

DEP SPECIFICATION

SHAFT SEALING SYSTEMS FOR CENTRIFUGAL AND ROTARY PUMPS (AMENDMENTS/SUPPLEMENTS TO ISO 21049:2004)

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DESIGN AND ENGINEERING PRACTICE

DEM1



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PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for type selection and basic design of shaft seals and their related seal systems for centrifugal and rotary pumps.

This DEP is based on ISO 21049:2004. Part III of this DEP amends, supplements and deletes various clauses of ISO 21049:2004. Part III follows the clause numbering of ISO 21049:2004 for easy reference.

All clauses of ISO 21049:2004 not modified by this DEP remain valid as written.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards.

This is a revision of the DEP of the same number dated February 2011; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. Application in other facilities may also apply.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

NOTE: In ISO 21049, the term **Vendor** is used. In this DEP, the term **Vendor** shall be understood to mean the Manufacturer/Supplier.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

NOTE: In ISO 21049, the term **Purchaser** is used. In this DEP, the term **Purchaser** shall be understood to mean the Principal.

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

See (Part III, clause 3).

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (Part IV).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated February 2011. The following are the main, non-editorial changes.

Clause	Change
Part III, 4.3.1	Modified the SHALL [PS] statement to clarify that it applies only to new pump/seal applications. Added a note clarifying that the need to modify/replace existing seal applications is evaluated in the existing site risk assessment process.

NOTE: This DEP was amended in September 2012. In that amendment, a number of technical changes were made to the previous version (dated February 2011) that are now carried forward in this version.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://www.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (Other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

PART II GENERAL

Part III of this DEP is written as amendments and supplements to ISO 21049:2004. Wherever reference is made to ISO 21049:2004, it shall be understood to mean ISO 21049:2004 as amended/supplemented by this DEP.

For ease of reference, the clause numbering of ISO 21049:2004 has been used throughout Part III of this DEP.

Clauses in ISO 21049:2004, which are not mentioned in this DEP, shall remain valid as written.

PART III AMENDMENTS/SUPPLEMENTS TO ISO 21049:2004**1 Scope**

Replace this clause by:

This DEP covers the minimum requirements for shaft seals and related sealing auxiliary systems for centrifugal and rotary pumps used in the petroleum, natural gas and chemical industries. It is applicable for all services. It is required for the improvement of equipment availability and the reduction of emissions to the atmosphere and of life-cycle sealing costs.

The applications addressed in this DEP cover sealing duties for pumps with a working temperature range of $-40\text{ }^{\circ}\text{C}$ to $+400\text{ }^{\circ}\text{C}$ ($-40\text{ }^{\circ}\text{F}$ to $750\text{ }^{\circ}\text{F}$) and a maximum allowable working pressure of 4,200 kPaa (615 psia). It covers seals for pump shaft diameters from 20 mm (0.75 in) to 110 mm (4.3 in). Seal applications outside these boundaries are subject to the same design and configuration principles, but require the Principal's approval.

Add new clauses:

- 1.1 Seals and auxiliary systems for ISO 13709 Type OH6 high speed integrally gear driven pumps shall comply with this DEP as far as practical, with allowance being made for the relatively inflexible constraints of the seal hardware arrangement.
- 1.2. Seals and auxiliary systems for hydraulic power recovery turbines shall conform to the requirements in this DEP as much as practical, but these are engineered systems and require Principal approval.
- 1.3 Any seals and seal systems outside the scope of this DEP require a review by the Principal. The seal Vendor shall supply references of seals in similar service.
- 1.5 The seal Vendors shall review all seal and auxiliary system applications and shall notify the Principal if, according to their best practice and experience with seals or auxiliary systems in similar applications, a deviation from the requirements in the data sheets or this DEP would result in equal or improved sealing.
- 1.6 In case of conflict between documents relating to the inquiry or purchase order, the following hierarchy of documents shall apply:
 - Upper level : purchase order and variations thereto
 - Second level : data/requisition sheets and drawings
 - Third level : This DEP.

3 Terms and definitions

Add new definitions:

3.79 hazardous service

service comprising the following categories, which shall be specified on the data/requisition sheets:

Category 1

- Liquids classified as "very toxic - acute"
- Liquids containing ethylene oxide

Category 2

- Liquids classified as "very toxic - chronic"
- Hydrocarbon liquids at an operating temperature above their auto-ignition temperature.

Category 3

- Hydrocarbon liquids with a seal chamber vapour pressure higher than 500 kPaa (73 psia);
- Light hydrocarbon services (ISO 21049:2004, Clause 3.38)
- Liquids classified as "very toxic - environment".

NOTE: Refer to DEP 01.00.01.30-Gen. for additional details concerning the definition of "very toxic - acute", "very toxic - chronic", and "very toxic - environment".

3.80 auto-ignition product

hydrocarbon liquid that may spontaneously ignite upon release to atmosphere

3.81 engineered seal

seal or seal system that is outside the scope of this DEP and requires approval of the Principal.

EXAMPLES:

- Seals that exceed the seal Vendor's standard design temperature limits;
- Seals that exceed the seal Vendor's standard design pressure limits;
- Seals that exceed the limitations listed in Annex A, A.1.2

3.82 vital, essential and non-essential services

These terms are defined as follows:

	SAFETY EQUIPMENT	OTHER EQUIPMENT		
	SERVICE CATEGORY			
	VITAL	ESSENTIAL		NON-ESSENTIAL
		Non-spared equipment	Spared equipment	
Definition	A service in which failure of equipment causes an unsafe condition of the plant or installation resulting in jeopardy to life and/or major damage (fire, explosion etc.).	A service in which failure of equipment renders a plant or process unit inoperable or reduces performance to a level unacceptable to the Principal.	A service in which failure of equipment renders a plant or process unit inoperable or reduces performance to a level unacceptable to the Principal.	All other services.
Examples	- Firewater pumps with diesel and motor drives; - Emergency Shutdown (ESD) systems; - Emergency Instrument Air (EIA) compressor.	- Hydrocracker (HCU) feed pump; - HCU recycle compressor; - Cat Cracker (FCCU) main air compressor; - Forced Draft (FD) and Induced Draft (ID) fans.	- Boiler Feedwater (BFW) pumps; - Fractionator's bottom pumps; - Fresh gas compressors (HCU).	- Drinking water pumps; - Sewage pumps.

3.83 low solids concentration

solids concentration such that plugging of seal chamber, plugging of flush lines, hang-up of dynamic gaskets, or erosion of components is not expected.

3.84 high solids concentration

solids concentration such that plugging of seal chamber, plugging of flush lines, hang-up of dynamic gaskets, or erosion of components is expected.

3.86 Plan 54 (plant wide)

Is a Plan 54 where the external seal barrier fluid is supplied from a plant-wide system engineered and supplied by the Buyer.

3.87 Plan 54 (stand-alone)

Is a Plan 54 where the external seal barrier fluid is supplied from a stand-alone seal support console engineered and supplied by the seal Supplier. There will be one such console per pump.

4 Sealing systems**4.3 Specifying and/or purchasing a sealing system**

Replace first sentence:

The mechanical seal datasheet DEP 31.29.00.94-Gen. shall be used to convey purchasing requirements.

Add new clause:

- 4.3.1 Annex A, as modified by this DEP, shall be applied to sealing system selection. The following "hazardous" services requirements of this DEP SHALL [PS] be applied to sealing system selections for new pump/seal applications:

Annex A, A.1.4, Sheet 6a	Hazardous service decision block
Annex A, A.1.4, Sheet 6b	All of sheet 6b
Annex A, A.1.5	All services specifically addressed in the table

Note: Annex A is intended and written as a seal selection guide for new seal installations, not necessarily for modification to existing seal systems (e.g. reliability improvement modifications to o-ring materials, seal design, etc.). The need to modify/replace existing seal applications is evaluated in the existing site risk assessment process (e.g. seal model bow tie).

5 General**5.1 Unit responsibility**

Replace this clause by:

- 5.1.1 The seal Vendor shall be responsible for the design and performance of the entire shaft auxiliary system. This includes the mechanical seal cartridge and the complete sealing system.

The seal Vendor shall remain responsible for the seal meeting the requirements of Clause 4.2. It is recognised that in this respect there are factors beyond the control of the Vendor, which may influence the ability of the equipment to comply with these requirements.

- 5.1.2 The seal Vendor and his major sub-suppliers shall have an implemented and effective quality system. This shall comply with ISO 9001 or an equivalent standard acceptable to the Principal.

6 Design requirements

6.1 Common design requirements (all categories)

6.1.1 General information

6.1.1.1 Add to this clause:

The requirement for seal removal is not applicable to vertical close-coupled pumps (i.e. ISO 13709, designation OH5).

6.1.1.4 Add to this clause:

The assembly bolting of seal cartridges shall have sufficient strength to withstand the force needed to remove the cartridge from the pump, taking into account the high friction which may be present due to deposits between the shaft and the shaft sleeve.

6.1.1.6 Add to this clause:

The static sealing pressure rating (SSPR) of mechanical seals shall be greater than or equal to the maximum static sealing pressure (MSSP), which shall be calculated as indicated below.

For Arrangement 1 seals, the MSSP of each seal shall be equal to the maximum static seal chamber pressure that can occur in the pump. Unless otherwise specified, this shall be the shut-off pressure of the pump at maximum suction pressure.

For Arrangement 2 seals, the MSSP of both the inner and outer seal shall be equal to the maximum static seal chamber pressure that can occur in the pump. Unless otherwise specified, this shall be the shut-off pressure of the pump at maximum suction pressure.

For Arrangement 3 seals, the MSSP of the outer seal shall be equal to the maximum static seal chamber pressure that can occur in the pump. Unless otherwise specified, this shall be the greater of 1) shut-off pressure of the pump at maximum suction pressure or 2) the maximum barrier fluid pressure. The MSSP of the inner seal shall be the greater of 1) differential between the maximum barrier fluid pressure and the minimum static seal chamber pressure or 2) the maximum barrier fluid pressure.

NOTE: Adding a relief valve in the suction of the pump is an option for consideration when this requirement would otherwise result in an undesirable seal or seal system selection.

6.1.1.11 Add to this clause:

Unless otherwise specified by the Principal, if a single mechanical seal is considered suitable it shall be of the metal bellows type and shall be suitable for the highest and lowest specified static or dynamic seal chamber pressure.

6.1.2 Seal chamber and gland plate

6.1.2.3 Add to this clause:

Internally mounted chamber type is not allowed.

6.1.2.8 b Add to this clause:

Default seal cartridge centering shall be with inside diameter fit.

For Category 1 seals, shaft centering is acceptable.

6.1.2.14 d) Replace this clause by:

Furnish arrangement 1 seals and/or inner seal of arrangement 2 with a distributed flush system unless space limitations preclude its use.

6.1.2.15 Add to this clause:

Lip seal type throat bushings shall not be supplied.

Throat bushings shall be used in specific seal flush plans as follows:

Plan 11	Fixed throat bushings are standard on ISO 13709 pumps. For ASME B73.1 and B73.2 pumps, throat bushings shall only be used if required to raise seal chamber pressure.
Plan 13	Fixed throat bushings are standard on vertical can or vertical turbine pumps. Do not use on other ISO 13709 pumps or on ASME B73.1 or ASME B73.2 pumps.
Plans 14, 23 and 32	Always required.
Plans 52, 53, 54, 72, 74, 75 and 76	Use only when required for the flush plan for the inner seal.

Fixed bushings shall be designed and supplied by the pump Vendor, based on the required flush flow as recommended by the seal Vendor.

6.1.2.16 *Modify this clause:*

Replace "purchaser" with "Principal".

6.1.2.17 *Add to Table 1:*

Process vent (V) connection for seal configurations 3NC-FF, 3NC-BB, and 3NC-FB shall only be used on vertical pumps with Plan 2.

Note d shall also apply to Plan 23 FI/FO connections for Category 2 and 3 seals.

Gland plate connection locations listed in the Table refer to the port entry to the ID of the gland plate. The external port locations on the OD of the gland may be altered to allow for tangential port connections or to avoid pump bracket obstructions.

6.1.2.20 *Add to this clause:*

For vertical pumps the seal chamber shall be continuously vented via a Plan 13, if contacting wet seals are used in 1CW arrangements or as the inner seal of 2CW or 3CW-FB arrangements. For Vertical in-line pumps a self-venting design (Plan 13) with seal flush piped to the pump suction line above the seal chamber is preferred. Use of a manual vent requires Principal approval.

6.1.2.24 *Modify this clause:*

Replace 'specified' with "recommended by the seal Manufacturer".

6.1.2.24.1 *Add new clause:*

If heating jackets are recommended by the seal Manufacturer, they shall have connections arranged so that the entire passageway can be mechanically cleaned, flushed and drained.

6.1.2.24.2 *Add new clause:*

If heating jackets are recommended by the seal Manufacturer, heating jacket systems shall be designed to positively prevent the process stream from leaking into the heat transfer medium. Heating passages shall not open into casing joints.

6.1.2.25 *Modify this clause:*

Delete "specified by the purchaser, or if".

6.1.3 Cartridge seal sleeves

6.1.3.2 *Add to this clause:*

Cartridge seals shall not be installed on an existing pump hook sleeve. Shaft-to-seal sleeve fits for Category 1 seals shall be Vendor standard. Fits shall be specified on the seal

drawing. Whenever fits are specified, the dimensions of the seal sleeve and its fit to the shaft shall limit seal sleeve runout to a maximum of 0.05 mm (0.002 in).

6.1.3.4 Add to this clause:

When Arrangement 3 seals for Hazardous Category 1 liquids (see 3.79) are applied, an additional o-ring seal between the shaft and the sleeve shall be located outboard of the sleeve o-ring. Two holes shall be drilled in the shaft sleeve between these two seals in order to provide barrier fluid under the sleeve. In addition to the normal barrier fluid selection criteria, only barrier fluids which are compatible with the pump shaft material shall be selected.

6.1.3.13 Replace this clause by:

For service where the MSSP exceeds 5,000 kPaa (725 psia), devices other than set screws shall be used for axially positioning and driving the sleeve. Examples include a shrink disk (see Figure 19) or a split ring engaging a groove in the shaft (see Figure 20). Alternative designs to the split ring construction require the specific approval of the Principal.

6.1.3.14 Add new clause:

For any service where the product temperature is in excess of 200 °C (400 °F), the seal Supplier shall take into account thermal expansion differences between drive device and pump shaft during normal and transient operating conditions.

6.1.6 Materials

6.1.6.1.4 Add new clause:

All materials for components exposed to hydrogen sulphide in concentrations exceeding 100 mg/kg (100 ppm) or exceeding the limits prescribed by ISO 15156 or NACE MR0103 (as applicable) shall conform to the reduced hardness requirements of ISO 15156 or NACE MR0103 (as applicable). NACE requirement shall be specified on the data sheet.

- NOTES:
1. ISO 15156 shall apply to oil and gas production facilities and natural gas sweetening plants. NACE MR0175 is equivalent to ISO 15156.
 2. NACE MR0103 shall apply to other applications (e.g. oil refineries, LNG plants and chemical plants).

6.1.6.2.2 Add to this clause:

Ring material for seal faces shall be suitable for continuous operation at the highest temperature specified for the pump in which the seal is incorporated.

6.1.6.5.1 Add to this clause:

When determining suitable material for secondary seals, the temperature limits in Annex B-5 shall be compared to the minimum/maximum temperature of pumped product. This limitation applies to all flush plans irrespective of their location or any cooling effect afforded by an applied seal plan.

6.1.6.5.2 Add to this clause:

If alternatives are available that are equal to or better than FFKM in the applicable service, they may be applied subject to the approval of the Principal. O-rings made of solid PTFE shall not be used (one identified exception is static o-rings in EO services where FFKM has proved unsuccessful – See A.1.5).

In addition to the temperature limit provided in Annex B.5, FFKM materials shall not be applied at pumping temperatures within 55 °C (100 °F) of their maximum published temperature limit without approval of the Principal.

NOTE: In most cases, the seal selection process will indicate the use of Type C seals with graphoil for temperature resistance if temperatures exceed the temperature limit of FKM. Type A seals with flush Plan 23 are one example where FFKM may be applied for transient thermal resistance, if normal temperatures are designed to remain within FKM limits.

If there are technical reasons to select a Type A seal in lieu of a Type C seal for a service over 175 °C (350 °F), FFKM elastomers may be utilized for thermal capability, subject to the requirements of ISO 21049 clause 6.1.6.7.2.

6.1.6.6 *Add to this clause:*

Alternative bellows materials for standard seals may be used if they have a proven service record in the specified duty and if approved by the Principal.

6.1.6.9.2 *Add to this clause*

Outside drive set screws may be hardened carbon steel if suitably treated for corrosion resistance.

Cadmium-plated bolts and machine screws shall not be used in any applications due to their susceptibility to stress-cracking, except as follows: cadmium screws may be used as the drive collar set screws, as the bolts to hold the inner and outer flanges together on a dual seal, and for the bolts that hold the setting plates on the flange. The seal Supplier shall verify that ASTM post-plating bake-out practices were used in the manufacture of these cadmium screws.

6.2 **Design requirements (category specific)**

6.2.1 **Category 1 seals**

6.2.1.2 Seal chamber and gland plate

6.2.1.2.1 *Add after the first paragraph of this clause:*

In addition to the requirements of 6.1.2.14, for Category 1, a distributed flush or multi-port flush arrangement or a stationary flexible element shall be provided when flush Plan 11 or Plan 11/52 is utilized for

- Shaft sizes over 38 mm (1.5 in), and
- Services where fugitive emissions are subject to regulations.

6.2.2 **Category 2 seals**

6.2.2.2 Seal chamber and gland plate (category 2)

6.2.2.2.1 *Add after the first paragraph of this clause:*

In addition to the requirements of 6.1.2.14, for Category 2, a distributed flush or multi-port flush arrangement shall be provided when flush Plan 11 or Plan 11/52 is utilized for

- Shaft sizes over 38 mm (1.5 in), and
- Services where fugitive emissions are regulated.

6.2.3 **Category 3 seals**

6.2.3.2 Seal chamber and gland plate (category 3)

Add after the first paragraph of this clause:

Distributed flush is not required for flush plans 13 or 23.

7 **Specific seal configurations**

7.1 **Arrangement 1 seals**

7.1.2 **Seal chamber and gland plate**

7.1.2.1b *Replace this clause by:*

- b) A fixed carbon throttle bushing shall be installed in the gland plate for Category 2 seals;
and

7.2 Arrangement 2 seals**7.2.1 General****7.2.1.2 Add to this clause:**

Use of 2NC-CS requires approval of the Principal.

7.2.2 Seal sleeves**7.2.2.1 Add to this clause:**

Auxiliary sleeves shall not be used.

7.2.2.2 Modify this clause:

Change reference to "Clause 6" to "Clause 6.1.3".

7.2.4 Contacting wet seals with a liquid buffer fluid (2CW-CW)**7.2.4.2 Replace this clause by:**

If space permits, a tangential buffer-fluid outlet shall be provided for Category 1 and Category 2 seal assemblies. A tangential buffer-fluid outlet shall be provided for Category 3 seals.

7.2.5 Seal chamber and gland plate for contacting wet inner seal with a dry running containment seal (2CW-CS)**7.2.5.1 Modify this clause:**

Replace "non-sparking" with "carbon" in the first sentence.

7.2.6 Seal chamber and gland plate for non-contacting inner seal with a dry running containment seal (2NC-CS)**Add to this clause:**

This is an engineered seal and is subject to the Principal's approval.

7.3 Arrangement 3 seals**7.3.1 General****7.3.1.3 Replace this clause by:**

Standard Arrangement 3 configurations shall utilize two seal rings and two mating seal rings. The use of a common mating ring (mono-block design) is not allowed unless approved by the Principal.

7.3.2 Seal sleeves**Add to this clause:**

Auxiliary sleeves shall not be used.

7.3.4 Contacting wet seal configurations with a liquid buffer fluid (3CW-FB,FF,BB)**7.3.4.3 Seal chambers and gland plates****Replace the first sentence of this clause by:**

If space permits, a tangential buffer-fluid outlet shall be provided for Category 1 and Category 2 seal assemblies. A tangential buffer-fluid outlet shall be provided for Category 3 seals.