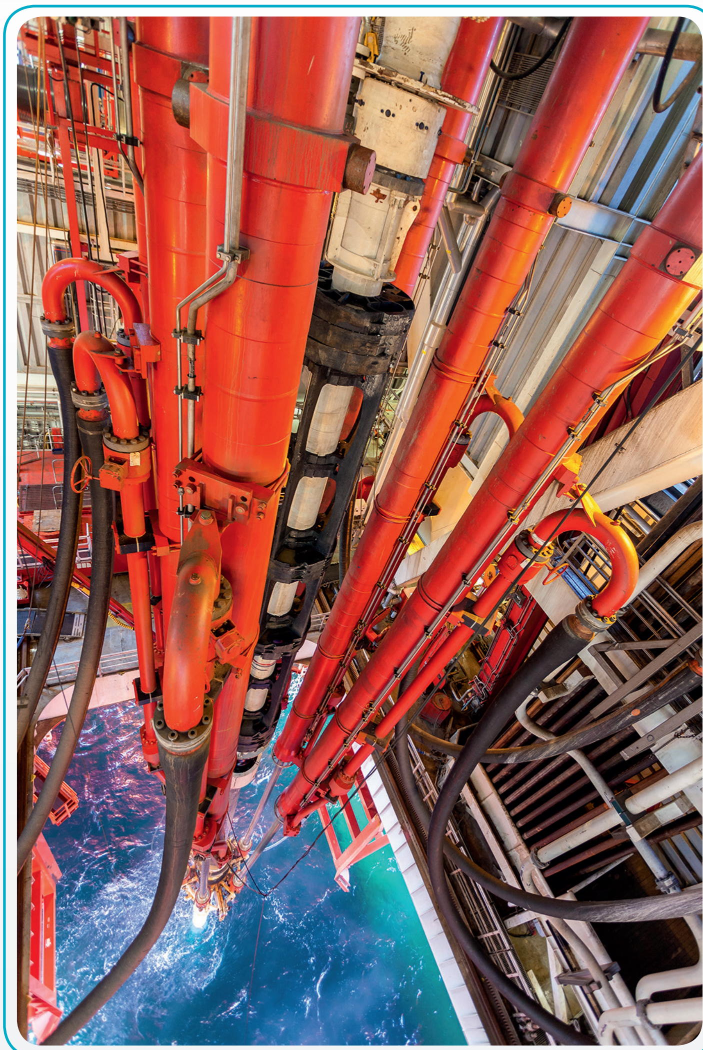
Testing of HFC Fluids on Common Seal Materials in High Temperature Applications



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Introduction

As the oil and gas industry moves to recover more challenging reserves and enters the development of High Pressure High Temperature (HPHT) fields, the risk of fire is increasing. There is therefore a move to the use of water-based hydraulic fluids, which present significant sealing challenges.

To ensure sealing performance is maintained in water-based hydraulic fluids, it is imperative that operators understand the effects of high-temperature exposure of sealing materials within water-based hydraulic fluids. Until now, these two elements have not been thoroughly tested together at high temperatures.

Seals need to be compatible with HFC fluids

Oil and gas hydraulic applications often involve demanding dynamic movements. For instance, sealing systems in offshore motion compensation cylinders can be subjected to significant wear due to long strokes.

Compared to oil-based HLP media, the water base of HFC fluids typically produces different reactions within the traditional sealing materials used in these applications. The different reactions can range from lower lubricity relative to dynamic sealing elements, to corrosion concerns of supporting metal hardware, to compatibly with sealing polymers. This can shorten seal life and potentially increase downtime for operators.

The optimum sealing material

Trelleborg Sealing Solutions and fluid manufacturer, MacDermid, therefore partnered to identify the optimum sealing materials. Tests were undertaken with different sealing materials, in a variety of fluids at a number of temperatures.

Results showed that Fluoroelastomer (FKM), the sealing material most commonly used at high temperatures in other fluids, was the least successful in water-based hydraulic fluids and that the most resilient was Perfluoroelastomer (FFKM).

About water-based hydraulic fluid

Water-based hydraulic fluids are widely used in oil and gas, mining, hot-rolling mills, and similar applications where the potential for fire could cause catastrophic consequences. They are also replacing traditional oil-based HLP fluids in applications where environmental regulations must be observed. As a result, they have become more prevalent in many applications within offshore energy production as a means of protecting people, the environment, and resources.

Low-viscosity versions operate more effectively than oil-based HLP fluids over long distances, and the low compressibility of water gives faster response times. The fire resistant and environmentally friendly qualities of HFC fluids make them ideal for use in offshore installations, whether on surface equipment such as motion compensation cylinders or on subsea equipment when used as a control fluid to operate valves and blow-out preventers. They contribute to better fire safety, offering more time to initiate fire-fighting measures and bring people to safety in the event of an accident.

Water-based hydraulic fluids constituents

Water glycol fluids consist of a solution of water, ethylene, or diethylene glycol, usually a high molecular weight polyglycol and an additive package. The water-to-glycol mixture typically contains 38% to 45% water.

HFC - Most commonly used

HFC fluids are the most common hydrous, fire-resistant hydraulic fluids because they have the best fire resistance and hydraulic properties. They are also used wherever hydraulic fluid escaping under high pressure can ignite on contact with hot materials. At temperatures above +600 °C / +1112 °F, these fluids should not ignite or continue to burn. They are commonly used at typical operating temperatures of -20 °C to +300 °C / -4 °F to +149 °F and up to working pressures of 3625 psi.

ISO categories for water-based hydraulic fluids

The International Standards Organization (ISO) classifies fire-resistant, water-based hydraulic fluids into four categories:

- **HFAE:** includes oil-in-water emulsions, typically with more than 80% water content
- **HFAS:** synthetic aqueous fluids, typically containing more than 80% water
- **HFB:** water-in-oil emulsions typically containing more than 40% water
- **HFC:** also known as glycol solutions, polyalkylene glycol solutions, and water glycols - include water polymer solutions, typically containing more than 35% water

Specifying and using water-based hydraulic fluid

Viscosity temperature behavior

As they are mostly made of water, HFC fluids have vastly different lubrication properties as compared to oil-based fluids. In hydraulic fluids, the interrelation between viscosity and temperature is described by the viscosity index (VI). HFC hydraulic fluids have a better viscosity temperature behavior than HLP mineral oil. In HFA hydraulic fluids, the dependency of the viscosity on the temperature is negligible.

The differing viscosity temperature behavior should be taken into consideration when selecting a hydraulic fluid for the required temperature range. With water in the formulation, evaporation may occur.

Regular condition checks are recommended every two to three month, depending on the application. Water loss can cause an imbalance relative to the additives and adversely affect viscosity, pH, and lubrication quality. Added water must be distilled or soft de-ionized because the calcium and magnesium present in potable water will react with additives, causing them to precipitate out of the fluid and compromise fluid performance.

Avoiding water loss

Owing to high vapor pressure, in comparison to a similar HLP mineral oil, the maximum operating temperature when working with fire-resistant, water-containing hydraulic fluids must be limited. Ideally, operating temperatures should be kept below +65 °C / +149 °F to minimize evaporation though in practice they can be significantly higher.

Reservoir temperatures above +50 °C / +122 °F must be prevented in open systems because they can lead to serious water loss and accelerate the aging process in the hydraulic fluid. Furthermore, in HFC hydraulic fluids, water losses that are too high can lead to both an increase in viscosity and a reduction in fire-resistant properties.

The minimum operating temperature for HFA hydraulic fluids is +5 °C / +41 °F. HFC hydraulic fluids respond very well at low temperatures and have a lower pour point compared to HLP mineral oils.

System compatibility

It's critical that the hydraulic fluid does not negatively affect the materials used in the components within any system that uses HFC fluids. Compatibility with coatings, seals, hoses, metals, and plastics should be observed to prolong the service life and integrity of equipment.

Viscosity-temperature properties

The polyglycol is a water-soluble polymer thickener that can be formulated to cover a wide range of viscosities. The resulting viscosity-temperature properties give water glycols good low-temperature cold-start pump wear protection and minimize cavitation.

The additive package imparts corrosion resistance, metal passivation, seal and hose compatibility, oxidation resistance, antimicrobial properties, antifoaming agents, and anti-wear properties. Water glycol fluids also have better thermal transfer properties than other fire-resistant fluids.

Testing HFC fluids

Trelleborg Sealing Solutions and fluid producer MacDermid partnered to investigate the effect of water glycol fluids on common seal materials.

Trelleborg undertook a series of tests on seven elastomeric and thermoplastic sealing materials to investigate the effect of immersion in six HFC fluids at three elevated temperatures up to +200 °C / +392 °F.

The tests took place over a 90-day period in 2016 in three Trelleborg research and development centers: Stuttgart, Germany; Tewksbury, England; Fort Wayne, Indiana in the U.S.

In all tests, samples of sealing materials were immersed in each of the water-based hydraulic fluid. Each seal and fluid combination was tested for hardness, tensile strength, strain, and volume. the seals were photographed before and after the test to document all physical changes.

Trelleborg materials tested:

Trelleborg Material Code	Material Type	Hardness	Operating Temperature	Rapid Gas Decompression Resistance	Sour Fluid Resistance
XploR™ H9T20	Hydrogenated Nitrile (HNBR)	90 Durometer Shore A	-13°F to +320°F -25°C to +160°C	NORSOK M-710 Total GS EPPVV 142	NORSOK M-710 ISO 10423/API 6A Annex F.1.13.5.2
XploR™ H9T21	Low Temperature Hydrogenated Nitrile (HNBR)	90 Durometer Shore A	-40°F to +320°F -40°C to +160°C	NORSOK M-710	-
XploR™ V9T20	Fluoroelastomer (FKM)	90 Durometer Shore A	-4°F to +392°F -20°C to +200°C	NORSOK M-710	NORSOK M-710
XploR™ V9T82	Low temperature Fluoroelastomer (FKM)	90 Durometer Shore A	54° to +392°F -48°C to 200°C	NORSOK M-710 Total GS EPPVV 142	NORSOK M-710 ISO 10423/API 6A Annex F.1.13.5.2
XploR™ J9513	Perfluoroelastomer (FFKM)	90 Durometer Shore A	-14° to +500°F -10°C to 260°C	NORSOK M-710	NORSOK M-710 ISO 10423/API 6A Annex F.1.13.5.2
Turcon® T05	Proprietary filled PTFE	N/A	-200°F to +500°F -129°C to +260°C	N/A	NORSOK M-710
Turcon® T46	Bronze filled PTFE	N/A	-200°F to +500°F -129°C to +260°C	N/A	NORSOK M-710

MacDermid fluids tested:

MacDermid Fluid Name	Description	Physical Properties	
Erifon 818TLP	Erifon 818 fluids have been designed for use In motion compensator systems for drilling systems and Tension Leg Platforms. The fluids are water-based with low compression/ignition ratios to give excellent fire and explosion resistant properties at the high pressures experienced in compensator systems. The formulations ensure good system response over a wide temperature range with the viscosity index kept to a minimum. The fluids contain a range of additives that ensure fluid stability as well as protect systems from corrosion and wear.	**Appearance**	Green, Slightly Viscous Liquid
		Viscosity (cSt) @ -20°C (-4°F) 0°C (+32°F) +20°C (+68°F) +40°C (+104°F)	 750 125 35 15
		Pour Point	Below -45°C (-79°F)
		Ph Value	9.1
		Specific Gravity @ +15.6°C (+60°F)	1.087
		Specific Heat	0.8
		Max. Recommended Operating Temperature	+60°C (+140°F)
Compenol™	Compenol™ has been developed and carefully tested to meet the needs of the motion compensation market. Compenol™ P/N 216003 is recommended for temperatures of 0° F (–18° C) and above Compenol™ P/N 216003 is recommended. For temperatures below 0°F (–18°C) Compenol™ LV. P/N 217939 is recommended.	**Appearance**	Fluorescent Red Viscous Liquid
		Viscosity (cSt) @ -20°C (-4°F) 0°C (+32°F) +20°C (+68°F) +40°C (+104°F)	 1200 260 88 38
		Pour Point	Below -45°C (-79°F)
		Ph Value	9.1
		Specific Gravity @ +15.6°C (+60°F)	1.060
		Specific Heat	0.8
		Max. Recommended Operating Temperature	+60°C (+140°F)

Oceanic HW fluids are water - based hydraulic media specifically formulated for use in modern subsea production control systems. Their low viscosity promotes optimum system response, while a sophisticated additive package provides a high degree of protection against wear, corrosion and microbiological degradation. The Oceanic HW fluids have been developed in close consultation with component manufacturers, and are now in worldwide use, helping to achieve maximum production system safety and reliability.

MacDermid Fluid Name	Description	Physical Properties	
Oceanic HW 525 P	Oceanic HW 525P (with fluorescent dye) is most commonly used in the Gulf of Mexico and Brazil, where temperatures rarely fall below -10°C (+14°F).	**Appearance**	Fluorescent Blue Green Liquid
		Viscosity (cSt) @ -20°C (-4°F) 0°C (+32°F) +20°C (+68°F) +40°C (+104°F)	 Solid 4.8 2.4 1.5
		Pour Point	-10°C (+14°F)
		Ph Value	9.4
		Specific Gravity @ +15.6°C (+60°F)	1.039
		Specific Heat	3721
		Max. Recommended Operating Temperature	+90°C (+194°F)
Oceanic HW 443	Fluids in the past (water based and hydrocarbon) have shown degradation when subjected to temperatures over +100°C (+212°F). However, sub-surface safety valves in hot wells can operate at temperatures exceeding this. The result of two and a half years of research and development, Oceanic HW443 was designed to help improve safety when producing hydrocarbons from hot wells; specifically developed for use in higher temperature wells and highly recommended for closed loop blow out preventors (BOP). Oceanic HW443 has an operating temperature range from -25°C (-13°F) up to +135°C (+275°F). Stable up to +135°C (+275°F) with no physical or chemical change, it improves performance and reduces the chance of blockage, corrosion and wear	**Appearance**	Fluorescent Green Liquid
		Viscosity (cSt) @ -20°C (-4°F) 0°C (+32°F) +20°C (+68°F) +40°C (+104°F)	 1200 260 88 38
		Pour Point	-25°C (+13°F)
		Ph Value	9.7
		Specific Gravity @ +15.6°C (+60°F)	1.071
		Specific Heat J.kg-1.K-1	3445
		Max. Recommended Operating Temperature	+135°C (+275°F)

MacDermid fluids tested:

MacDermid Fluid Name	Description	Physical Properties	
Oceanic HW 740R	Oceanic HW 740R was developed for higher temperatures and more demanding well conditions. Extensive environmental research has led to a biodegradable red dye, hence its "R" designation.	**Appearance**	Red / Pink Fluorescent Liquid
		Viscosity (cSt) @ -20°C (-4°F) 0°C (+32°F) +20°C (+68°F) +40°C (+104°F)	 24.9 8.9 4.3 2.5
		Pour Point	-31°C (-23.8°F)
		Ph Value	9.2
		Specific Gravity @ +15.6°C (+60°F)	1.070
		Specific Heat Capacity J.kg-1.K-1	3445
		Max. Recommended Operating Temperature	+160°C (+320°F)
Oceanic XT900	Oceanic XT900 is an extreme temperature, high-performance, water-based hydraulic fluid with an operational temperature range from -30°C to +220°C (-22°F to +428°F). Oceanic XT900 is used in modern open and closed loop Subsea Production control systems and potentially in closed loop Blow Out Preventer (BOP) control systems. Oceanic XT900 has passed ISO 13628-6 specified test criteria and meets equipment manufacturers' requirements.	**Appearance**	Clear Straw Coloured Liquid
		Viscosity (cSt) @ -20°C (-4°F) 0°C (+32°F) +40°C (+104°F)	 59 16.9 3.74
		Pour Point	-35°C (-31°F)
		Ph Value	9.0
		Specific Gravity @ +15.6°C (+60°F)	1.130
		Specific Heat Capacity J.kg-1.K-1	3261
		Max. Recommended Operating Temperature	+220°C (+428°F)

Test Results

Erifon 818 TLP

Fluid for use in motion compensators for drilling systems and tension leg platform.

90 days at +70 °C / +158 °F in Erifon 818 TLP							
	H9T20	H9T21	J9513	T05	T46	V9T20	V9T82
Hardness Change (pts)	-3	-4	-9	-1	-2	-8	-16
Tensile Strength Change (%)	-23	-9	-16	-10	-17	-58	-27
Strain Change (%)	-19	-3	6.1	-6	-13	19	17
Volume Change (%)	5	6	1	1	1	22	14

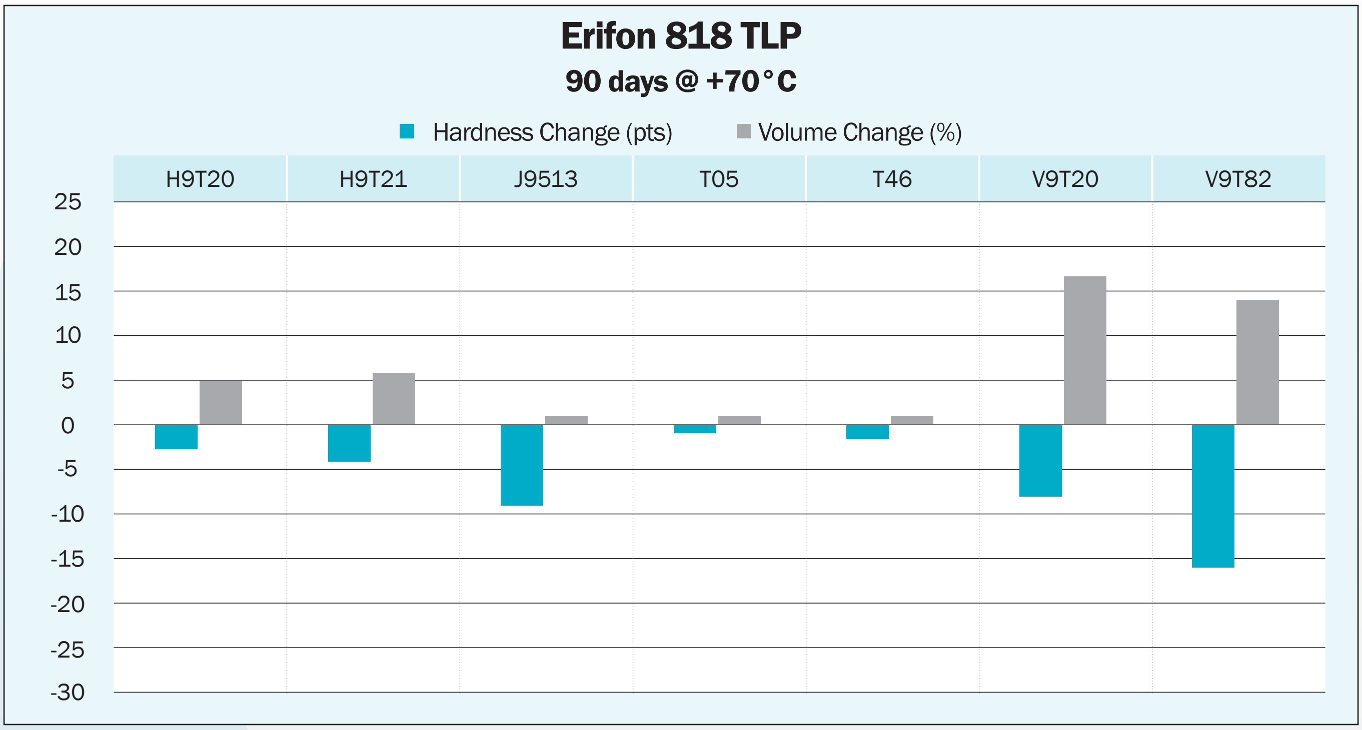

Chart 1 – Hardness and Volume Change of Seal Materials in Erifon 818 TLP

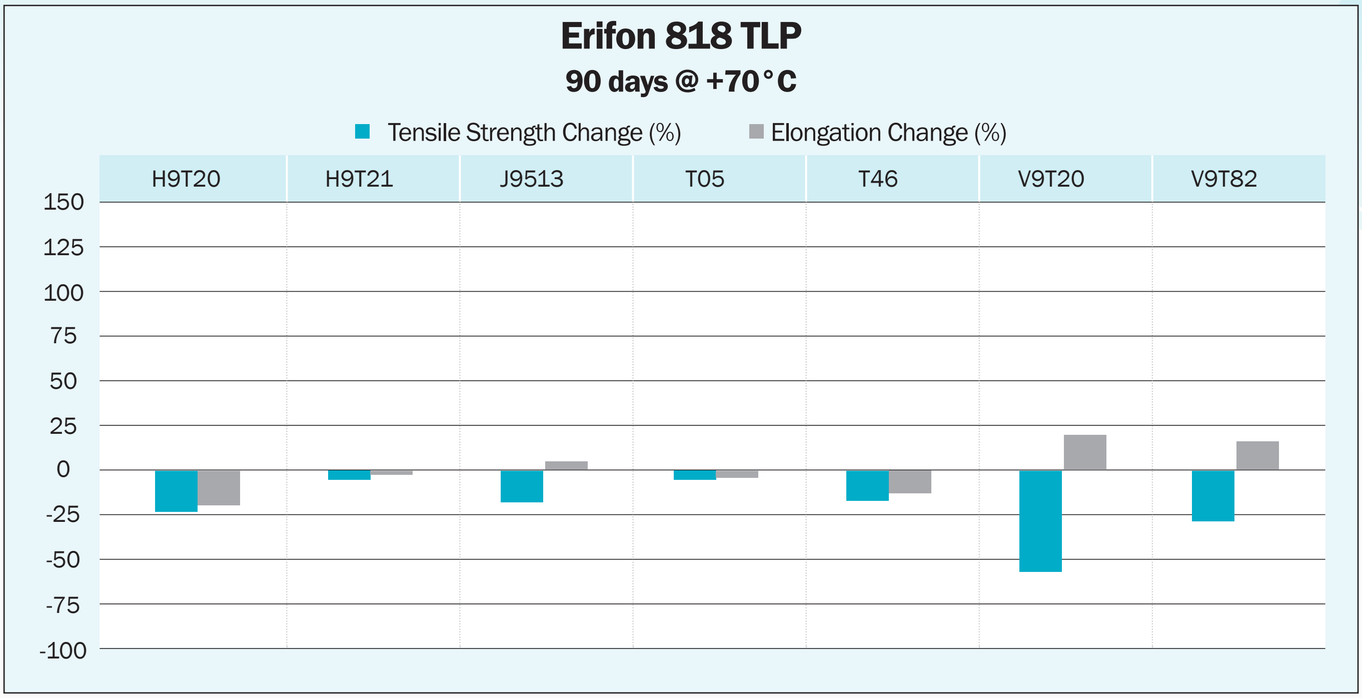

Chart 2 – Tensile Strength and Elongation Change of Seal Materials in Erifon 818 TLP

Compenol™

Fluid for use in motion compensators.

90 days at +70 °C / +158 °F in Compenol	H9T20	H9T21	J9513	T05	T46	V9T20	V9T82
Hardness Change (pts)	-4	-1	-4	0	0	-6	-18
Tensile Strength Change (%)	-25	-9	0	-13	-14	-53	-26
Strain Change (%)	-16	4	24	-21	-9	-17	18
Volume Change (%)	2	2	1	1	1	18	22

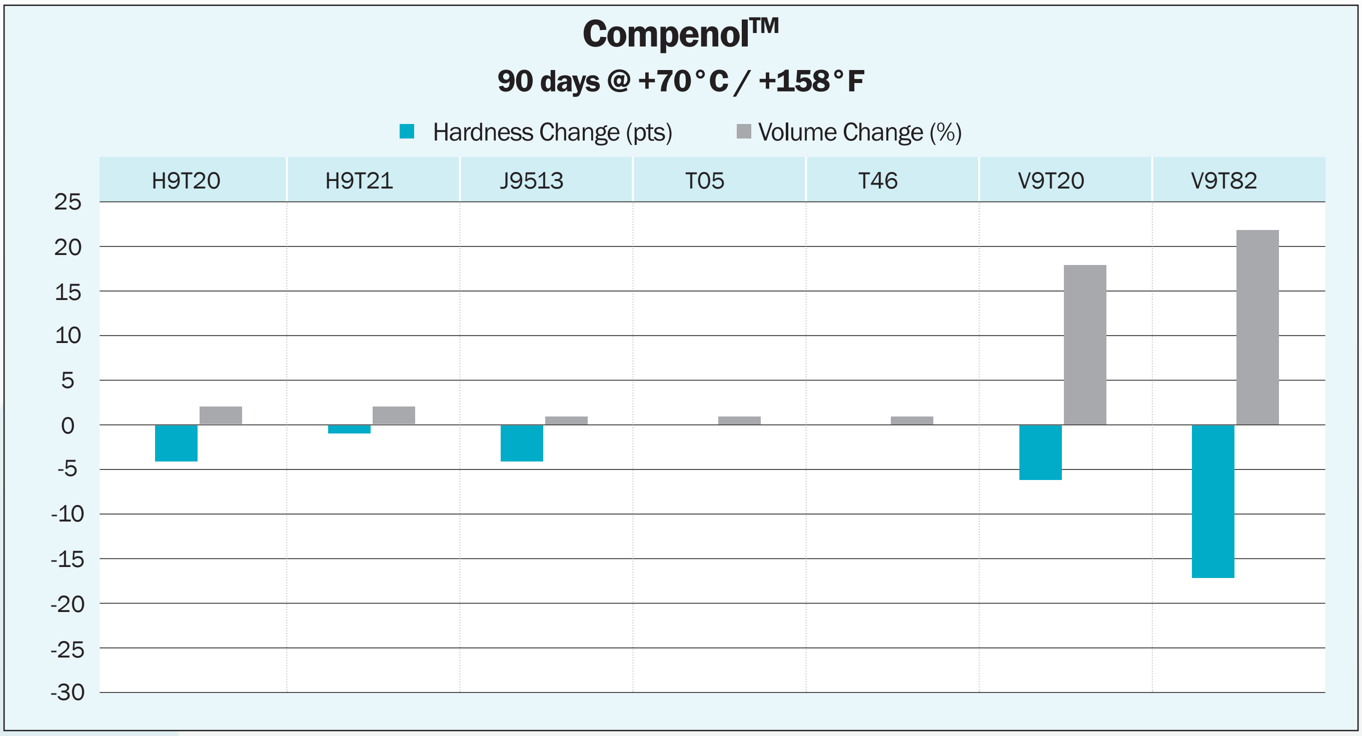

Chart 3 – Hardness and Volume Change of Seal Materials in Compenol™

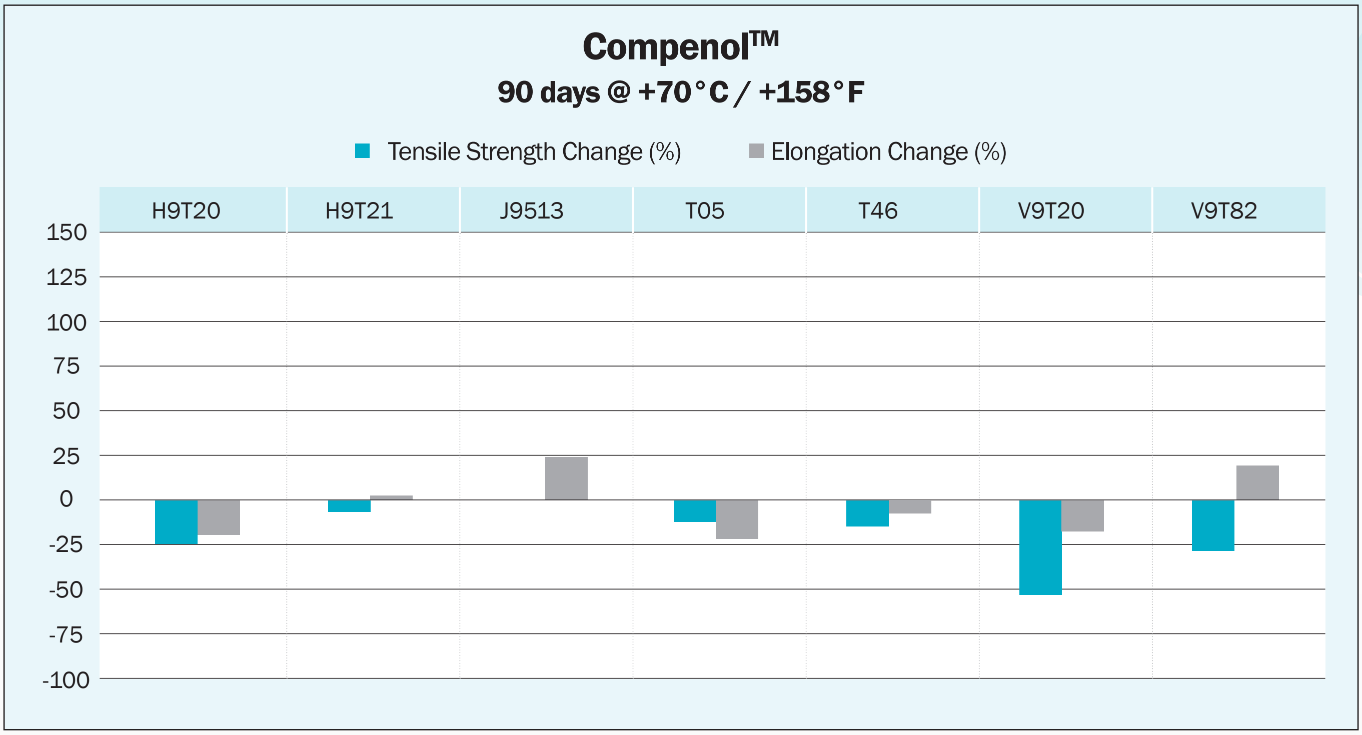

Chart 4 – Tensile Strength and Elongation Change of Seal Materials in Compenol™

Oceanic 525 P

Fluid primarily used in the Gulf of Mexico and Brazil.

90 days at +70 °C / +158 °F in Oceanic HW 525 P							
	H9T20	H9T21	J9513	T05	T46	V9T20	V9T82
Hardness Change (pts)	-4	-13	-10	-1	-2	-9	-13
Tensile Strength Change (%)	-25	-10	-15	-18	-11	-4	-24
Strain Change (%)	-19	-5	-1	-25	-2	1	9
Volume Change (%)	9	15	5	0	1	11	25

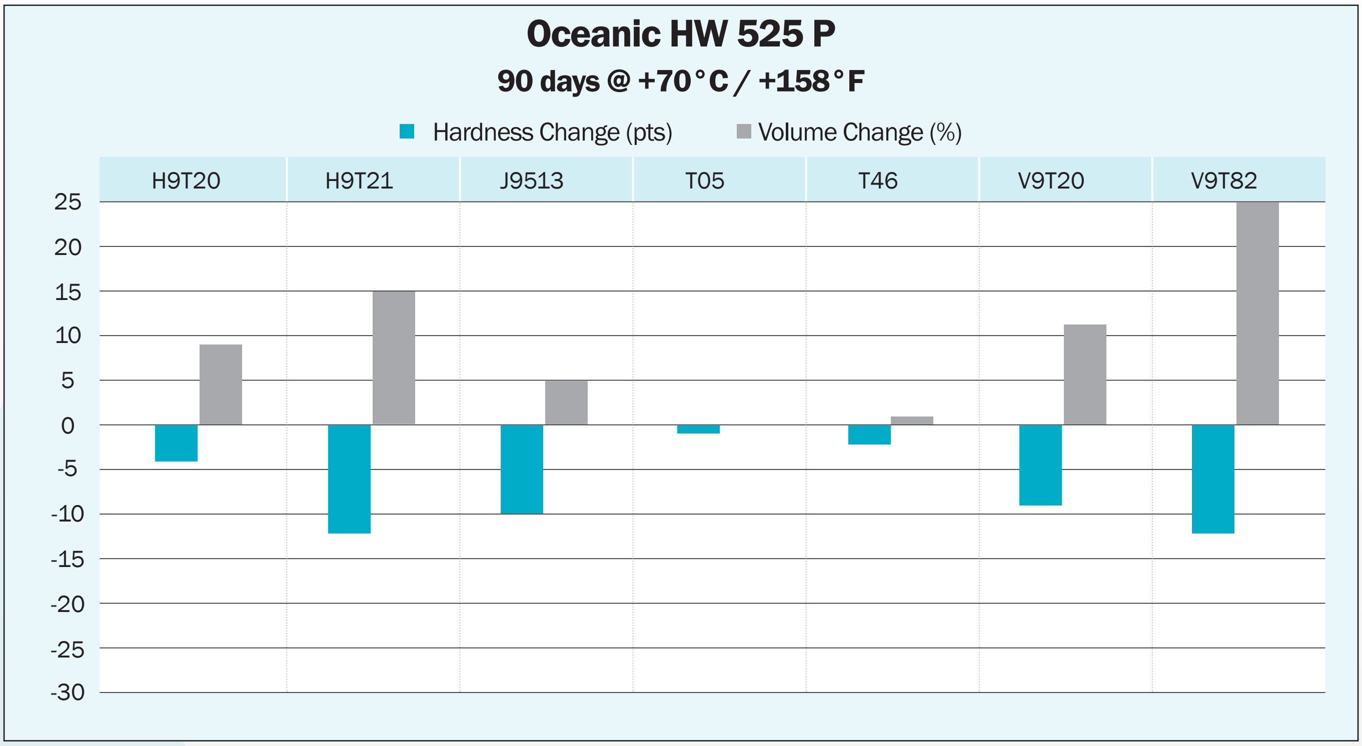

Chart 5 – Hardness and Volume Change of Seal Materials in Oceanic HW 525 P

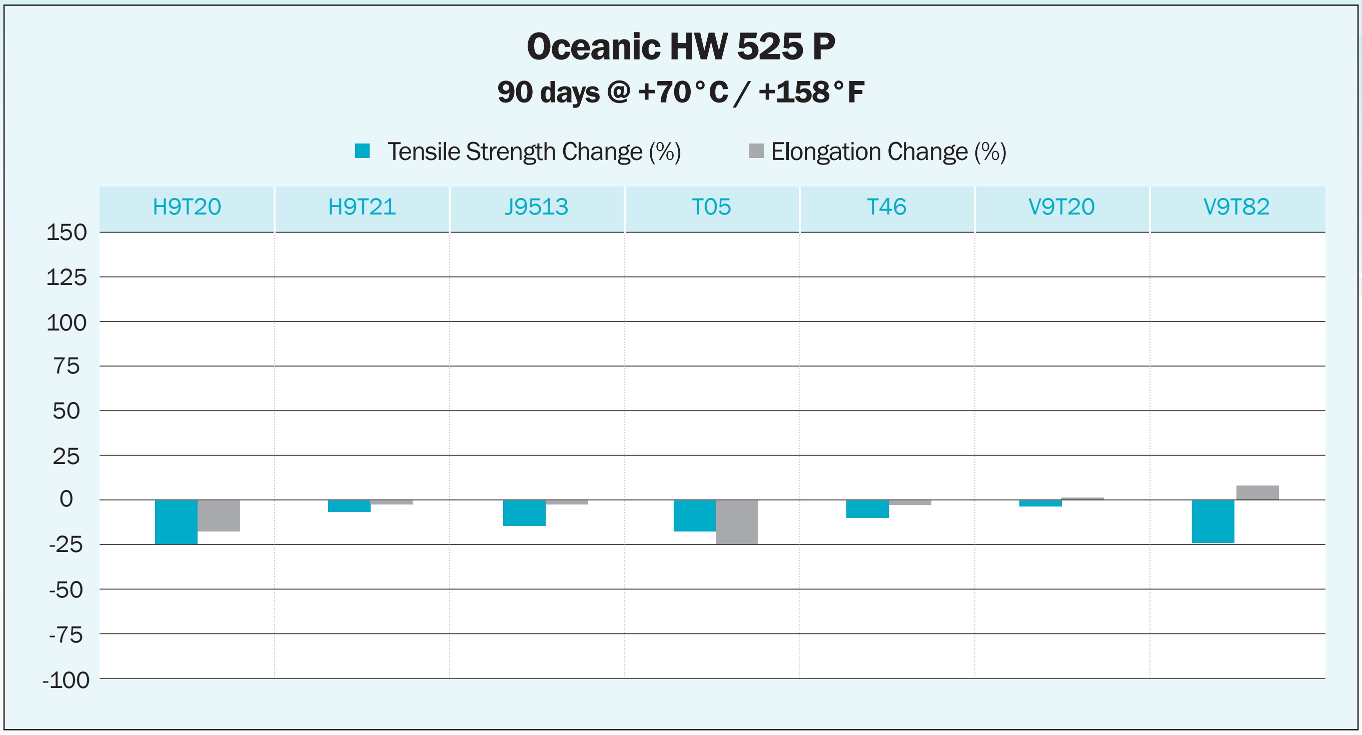

Chart 6 – Tensile Strength and Elongation Change of Seal Materials in Oceanic HW 525 P

Oceanic HW 443

Fluid for use in hot wells.

90 days at +135 °C / +275 °F in Oceanic HW 443	H9T20	H9T21	J9513	T05	T46	V9T20	V9T82
Hardness Change (pts)	-6	-6	-7	-1	-3	-22	-25
Tensile Strength Change (%)	-20.8	-15.2	-11.3	-17	-18	-61	-59
Strain Change (%)	-13.6	-13.4	5.1	-8	-9	26	28
Volume Change (%)	8.2	7.5	1.2	0	1	25.8	25.3

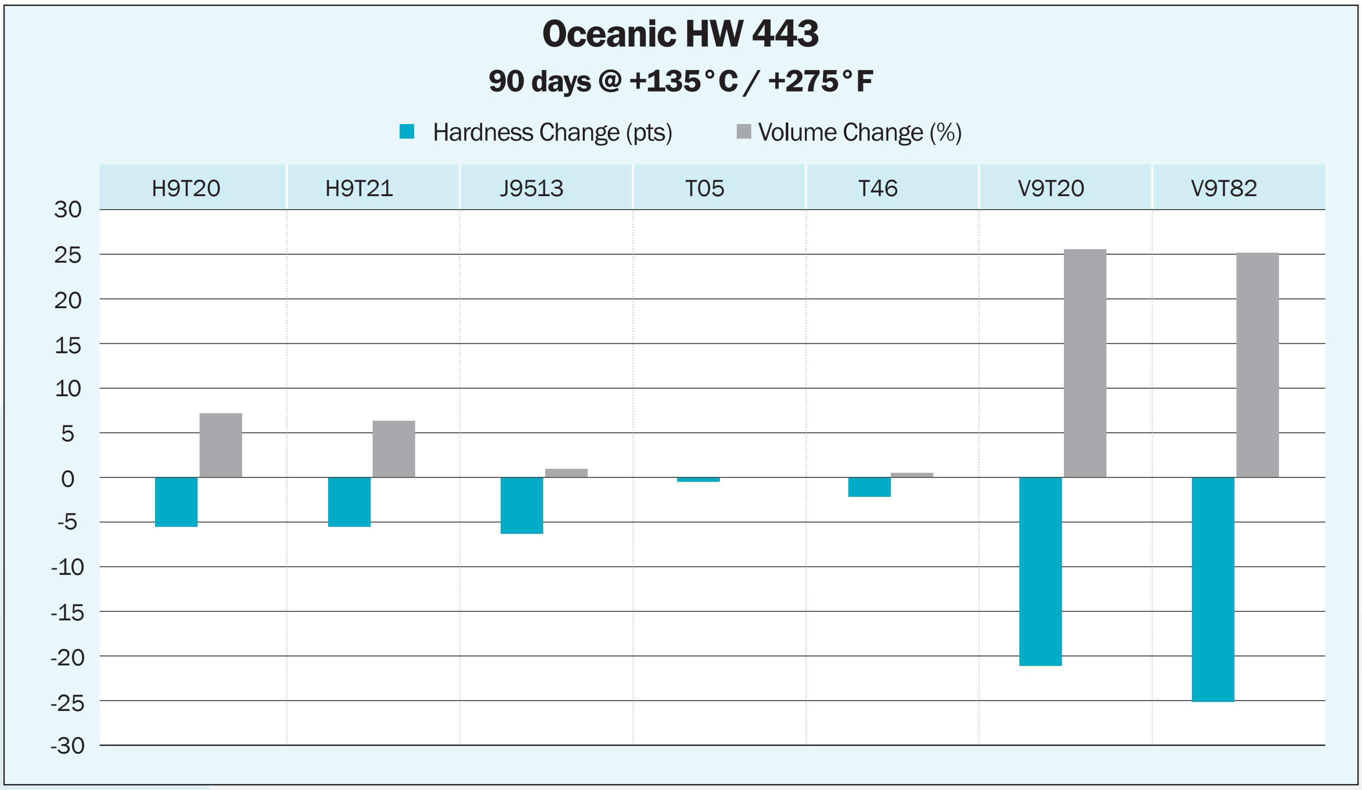

Chart 7 – Hardness and Volume Change of Seal Materials in Oceanic HW 443

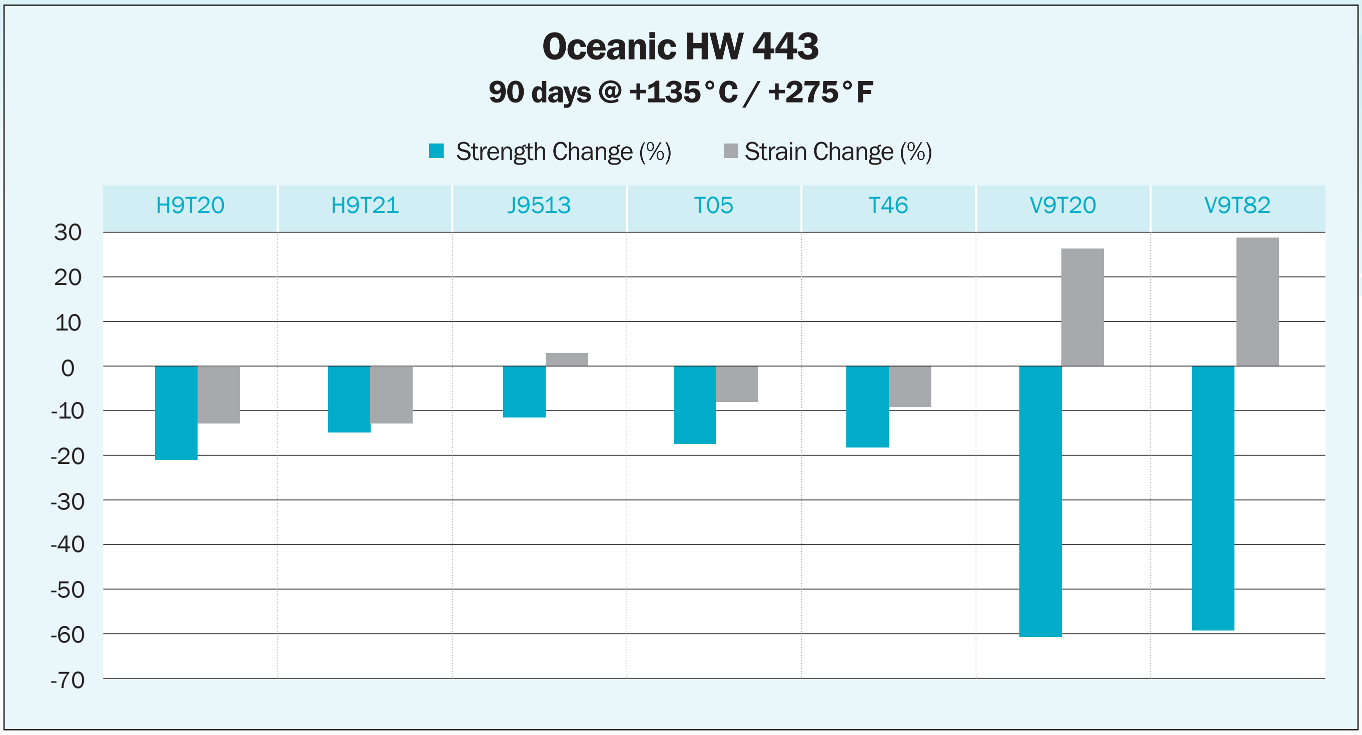

Chart 8 – Tensile Strength and Elongation Change of Seal Materials in Oceanic HW 443

Oceanic HW 740 R

Fluid for use in higher temperatures and more demanding well conditions.

90 days at +70 °C / +158 °F in Oceanic HW 740 R	H9T20	H9T21	J9513	T05	T46	V9T20	V9T82
Hardness Change (pts)	-2	-2	-4	4	-7	-12	-17
Tensile Strength Change (%)	-24.8	-16.5	-5.2	-7	-13	-16	-29
Strain Change (%)	-4.8	11.4	11.2	-3	-2	84	17
Volume Change (%)	3.3	4.6	0.7	0	1	18	23

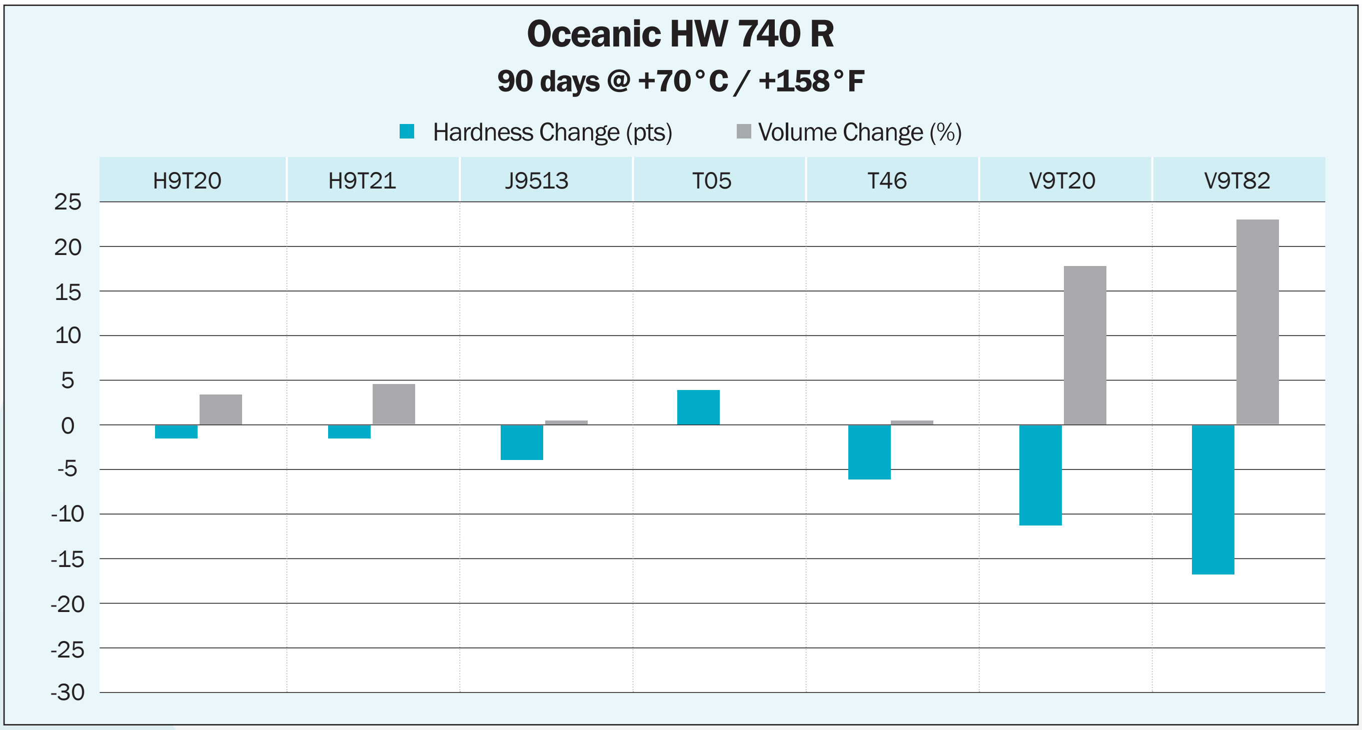

Chart 9 – Hardness and Volume Change of Seal Materials in Oceanic HW 740 R

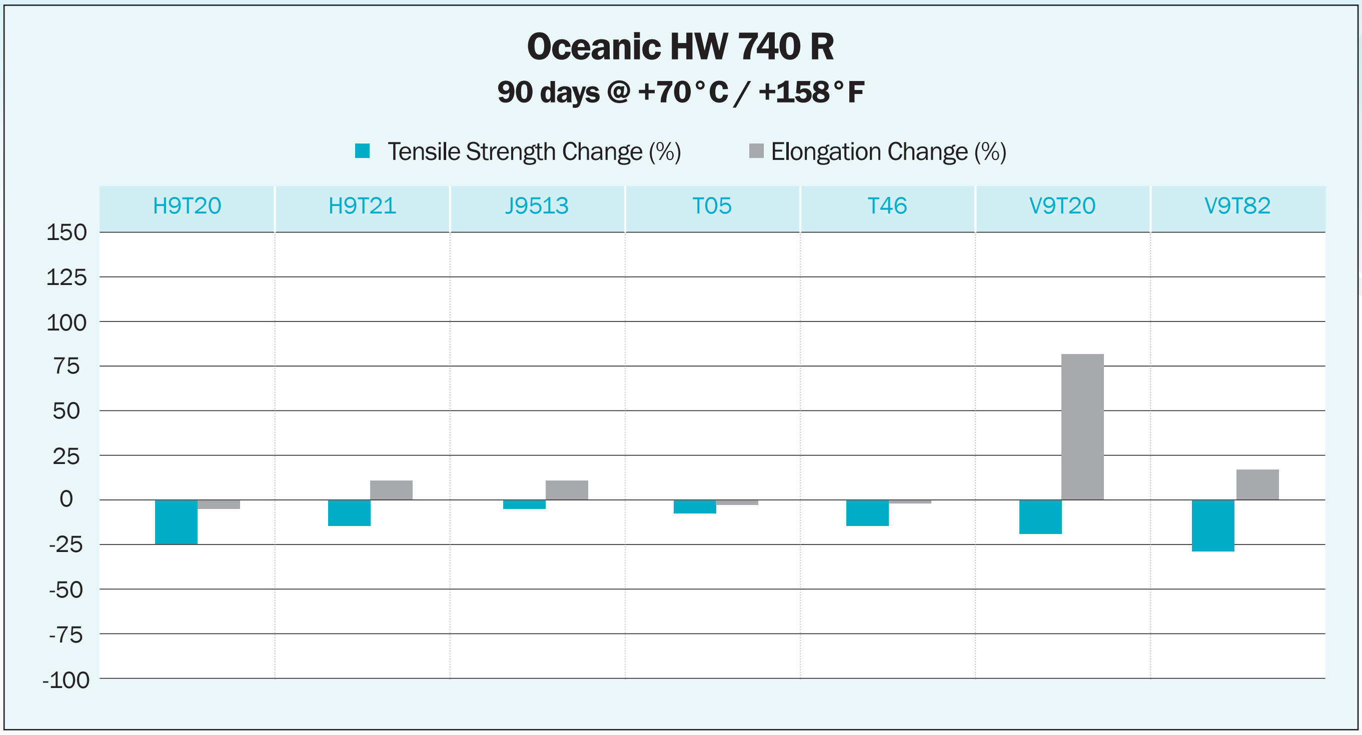

Chart 10 – Tensile Strength and Elongation Change of Seal Materials in Oceanic HW 740 R

Oceanic HW 740 R

90 days at +135 °C / +275 °F in Oceanic HW 740 R							
	H9T20	H9T21	J9513	T05	T46	V9T20	V9T82
Hardness Change (pts)	-15.7	-18.6	1.7	-11	-12	-48.2	-53.1
Tensile Strength Change (%)	-8.7	-13.9	-10.5	-18	-3	-25.5	-26.4
Strain Change (%)	-8.7	-13.9	-10.5	-18	-3	-25.5	-26.4
Volume Change (%)	3.7	4.2	1.4	0	1	28.9	27.6

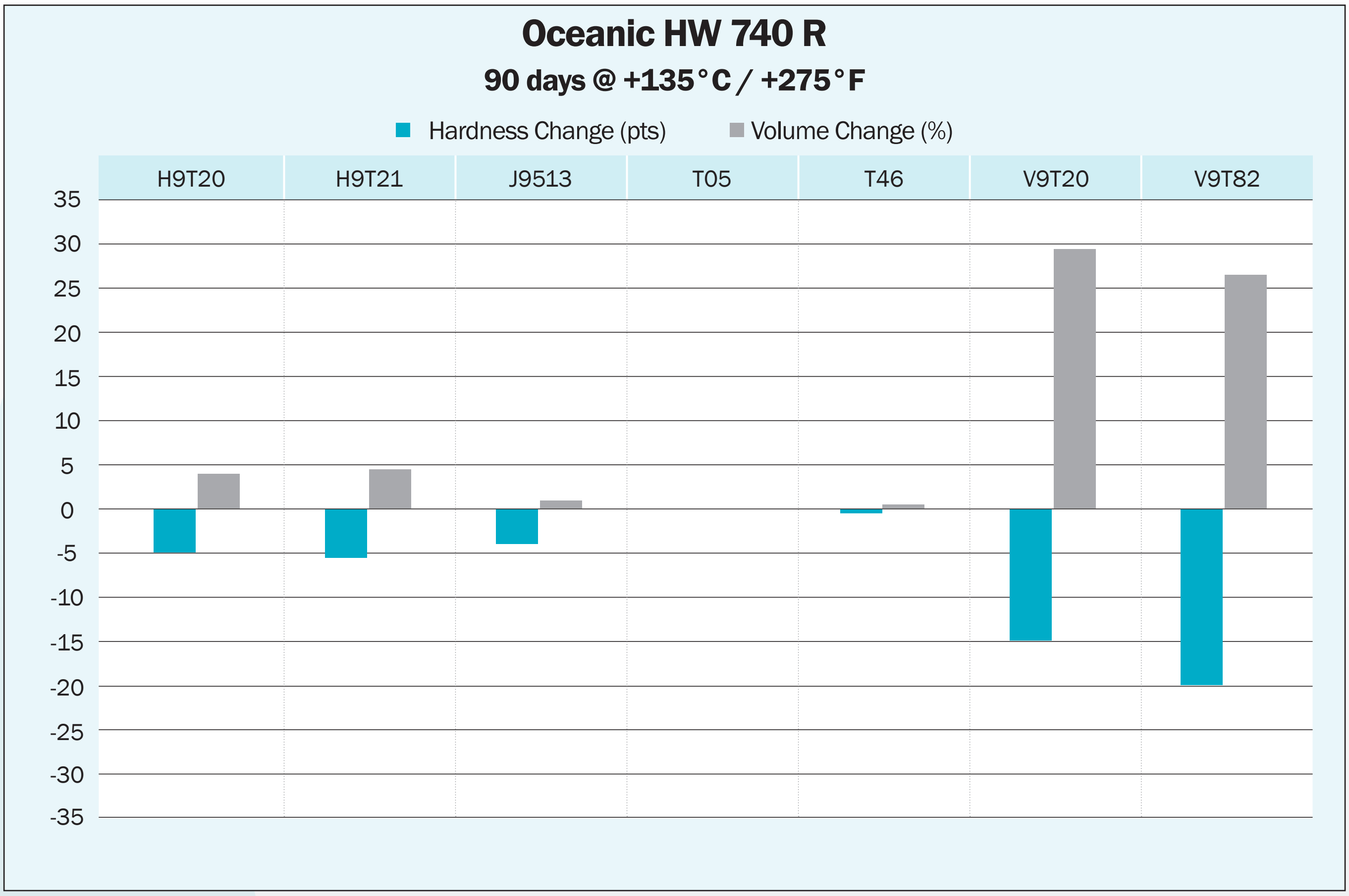

Chart 11 – Hardness and Volume Change of Seal Materials in Oceanic HW 740 R

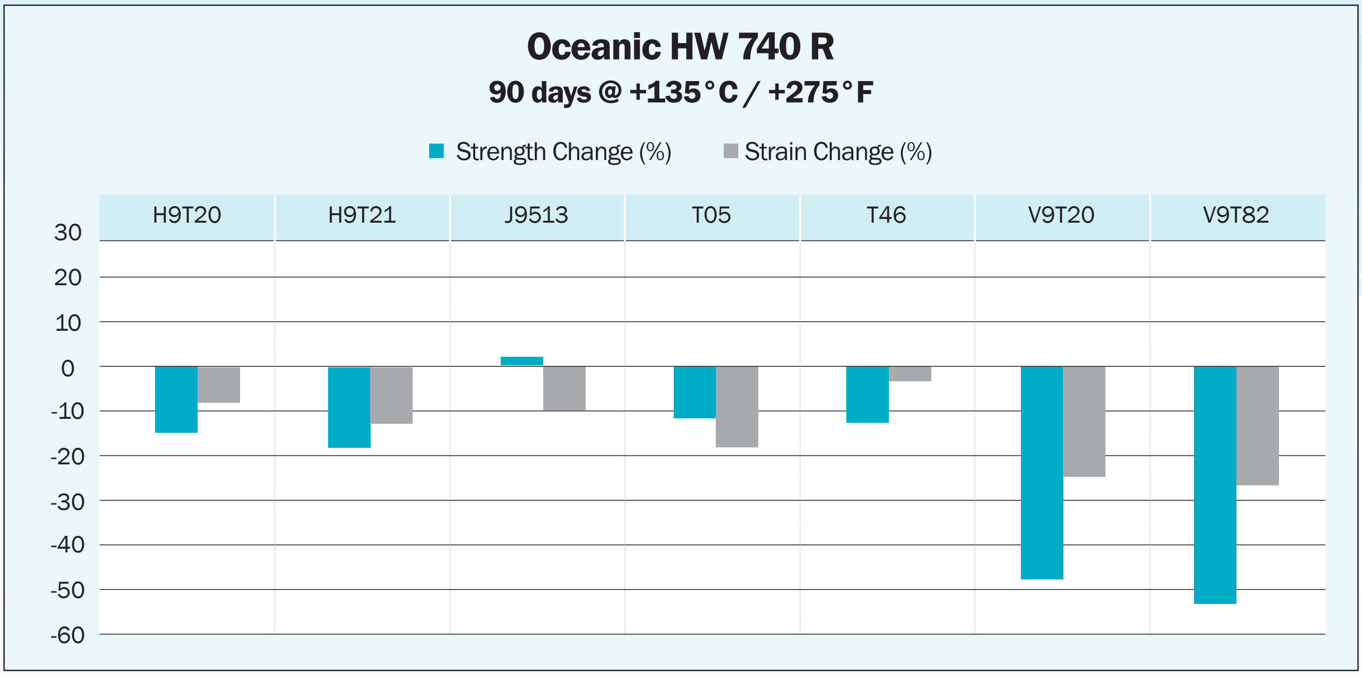

Chart 12 – Tensile Strength and Elongation Change of Seal Materials in Oceanic HW 740 R

Oceanic XT 900

Fluid for use in extreme temperatures.

90 days at +70 °C / +158 °F in Oceanic XT 900

	H9T20	H9T21	J9513	T05	T46	V9T20	V9T82
Hardness Change (pts)	-2	-1	-2	-9	-3	-2	-1
Tensile Strength Change (%)	-3.6	-9.7	-8.4	-25	3	-3	-8
Strain Change (%)	-1.7	-3	7.9	-6	-14	28	5
Volume Change (%)	1.1	1.5	0.2	1	1	2	0

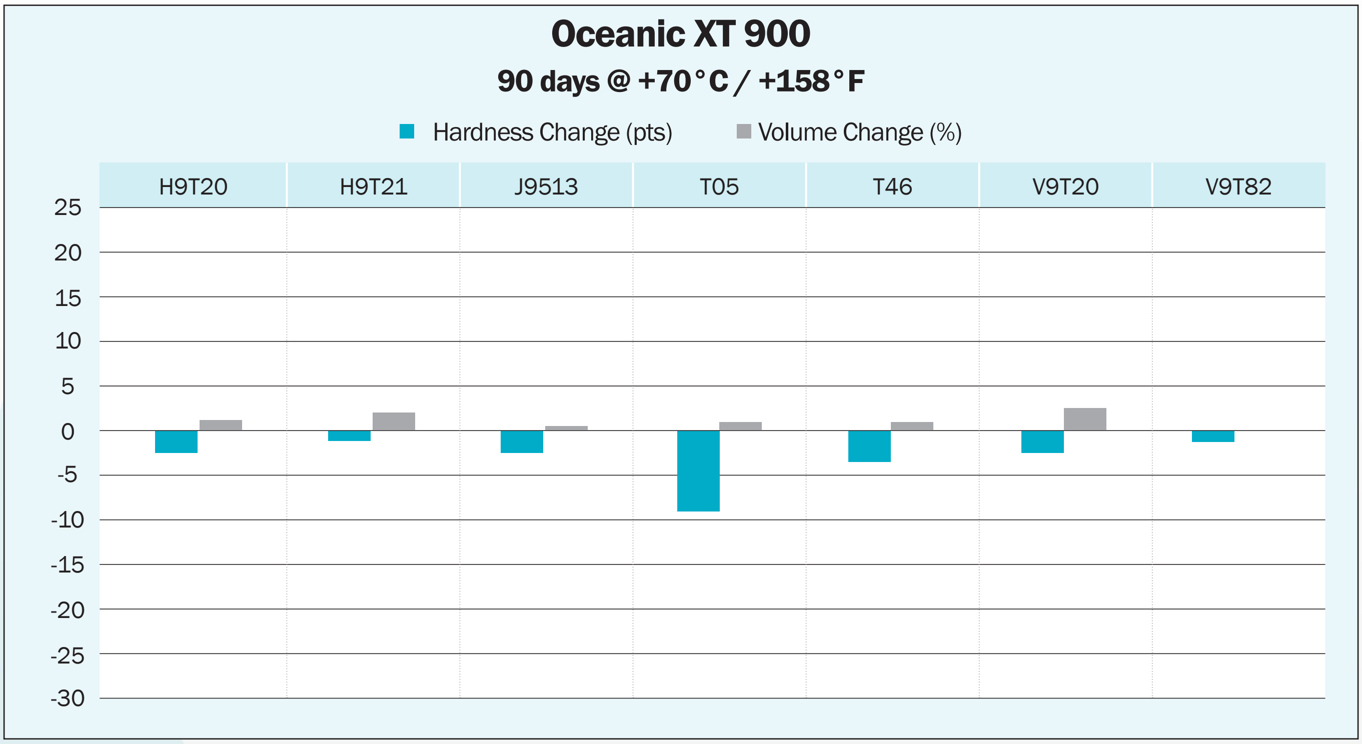

Chart 13 – Hardness and Volume Change of Seal Materials in Oceanic XT 900

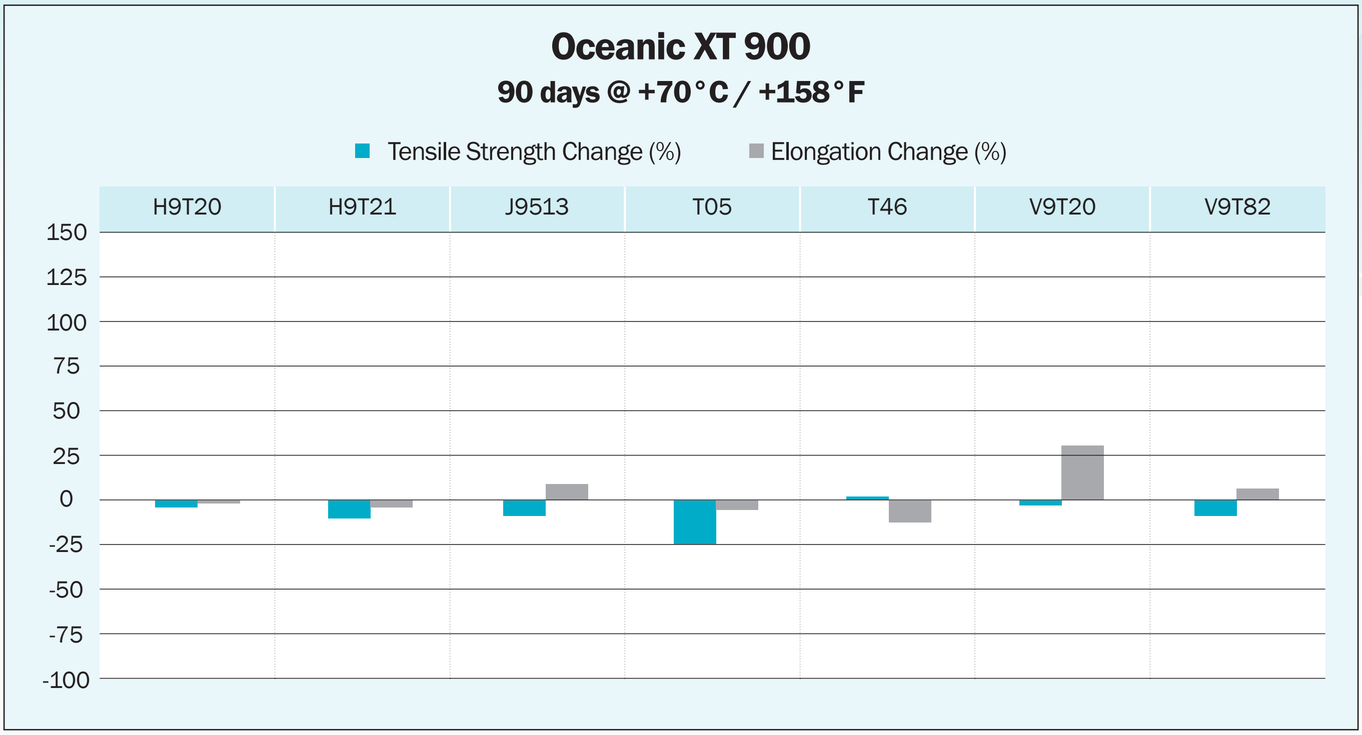

Chart 14 – Tensile Strength and Elongation Change of Seal Materials in Oceanic XT 900

Oceanic XT 900

90 days at +135 °C / +275 °F in Oceanic XT 900	H9T20	H9T21	J9513	T05	T46	V9T20	V9T82
Hardness Change (pts)	-7	-7	-7	1	4	-10	-13
Tensile Strength Change (%)	-20.3	-28.4	-16.3	-7	-6	-5.8	-13.1
Strain Change (%)	-16.5	-16.3	-1.3	-19	-2	8.8	18.2
Volume Change (%)	9.8	10.9	7.8	0	0	17.8	27.6

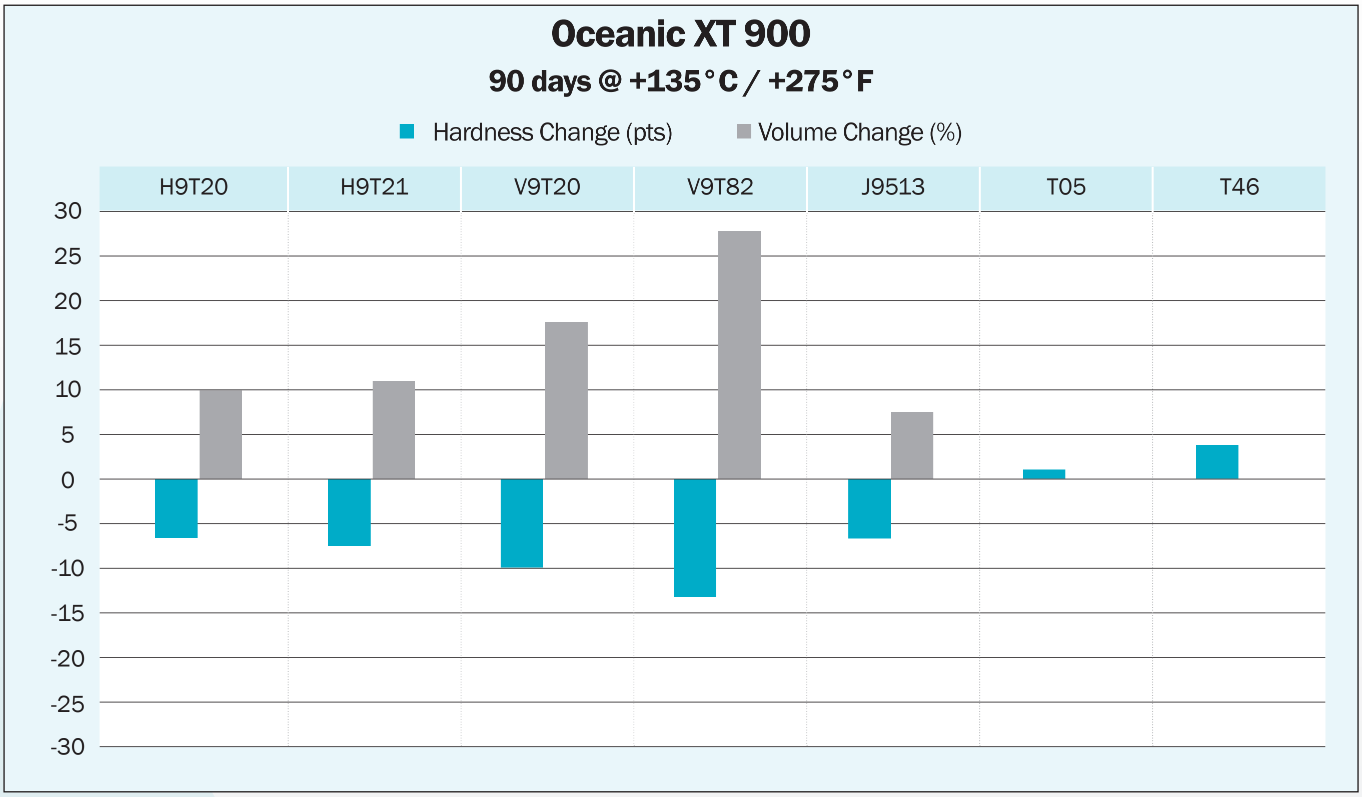

Chart 15 – Hardness and Volume Change of Seal Materials in Oceanic XT 900

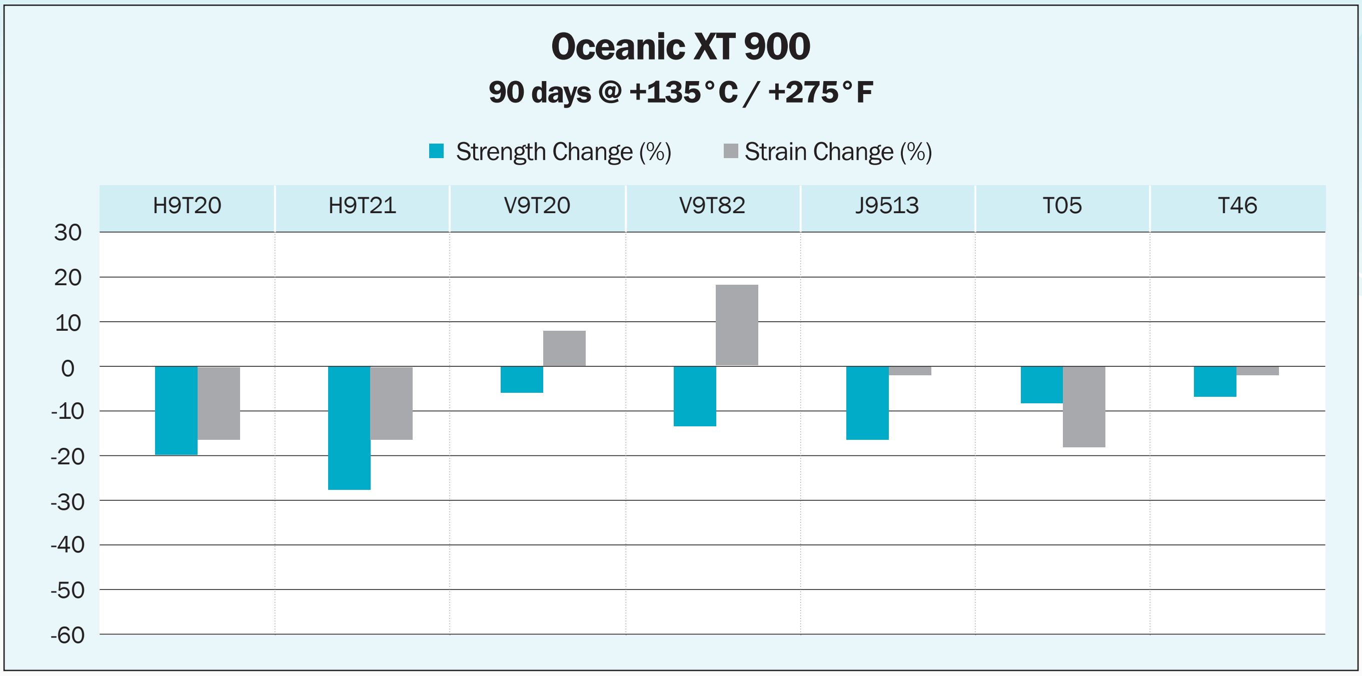

Chart 16 – Tensile Strength and Elongation Change of Seal Materials in Oceanic XT 900

Oceanic XT 900

90 days at +220 °C / +428 °F in Oceanic XT 900				
	J9513	T05	T46	V9T82
Hardness Change (pts)	-10	-4	6	6
Tensile Strength Change (%)	-16	-10	-21	-21
Strain Change (%)	-10	-13	-14	-14
Volume Change (%)	9	0	0	0

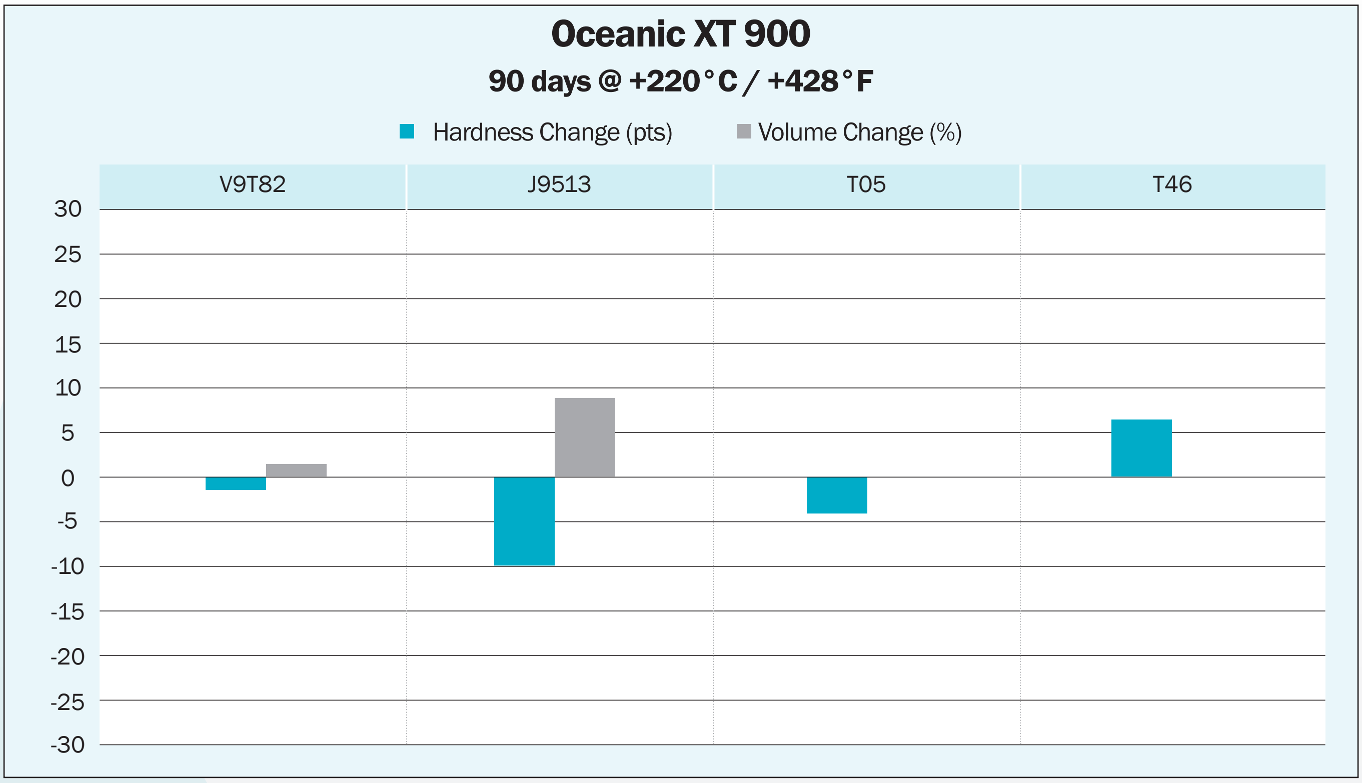

Chart 17 – Hardness and Volume Change of Seal Materials in Oceanic XT 900

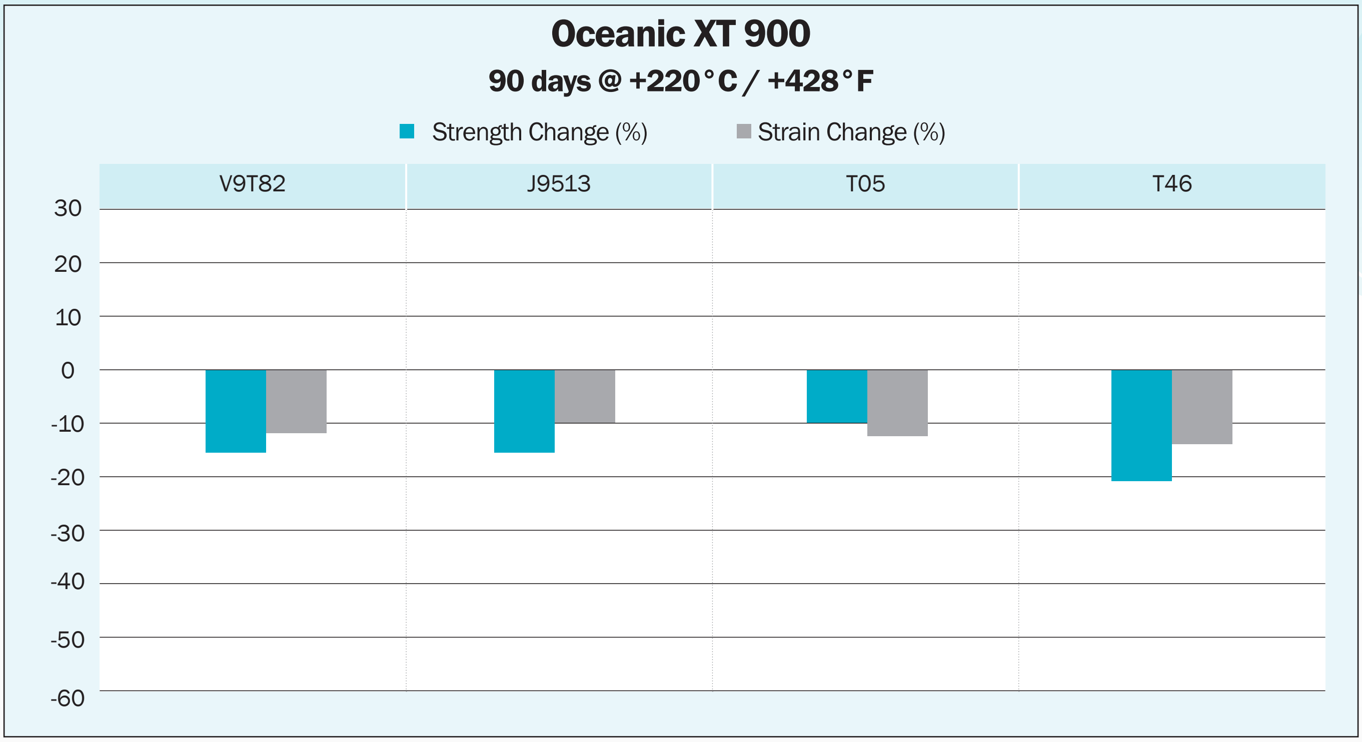

Chart 18 – Tensile Strength and Elongation Change of Seal Materials in Oceanic XT 900

Conclusion

HNBR acceptable up to +135 °C/ +275 °F

Relative to elastomer materials, the testing highlighted that while HNBR (XploR® H9T20 & H9T21) exhibits relatively small changes in hardness, volume, and strain with Oceanic HW 740 R (and other HFC fluids) up to +70°C / 158°F, there is a more pronounced change in these properties when the test is performed at temperatures of +135°C / +275°F.

The HNBR property change from +70°C to +135°C / +158°F to +275°F is expected and typical because rubber materials generally lose properties as temperature increases. Therefore, the test results for HNBR are well within acceptable seal performance and operational limits and suggest the best combination of compatibility and material property retention at temperatures up to +135°C / +275°F.

FKM not recommended at any temperature

In applications where temperatures are above +135°C / +275°F, industry professionals would typically look to FKM (Fluoropolymer) materials to provide a solution. However, our testing illustrates that water-based HFC fluids create a significant change to the properties of FKM at both +70°C / +158°F and +135°C / +275°F. As a result, FKM would not typically be recommended for any applications involving these fluids.

FFKM and PTFE recommended for high temperatures

By comparison, we see relatively small changes in the properties of perfluoroelastomer Isolast® J9513 and Turcon® PTFE materials. At temperatures above +135°C / +275°F, these materials offer a potential solution when dealing with high temperature applications that involve HFC fluids.
More and more deep sea wells are reaching temperatures up to +200°C / +392°F and additional testing within Trelleborg has shown Isolast® J9513 and Turcon® materials retain a significant portion of their material properties in the high temperature water glycol fluids, such as MacDermid Oceanic XT900.

Chemical compatibility checks are vital

The testing reveals the importance of fluid type and seal material choice in ensuring optimum seal performance and service life. Traditional sealing materials, such as FKM, often inert in most fluids, are exhibiting disadvantageous behavior in HFC fluids.

Beware additive compatibility

However, the material compatibilities mentioned here may not automatically result in success. Offshore operators are free to add extra additives to suit their particular application, and the extra additives were not included in the Trelleborg test. The extra additives may lead to seal material incompatibilities and could have dramatic adverse effects on sealing materials. Chemical incompatibility may lead to accelerated aging of the hydraulic fluid and to increased wear and degradation of the sealing components.

Testing in application important

Each application must be reviewed uniquely to optimize the seal materials with the HFC fluid. It is important that seals are proved in specific applications with specific fluids and under actual operating conditions to ensure seal performance and life.

Trelleborg is a world leader in engineered polymer solutions that seal, damp and protect critical applications in demanding environments. Its innovative engineered solutions accelerate performance for customers in a sustainable way. The Trelleborg Group has local presence in over 40 countries around the world.

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