PETROBRAS	**TECHNICAL SPECIFICATION OF REQUIREMENTS**	NO: 3000.00-1210-130-PPQ- 001	
	PROGRAM: **WELLS**		Sheet 1 of 17
	AREA: **NON-METALLICS**		-
POCOS/CTPS	TITLE: **Elastomeric Well Components**		PUBLIC
			POCOS/CTPS

REVIEW INDEX

REV.	DESCRIPTION AND/OR LEAVES AFFECTED
0	Original issue
A	Modification in Appendix A of the concentration of the densifying salt from NaCl to $CaCl_2$ The words "Sealing elements for plugs, standing valves and GR valves must have a service life of three years only, for the same temperatures." have been deleted, given that properly monitored wells can remain in temporary abandonment indefinitely.
B	Replace the keys with the acronyms of the managers involved and change the classification of the document from NP-1 to Public.
C	Table 3 changes the maximum temperature for injection water for water injection wells from 45 ºC to 70 ºC.
D	Correction of text formatting. Correction of the text of Item 4 - Arrhenius equation. Amendment of item 5.3.1

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F
DATE	04/2018	07/2018	27/08/2018	11/02/2020	06/09/2023		
PROJECT	POCOS/CTPS	POCOS/CTPS	POCOS/CTPS	POCOS/CTPS	POCOS/CTPS		
EXECUTION	WELL/CTPS/CT-	WELL/CTPS/CT -	WELL/CTPS/CT	WELL/CTPS/CT	WELL/CTPS/CT		
CHECK	CENPES/PDISO/TME -	CENPES/PDISO/TME -	CENPES/PDISO/TME	CENPES/PDISO/TME	CENPES/PDISO/TME		
APPROVAL	WELL/CTPS/CT -	WELL/CTPS/CT -	WELL/CTPS/CT	WELL/CTPS/QC	WELL/CTPS/QC		

SUMMARY

1. INTRODUCTION

1.1. The purpose of this document is to establish the Technical Specification for elastomeric equipment elements that remain in the well throughout its productive life and are intended to promote sealing, guaranteeing the integrity of the well equipment.

2. SCOPE

2.1. This Technical Specification applies to all elastomers contained in permanent or retrievable well equipment and which form part of the joint barrier assembly. Equipment to which this definition applies is:

- *Packers/blowers*, open pit or *lined*, or *liner packer*.
- Motion compensation elements, *locator* or TSR.
- Linking elements, anchors.
- *Gas-lift* valves.
- Chemical injection valves.
- Isolation valves: VIF, VHIF, CI.
- BCSS.
- DSSS.
- *Standing valves*.
- *Plugs* (or mechanical *plugs*).
- Subsea equipment in general (mainly *tubing hanger* seals).

2.2. Even if not listed, all well equipment with an elastomeric seal, whether primary or secondary, that becomes part of the solid set of well barriers must comply with this Technical Specification.

2.3. The equipment was divided into bottom, subsea and chemical *injection/gas-lift* applications.

2.3.1. Examples of bottom applications are: plugs, TSRs, *locators,* anchors, VHIF, CI, DSSS (bottom), formation isolation valves and *gas-lift and* chemical injection valves.

2.3.2. Subsea applications include DSSS (installed close to the TH), *tubing hanger* and Wet Christmas Trees.

2.3.3. Injection applications are all those that conduct inhibitors via the umbilical to the inside of the column, such as mandrels and chemical injection valves, or even via gas-lift in some cases.

2.4. Four scenarios are established: PRODUCER wells 01 and 02, distinguished by the characteristics of the reservoirs to be exploited; WATER INJECTOR wells and WATER ALTERNATING GAS INJECTOR wells (WAG).

3. REFERENCE DOCUMENTS

API 19AC - *Specification for Completion Accessories*

PI 11D1 **-** *Down Hole Equipments - Packers and Bridge Plugs*

ISO 23936-2 - *Petroleum, petrochemical and natural gas industries - Non-metallic materials in contact with media related to oil and gas production - Part 2: Elastomers*

4. TERMS AND DEFINITIONS

- Arrhenius equation - Relates the reaction rate constant to temperature and is widely used to predict the lifespan of polymers under certain operating conditions.

- Rubber - A polymer with "elastic" properties after vulcanization. There are 3 different definitions depending on the context applied, according to ISO 138:1996. The term can be applied to the product material (composition), the basic raw material (molecule) or the product itself. Chemical compatibility - Characteristic resulting from the elastomer's low chemical interaction with the environment or specific chemical products and their mixtures, under a given exposure condition.

- *Grade* - An English term that defines the architecture, molecular structure and molar mass of a family of polymers.

- Elastomer - A polymer with elastic properties, which can be obtained through cross-linking (thermosets) or not (thermoplastics). This type of material can withstand large deformations before breaking.

- Ageing - Changes in the characteristics of a material due to its exposure to different chemical agents and operating environments.

- FEPM - Fluorinated copolymer of tetrafluoroethylene (VDF) and propylene (P). Commercial examples: Aflas®

- FFKM - Fluorinated copolymer of tetrafluoroethylene (VDF) and perfluoroalkene. Commercial examples: Kakrez® , Chemraz® , Tecnoflon®

- FKM - Fluorinated vinyl polymer. FKMs can be divided into different classes based on their chemical composition, their fluorine content and their crosslinking mechanisms.

- FKM Type I - Fluorinated copolymer formed from the monomers vinylidene fluoride (VDF) and hexafluorpropylene (HFP), with a fluorine content of approximately 66 %. Commercial examples: Tecnoflon® N935, Fluorel®, Dai-El®.

- FKM Type II - Fluorinated terpolymer formed from the monomers vinylidene fluoride (VDF), hexafluorpropylene (HFP) and tetrafluoroethylene (TFE), with a fluorine content of between 68 and 69 %. Commercial examples: Viton® B, Tecnoflon® TN.

- FKM Type III - Fluorinated tetrapolymer formed from the monomers vinylidene fluoride (VDF), hexafluorpropylene (HFP), tetrafluorpropylene (TFE) and perfluormethylvinylether (PMVE), with a fluorine content of between 62 and 68%. Commercial examples: Viton® GLT, Tecnoflon® PL 855.

- FKM Type IV - Fluorinated terpolymer made up of vinylidene fluoride (VDF), tetrafluoroethylene (TFE) and propylene (P), with a fluorine content of approximately 67 %. Commercial examples: Aflas® MZ201, BRE 7132X, Aflas® SP.

- FKM Type V - Fluorinated pentapolymer made up of vinylidene fluoride (VDF), hexafluorpropylene (HFP), tetrafluoroethylene (TFE), perfluormethylvinylether (PMVE) and ethylene (E), with a fluorine content of approximately 65 %. Commercial examples: Tecnoflon® BR9151, Dai-El®.

- HNBR - Hydrogenated nitrile rubber.

- NBR - Polymer of acrylonitrile and butadiene, known as nitrile rubber

5. DESCRIPTION OF FUNCTIONAL AND TECHNICAL REQUIREMENTS

5.1. THERMOMECHANICAL REQUIREMENTS

5.1.1. The main function of elastomeric components in well equipment is to promote sealing. The effects of variations in pressure, temperature and movement must be assessed as described in the equipment's Technical Specification in accordance with the degree of validation of the relevant standard, such as API 11D1 and API19AC.

5.2. CHEMICAL COMPATIBILITY

5.2.1. The elastomers must be compatible with the fluids produced by the reservoir and used for well control, continuous chemical injection and chemical treatments with probe or remote, proven by ageing and explosive decompression tests, with reference to ISO 23936-2.

5.2.2. Fluid produced by the reservoir means mixtures of carbon chains of different sizes and geometries in the liquid or gaseous phases, which may contain acidic contaminants such as H_2S and CO_2, while also taking into account the aromatic content of the fluids produced.

5.2.3. The fluids for well control and injection include brines (sodium and calcium chloride) and acids for stimulation (hydrochloric acid, acetic acid, ethylene diamine tetra acetic acid - EDTA, HAc-HForm Mixture, Inorganic *Mud Acid*), as well as inhibitors made up of solvents, H_2S sequestrants and alcohols.

5.2.4. This Technical Specification defines four application scenarios and three sets of equipment:

SETS OF EQUIPMENT

- ✓ Bottom
- ✓ Subsea
- ✓ Chemical Injection and Gas-Lift

SCENARIOS

- ✓ Producer 1
- ✓ Producer 2
- ✓ Water Injector
- ✓ Gas/water injector

5.2.5. The operating parameters for which each set of equipment must be compatible with the relevant fluids during the lifespan required in the project are specified in the tables "Table 1 - Operating Parameters for Production Wells from Scenario 1" to "Table 4 - Operating Parameters for Injection Wells" below:

Table 1 - Operational Parameters for Scenario 1 Production Wells

PRODUCER 01	BOTTOM	SUBSEA	CHEMICAL INJECTION AND *GAS-LIFT*
Aromatics [%]	35	35	100
CO_2 [%]	40	40	4
H_2 S (ppm)	1200	100	10
Contact Brine	YES	NO	NO
Tmin [°C]	82	4	82
Tmax [°C]	130	25	130
Contact with acid (Yes/No)	YES	YES	NO

Table 2 - Operational Parameters for Scenario 2 Production Wells

PRODUCER 02	BOTTOM	SUBSEA	CHEMICAL INJECTION AND *GAS-LIFT*
Aromatics [%]	30	30	100
CO_2 [%]	3	3	4
H_2 S (ppm)	300	300	10
Contact Brine	YES	NO	NO
Tmin [°C]	50	4	50
Tmax [°C]	85	25	85
Contact with acid (Yes/No)	YES	YES	NO

Table 3 - Operating Parameters for Water Injection Wells

Water Injector	BOTTOM	SUBSEA	CHEMICAL INJECTION AND GAS-LIFT
Aromatics [%]	-	-	-
CO_2 [%]	-	-	-
H_2 S (ppm)	-	-	-
Contact Brine	YES	SEA WATER	-
Tmin [°C]	10	4	-
Tmax [°C]	125	70	-
Contact with acid (Yes/No)	YES	YES	-

Table 4 - Operating Parameters for Gas/Water Injection Wells

Water Injector	BOTTOM	SUBSEA	CHEMICAL INJECTION AND *GAS-LIFT*
Aromatics [%]	-	-	-
CO_2 [%]	65	65	-
H_2 S (ppm)	-	-	-
Contact with brine	YES	SEA WATER	-
Tmin [°C]	7	4	-
Tmax [°C]	125	40	-
Contact with acid (Yes/No)	YES	YES	-

5.3. QUALITY CONTROL

5.3.1. Each material must present a *Material Test Report* (*MTR*) or Certificate of Conformance (COC), dimensional inspection, the batch and the date and type of curing or vulcanization of the elastomer that is part of the tool, with the minimum information described in item 7.2 of this Technical Specification.

5.3.2. The storage conditions necessary to preserve the properties of the elastomer must be presented, as well as the company's plan for meeting these conditions. The supplier must provide clear recommendations in its tool preparation procedures regarding care during assembly and positioning of the elastomers in the tools.

6. ADDITIONAL TECHNICAL REQUIREMENTS

6.1. Suppliers must submit compatibility tables in terms of minimum and maximum pressures and temperatures, concentrations of the fluids evaluated and pH, and the conditions for validating this table. An example of a compatibility table is shown in Appendix B.

6.2. All tests must be done in accredited laboratories: the calibration certificates of measuring and control instruments, such as temperature controllers, tensile testing machines, etc. must be attached.

7. DOCUMENTATION

7.1. SUPPORTING DOCUMENTATION

7.1.1. Ageing tests

7.1.1.1. The supplier must present validation tests for use in *offshore* wells considering the ageing phenomenon in accordance with Annex A of ISO 23936-2, for each equipment group and scenario requested in the Technical Specification for the Requisition of Goods and Services.

7.1.1.2. Tests must be reported in the ISO 23936-2 format, analogous to table A.7.

<u>PRODUCER SCENARIO 01</u>

7.1.1.3. Ageing tests for 27 years at a temperature of 130°C for bottom equipment, chemical injection and *gas lift*

7.1.1.4. Ageing tests for 27 years at a temperature of 25°C for subsea equipment.

7.1.1.5. Table 5 gives the composition of the fluid for the chemical compatibility test with formation fluid.

7.1.1.6. Table 6 gives the composition of the fluid for the gas compatibility test.

Table 5 - Composition of fluid for aging test with formation fluid from well scenario PRODUCER 1

Equipment	Heptane [%]	Cyclohexane [%]	Toluene [%]
Bottom	45	20	35
Subsea	45	20	35
Injection	0	0	100*

Table 6 - Composition of the fluid for the formation gas aging test of the well scenario PRODUCER

Equipment	CO_2 [%]	H_2S [ppm]	CH_4 [%]
Bottom	40	1200	59,9
Subsea	40	100	59,9
Chemical Injection and *Gas-Lift*	4	15	96

Only for wells expected to inject asphaltene inhibitor

7.1.1.7. A 27-year ageing test with calcium chloride pH 9 (composition and properties in Appendix A) is also requested for the bottom equipment.

7.1.1.8. In addition, an ageing test with hydrochloric acid at a volumetric concentration of 15% for a duration of one day is requested for the bottom and subsea equipment.

7.1.1.9. For injection equipment, the ageing test must be carried out with ethanol fluid for a duration of 27 years. The test must be repeated with pure toluene, according to Table 5 - Composition of the fluid for the ageing test with formation fluid from the well scenario PRODUCER 1

PRODUCER SCENARIO 02

7.1.1.10. Ageing tests for a service life of 27 years at a temperature of 85°C for bottom, chemical injection and *gas-lift applications.*

7.1.1.11. Ageing tests for a service life of 27 years at a temperature of 25°C for subsea applications.

7.1.1.12. Plug sealing elements, *standing valves* and GR valves should have a service life of three years only, for the same temperatures.

7.1.1.13. Table gives the composition of the fluid for the chemical compatibility test with formation fluid.

7.1.1.14. Table gives the composition of the fluid for the gas compatibility test.

Table 7 - Composition of fluid for aging test with formation fluid from well scenario PRODUCER 2

Equipment	Heptane [%]	Cyclohexane [%]	Toluene [%]
Bottom	50	20	30
Subsea	50	20	30
Chemical Injection and *Gas-Lift*	0	0	100*

Table 8 - Composition of the fluid for the formation gas aging test of the PRODUCER 2 well scenario

Equipment	CO_2 [%]	H_2S [ppm]	CH_4 [%]
Bottom	3	300	96,9
Subsea	3	300	96,9
Chemical injection and *Gas-Lift*	4	15	96

<u>Only for wells expected to inject asphaltene inhibitor</u>

7.1.1.15. A 27-year ageing test with calcium chloride pH 9 (composition and properties in Appendix A) is also requested for the bottom equipment.

7.1.1.16. In addition, an ageing test with hydrochloric acid at a volumetric concentration of 15% for a duration of one day is requested for the bottom and subsea equipment.

7.1.1.17. For injection equipment, the ageing test must be carried out with ethanol fluid for a duration of 27 years. The test must be repeated with pure toluene (according to Table 7 - Fluid composition for ageing test with formation fluid from the PRODUTOR 2 well scenario).

<u>WATER INJECTOR SCENARIO</u>

7.1.1.18. As the elastomers in this scenario do not come into contact with the reservoir fluids, it is only necessary to present ageing tests with hydrochloric acid at a volumetric concentration of 15% and with calcium chloride at pH 9 (composition and properties in Appendix A) for a duration of 27 years at a temperature of 125°C.

7.1.1.19. Sealing elements for plugs, standing valves and GR valves must have a service life of three years only, for the same temperatures

GAS/WATER INJECTOR SCENARIO

7.1.1.20. Ageing tests for a service life of 27 years at a temperature of 125°C for bottom and chemical injection and *gas lift* applications.

7.1.1.21. Ageing tests for a service life of 27 years at a temperature of 40° for subsea applications.

7.1.1.22. Sealing elements for plugs, standing valves and GR valves should have a service life of three years only, for the same temperatures.

7.1.1.23. Table 9 gives the composition of the fluid for the chemical compatibility test with the gas. It is not necessary to check the chemical compatibility of the elastomer with the formation oil

Table 9 - Fluid composition for formation gas aging test of gas/water injection well scenario

Equipment	CO_2 [%]	H_2 S [ppm]	CH_4 [%]
Bottom	65	-	40
Subsea	65	-	40

7.1.1.24. A 27-year ageing test with calcium chloride pH 9 (composition and properties in Appendix A) is also requested for the bottom equipment.

7.1.1.25. In addition, an ageing test with hydrochloric acid at a volumetric concentration of 15% for a duration of one day is requested for bottom and subsea equipment.

7.1.2. Rapid Explosive Decompression Tests

7.1.2.1. The supplier must present validation tests for use in *offshore* wells considering the explosive decompression phenomenon according to Annex B of ISO 23936-2, for each equipment group and scenario.

7.1.2.2. The test must be carried out at a minimum of 100 °C and a pressure of 600 bar, but may be carried out at higher temperatures and pressures.

7.1.2.3. At least 8 cycles must be carried out at a depressurization rate of 20 bar/min on 4 similar samples down to 0 psi, in accordance with ISO 23936-2, Annex B.

7.1.2.4. The tests must be presented in the format of ISO 23936-2, table B-6.

7.1.2.5. It is not necessary to check resistance to the explosive decompression phenomenon for water injection applications in any of the equipment groups mapped.

PRODUCER SCENARIO 01

7.1.2.6. The fluid for explosive decompression tests must be 40 mol% CO_2 and 60 mol% N_2 in accordance with ISO 23936-2, Annex B, Table B.1, *Bespoke,* for bottom and subsea applications.

PRODUCER SCENARIO 02

7.1.2.7. It is not necessary to demonstrate resistance to explosive decompression for PRODUCER wells in this scenario.

WATER INJECTOR SCENARIO

7.1.2.8. It is not necessary to demonstrate resistance to explosive decompression for water injection wells.

GAS/WATER INJECTOR SCENARIO

7.1.2.9. The fluid for explosive decompression tests must be 65 mol% CO_2 and 35 mol% N_2 in accordance with ISO 23936-2, Annex B, Table B.1, *Bespoke,* for bottom and subsea applications.

7.1.3. Glass Transition Temperature

7.1.3.1. The elastomers must have a glass transition temperature lower than the temperatures given below for each equipment group and scenario, according to Table 10 below

Table 10 - Minimum Vitreous Transition Temperatures for elastomers

Minimum Vitreous Transition Temperatures	PRODUCER 01	PRODUCER 02	WATER INJECTOR	GAS/WATER INJECTOR
Bottom	82°C	50 °C	10°C	7 °C
Subsea	4° C	4° C	4° C	4 °C
Chemical Injection and *Gas-Lift*	82°C	50 °C	-	-

7.2. TECHNICAL DOCUMENTATION

7.2.1. For the purposes of additional studies or investigations, well equipment containing elastomeric seals must submit information on the sealing material with the equipment proposal:

- Name of elastomer manufacturer Name of elastomer supplier
- Type of elastomer
- Grade
- Density
- Hardness
- Yield value
- Tension applied at 50% elongation
- Tension applied at 100% elongation
- Elongation at break

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APPENDIX A - COMPLETION FLUID COMPOSITION

A1- Composition

CASAC		
Product	**Function**	**Scheduled Concentration (lb/bbl)**
Sea water	Thinner	QSP
$CaCl_2$	Densifier	180
NaHSO3 (@40%)	Oxygen sequester	0.045% v/v
Glutaraldehyde (@40%)	Bactericidal	0.053 % v/v
Emulsion preventer	Emulsion preventer	0.200 % v/v
NaOH	pH controller	up to pH 9
Corrosion Inhibitor	Corrosion Inhibitor	0.24 % v/v

A2- Properties

Properties	CASAC
Weight (ppg)	9,6
Salinity (mg/L NaCl)	190.000 a 260.000
pH	8 - 9
Ca2+ (mg/L)	500 - 700
Mg2+ (mg/L)	1.500 - 2.000
Turbidity (NTU)	< 30

APPENDIX B - SAMPLE TABLE

Elastomer type	Upper temp [a] °C	Characteristics	Selected general fluid resistance				
			Crude oil	Alkaline	MeOH	Water	H_2S
EPDM	150	Good in water and steam; poor in hydrocarbons	NO [b]	OK [c]	OK	OK	OK
CR	100	Good in water; can be used as a hose cover, good weathering properties	C [d]	NO	OK	OK	C
NBR	120	Nitrile; highly unsaturated; a good general purpose sealing material, susceptible to ageing; vary acrylonitrile content to affect low temperature performance and oil swell	OK	OK	OK	OK	NO
HNBR	160	Hydrogenated nitrile; largely saturated, improved heat ageing, chemical and weather resistance; vary acrylonitrile content to affect low temperature performance and oil swell	OK	OK	OK	OK	C
FKM 1	200	Copolymer; most widely specified type; poor in methanol and alkaline fluids	OK	NO	NO	OK	C
FKM 2	200	Terpolymer; high fluorine grades good in methanol	OK	NO	OK	OK	C
FKM 3	200	Terpolmer; low T_g; low fluorine grades not good in methanol	OK	NO	NO	OK	C
FKM 5	200	Pentapolymer; developed for alkaline fluid resistance; very little performance info available	OK	OK	OK	OK	C
FEPM	230	TFE/P copolymer; poor in aromatic solvents; good H_2S, steam and alkaline resistance; high T_g	C	OK	OK	OK	OK
	200	ETP – Ethylene containing terpolymer; developed for alkaline resistance	OK	OK	OK	OK	C
FFKM	220 to 315	Thermal performance depends on crosslink chemistry; very good fluid/chemical resistance;	OK	OK	OK	OK	OK

[a] Maximum rated temperature in air.

[b] NO: considered unsuitable for service; excessive volume swell at equilibrium: also, chemical ageing may occur.

[c] OK: considered suitable for service, in terms of volume swelling (< 20 %) and ageing.

[d] C: could be suitable for service, in terms of volume swelling and ageing, but refer to qualifying notes; also, fluid contact may not be relevant.

NOTE 1 OK covers a range of performance, e.g. FKM crude oil resistance is better than that of NBR/HNBR, although nitrile are usually considered as acceptable.

NOTE 2 Service situations involving CR contact with H_2S are unlikely to exist.

NOTE 3 Nitriles will chemically age, NBR more readily than HNBR, in contact with H_2S; temperature and concentration factors apply.

NOTE 4 Methanol is 100 % (neat); dilution with water will make methanol less aggressive.

NOTE 5 FKM 5 has better resistance than FKM 1-3. As some fluids may degrade this elastomer type testing is recommended.

NOTE 6 FKM cure important; generally, peroxide cure gives better chemical resistance than bisphenol cure chemistry.