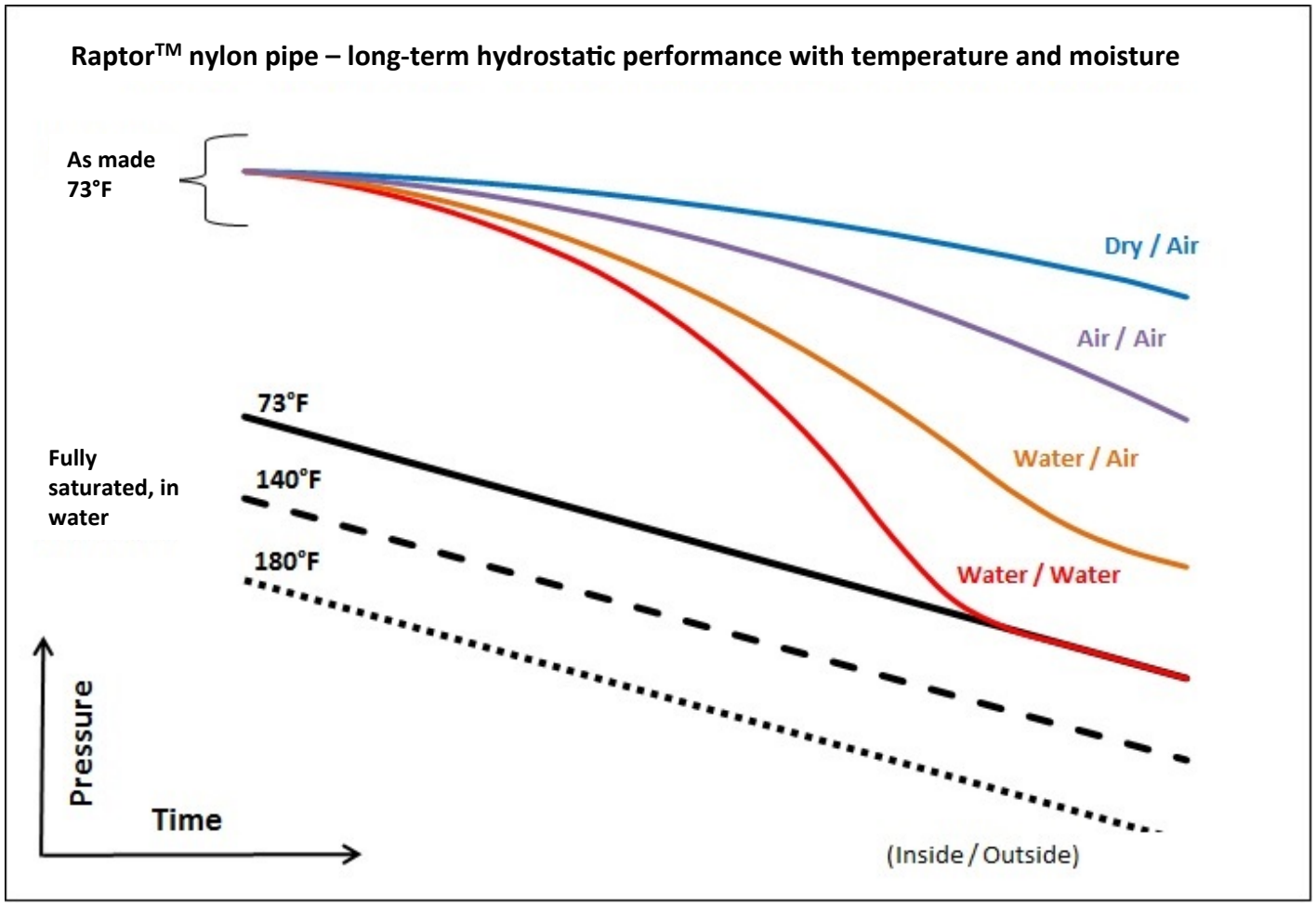

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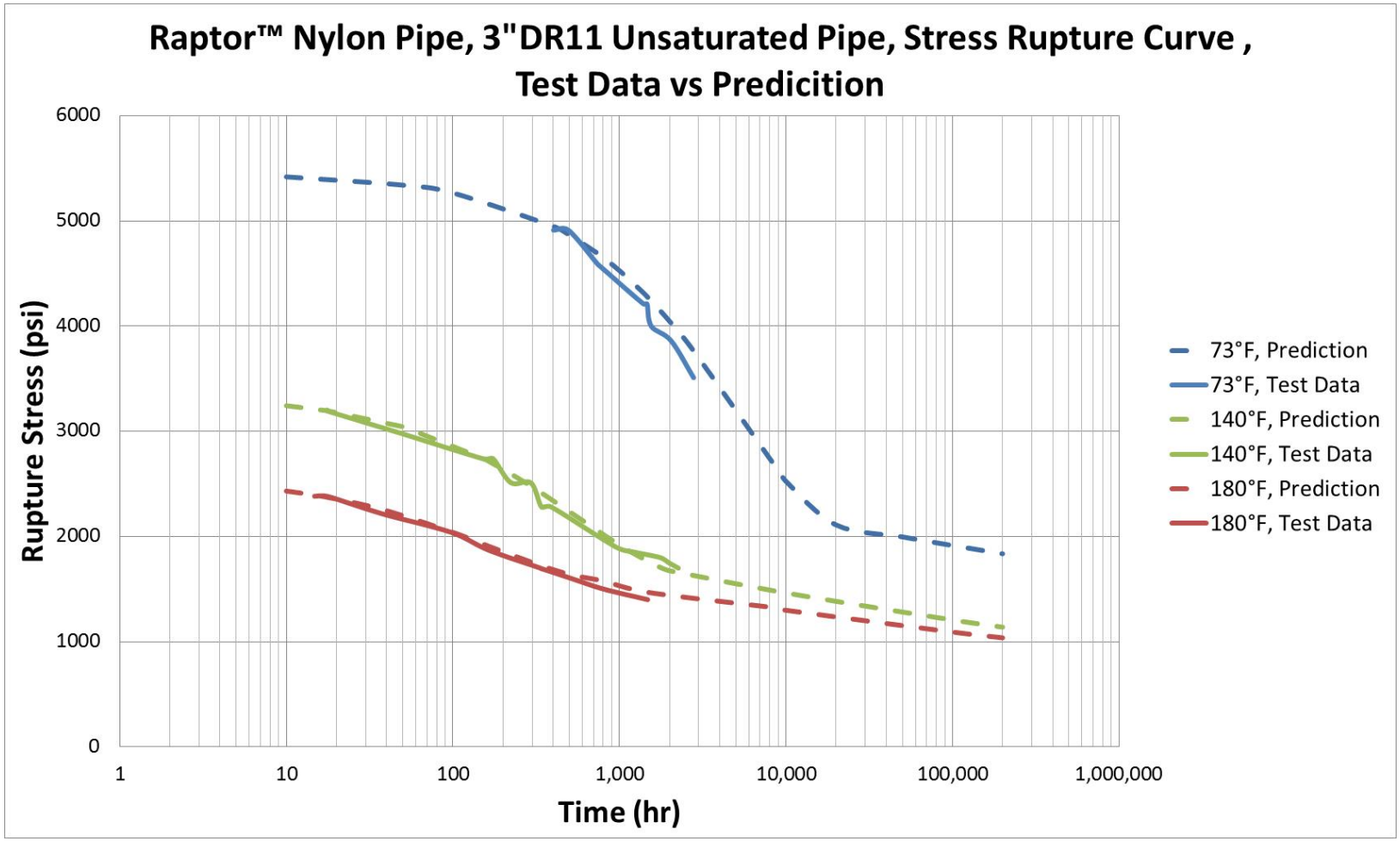

# SHORT-TERM PRESSURE MODEL

## Design considerations

- Could a short-term pressure model bring new value to the well?
- Can short-term design protocols be established to run alongside conventional long-term HDB engineering design?

# RAPTOR™
## NYLON PIPE

# MADE OF TOUGH.™