

Learnings & selection guidelines of mechanical seal flush plan for pumps in a typical plant

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ABSTRACT

KEYWORDS

Mechanical Seal,
Seal Flush Plan,
Selection Guideline,
Pump/Seal Vendor,
OG & C Plant,
Work Process Diagram,
Plant Owner,
API 682.

Pump mechanical seal failure incidents out number any other rotating component of a pump in a typical OG & C Plant. This is also well-known fact that up to 70% of pump maintenance expenditure is responsible for seal repair/maintenance or replacements. This arises the need for accurate selection of mechanical seal for given pump & particular service conditions.

As a standard industry practice, Pump Buyer usually follows Pump/Seal Vendor recommendation for final selection of Seal Plan. Although the onus of deciding the seal plan and material selection is fairly & squarely on the Pump/Seal Vendor, however it is recommended that Buyer shall also validate/verify the seal selection during bid evaluation stage himself (based on seal selection guidelines). This will help in avoiding changes in seal plan during detailed engineering (after award) which otherwise led to cost/schedule impact. Before selecting the seal material, type of seal the designer or pump manufacturer either needs to go through exhaustively complete scope of API 682 and their field experience (operational experience of using Seal Type X in Pump Type Y with process parameters Z).

This paper will illustrate the selection guidelines based on seal vendor recommendations, feedback from Plant Owner (Plant O&M personals) and in-house lesson learnt. This paper will also discuss the work process diagram for the mechanical seal selection/coordination for OG&C plant along with brief information on various Seal types for Pumps per API 682.

The recommendations in this paper are based on the "typical cases" of a seal for centrifugal pumps. Other types of machine, installation conditions, modes of operation, designer's, manufacturer's and operator's specifications, local regulations and so on can result in a different choice of mechanical seal. For complex sealing duties it is always advisable for the user to consult with the specialist engineer/Operator/Consultant/Seal Manufacturer.

A sealing system for hydrocarbons must often make allowance for partial dry running due to their low boiling points. However, with the right design features and face materials, it is possible to guarantee fail safe operation of the mechanical seal.

There is no doubt that the marginally higher cost for the better-quality seals will probably be recovered during the first year of operation of pumps itself. Although this seal selection guideline is applicable for new installations /Procurement of Pumps, however this may be extended for upgrading seals of Pumps in existing OG&C installations where frequent maintenance is encountered.

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Definitions:

Pumps: refers to Centrifugal and Rotary pumps.

VOC: volatile organic compound as defined in the CAAA.

In VOC Service: means that the piece of equipment contains a process fluid (light liquid, heavy liquid or gas/vapor) that is at least 5% VOC by weight.

Light Liquid: liquid organic compound with a vapor pressure ≥ 0.044 Psia @ 70 degF.

Heavy Liquid: liquid organic compound with a vapor pressure < 0.044 Psia @ 70 degF.

HAP: Hazardous Air Pollutant.

Buffer Fluid: A fluid used as a lubricant or buffer between dual mechanical seals. The fluid is always at a pressure lower than the pump process pressure being sealed.

Barrier Fluid: A fluid which is introduced between dual mechanical seals to completely isolate the pump process liquid from the environment. Pressure of the barrier fluid is always higher than the process pressure being sealed

P & ID: Process & Instrumentation diagram.

O & M: Operation & Maintenance

OEM: Original Equipment Manufacturer

OG & C: Oil Gas & Chemical

LNG: Liquefied Natural Gas

API: American Petroleum Institute

1. Introduction

Mechanical Seal is a device used to seal the interface between a rotating shaft and stationary housing Mechanical seals are used throughout industry to minimize or eliminate leakage in the Pumps, Mixers and other rotating equipment's. The ability of mechanical seal to meet its performance objectives depends upon wide

range of factors involving equipment design, operating conditions (process parameters) and support system. Mechanical seals have gained success over the years for their ability to minimize or eliminate leakage of process fluids to atmosphere. This has resulted in improved equipment reliability, reduced emissions and improved safety. While the purpose of the seal appears to be simple enough however the design of seal components are significant engineering challenges.

However still LNG, Oil and Power plants are being confronted with several no. of available mechanical designs hence the end customer should use inexpensive standard seal and exotic, highly engineered seal models.

Before selecting the seal material, type of seal; the designer or pump manufacturer either needs to go through exhaustively complete scope of API 682 and their field experience (operational experience of using Seal Type X in Pump Type Y with process parameters Z). To make the selection less complicated, selection guideline/strategy is illustrated in this paper below based on seal vendor recommendations, feedback from Plant Owner (Plant O&M personals) and in-house lesson learnt (previous projects experience).

Selection strategy outline which makes the maximum use of capabilities of pump and seal manufacturer and Operational & Maintenance personal in plants is presented here. This strategy will allow to selection of high-quality seal for given type of pump in given installation.

Principal features of optimum seals are also highlighted in this paper. This selection strategy provides a guideline for the selection of mechanical seals and support systems for hydrocarbon services. Additional attention must be given to issues not covered by this paper (i.e. selection guideline) like availability of auxiliary systems such as vapor recovery (flare) for a dual seal equipped with an API Plan 52, nitrogen for a dual seal equipped with an API

Table D.1

Example of an arrangement 1 mechanical seal code.

Seal			Design Options				Size	Plans		
Category	Arrangement	Type	Containment device	Gasket material	Face material	Shaft Size mm	Piping Plan			
1	1	A	-	P	F	O	-	050	-	11

Plan 53, cooling water, containment areas for seal leakage to reduce/eliminate the risk of environmental incidents, etc. Safety and environmental concerns should be evaluated on a case by case basis.

1.1 API 682 4th edition seal code quick reference

API 682 extract (refer Table D.1) below explains regarding Seal Code depicting various nomenclatures for the Seal Category,

Table D.2

Mechanical seals for pumps in hydrocarbon service - selection procedure.

Hydrocarbon Services with Specific Gravity 0.7 and Seal Chamber Pressure 280 Psig

3.5" Maximum Sleeve or Shaft diameter

Emissions Target Control Level = 500 ppmv

Service Temp. (degF)	Vapor Pressure (Psia)	Seal chamber pressure / vapor pressure ratio @ service temp. (calculated in Psia).	Standard Seals	Seal Arrangement	Primary Flush	Secondary Flush	Additional Information
20 to 250	14.7		Pusher seal or Metal Bellows seal	Special purpose single balanced cartridge seal	11, 13 or 14 ⁽¹⁾		⁽¹⁾ For new pumps, seal manufacturer to coordinate with pump OEM on primary seal flush selection (11,13 or 14) and determine seal flush orifice size.
	>14.7	1.5	Pusher seal	Special purpose single balanced-cartridge seal	11, 13 or 14 ⁽¹⁾		⁽²⁾ Dry running secondary emission containment seals and seals equipped with an API Plan 52 vented to a vapor recovery system are not considered zero emission seals, and must be approved by the owner.
	>14.7	<1.5	Pusher seal	Dual balanced cartridge seal	11, 13, 14 ⁽¹⁾ or 23 ⁽⁷⁾	52 ⁽²⁾ or 74 ^(3,4,5,6)	⁽³⁾ Barrier fluid compatibility with the process must be evaluated. ⁽⁴⁾ Preferred for continuous duty service ⁽⁵⁾ Select Plan 53 or 74 if difference between product vapor pressure and seal chamber pressure is less than 25psi.
250 to 450	>14.7		Pusher seal or Metal bellows seal	Special purpose single balanced-cartridge seal	23	53 ^(3,5,6,8) or 74 ^(3,4,5,6)	⁽⁶⁾ Bellows type seals may be used in products with particulates present with owner approval. ⁽⁷⁾ API Plan 23 can be used as an option to obtain desired vapor pressure margin.
	14.7		Pusher seal or Metal bellows seal	Special purpose single balanced-cartridge seal	23 11, 13 or 14 ⁽¹⁾	62	⁽⁸⁾ API Plan 53 is an option in locations where vapor recovery system is not available or when flaring of seal emissions or a product release into the flare (in the case of a seal failure) is not allowed.

Hydrocarbon Services with Specific Gravity < 0.7 and Seal Chamber Pressure 280 Psig 3.5" Maximum Sleeve or Shaft diameter Emissions Target Control Level = 500 ppmv							
Service Temp. (degF)	Vapor Pressure (Psia)	Seal chamber pressure / vapor pressure ratio @ service temp. (calculated in Psia).	Standard Seals	Seal Arrangement	Primary Flush	Secondary Flush	Notes /Additional Information
20 to 450			Pusher seal ⁽⁸⁾	Dual balanced-cartridge seal	11,13 or 14 ⁽¹⁾ 23 ⁽³⁾	52 ⁽²⁾ 52 ^(2,6) 53 ^(4,5,6,7,8,9) or 74 ^(5,7,8,9,10)	⁽¹⁾ For new pumps, seal manufacturer to coordinate with pump OEM on primary seal flush selection (11,13 or 14) and determine seal flush orifice size. ⁽²⁾ Dry running secondary emission containment seals and seals equipped with an API Plan 52 vented to a vapor recovery system are not considered zero emission seals, and must be approved by the owner. ⁽³⁾ API Plan 23 can be used as an option to obtain desired vapor pressure margin. ⁽⁴⁾ API Plan 53 is an option in locations where vapor recovery system is not available or when flaring of seal emissions or a product release into the flare (in the case of a seal failure) is not allowed. ⁽⁵⁾ Barrier fluid compatibility with the process must be evaluated. ⁽⁶⁾ Based on seal heat generation calculations, seal manufacturer to evaluate barrier fluid cooling requirements and methods. Must be reviewed and approved by owner. ⁽⁷⁾ API Plan 53 or 74 must be selected if specific gravity is below 0.45 ⁽⁸⁾ Bellows type seals may be used in products with particulates present with owner approval. ⁽⁹⁾ Select Plan 53 or 74 if difference between product vapor pressure and seal chamber pressure is less than 25 psi. ⁽¹⁰⁾ Preferred for continuous duty service

arrangement, type and Design Options along with Size and Piping plans.

First Position: Seal Category (1, 2, 3)

Second Position: Seal Arrangement (1, 2, 3)

Third Position: Seal Type (A, B, C)

Fourth Position: Containment Device (P, L, F, C, S, X)

Example: P—plain gland with no bushing:

this design can be used in Arrangement 2 or Arrangement 3 seals

Fifth Position: Secondary Sealing Element (Gasket) Material (F, G, H, I, R, X)

The available options are shown below:

F—FKM gaskets;

G—polytetrafluoroethylene (PTFE) spring energized gaskets;

H—nitrile gaskets;
 I—FFKM gaskets;
 R—flexible graphite (with spiral wound flexible graphite gaskets for gland gasket);
 X—unspecified: the option for the secondary sealing element is unknown or not covered by the standard options. This will be specified separately.

Sixth Position: Seal Face Material Combination (M, N, O, P, Q, R, S, T, X)
 Example: M—carbon vs nickel bound tungsten carbide;

Seventh Position: Shaft Size in mm
 Example: 25 mm is described as 025.

Eighth Position: Piping Plans
 Example: A seal using a Plan 11 and a Plan 53A would be described as 11/53A

Examples of Finished Seal Codes
 Example: 31B-LIN-075-53A

2. Mechanical Seal Selection Procedure - A

This seal selection procedure is used when service temperature and Vapor pressure of the Hydrocarbon is known. This procedure provides a guideline for the selection of mechanical seals and support systems for new pumps, and seal upgrades of existing pumps.

Refer Table D.2 for selection of Mechanical seal of Pumps along with necessary notes. The “NOTES” sections at the bottom of this procedure must be read prior to selecting any seal & seal support system.

Mechanical seals in light liquid VOC service containing 5% or more Hazardous Air Pollutants (HAP) by weight are treated as a separate group as described in #1 in the “NOTES” section. Also refer Figure D.4 for Vapor Curves of Hydrocarbons.

2.1 Notes

- New pumps in light liquid service (Pv 0.044 Psia @ 70 degF) that contain 5% VOC by weight AND 5% HAP by weight, must be equipped with dual cartridge seals. API Plan 53 or 74 are the preferred secondary piping plan options for these services. Dry running secondary emission containment seals and seals equipped with an API Plan 52 vented

to a vapor recovery system (flare) are not considered zero emissions seal systems and may be used only with approval of the owner.

- If the required Barrier fluid pressure in an API Plan 53 is above 150 Psi(g), the use of alternate technologies like pressure pistons or API 53 modified reservoirs with bladders is required.
- Hydrocarbon services containing HF or H₂S in hazardous concentrations are not covered by this procedure and must be engineered in a combined effort between the owner, seal manufacturer and pump OEM.
- Services in pressure, temperature and size ranges not covered by this procedure must be engineered in a combined effort between the owner, seal manufacturer and pump OEM.
- The use of alternative and new technologies is encouraged. Seals and seal support systems not covered by this procedure are must be approved by the owner.
- If seals and seal support systems are used in a different way than the one described in this procedure, it must be approved by the owner.
- This selection procedure assumes that low emission special purpose inside-mounted seals are utilized. Pusher and bellows seals must be designed in accordance with the standard seals A, B and C types recommended on the API Standard 682 (First Edition, October 1994). Any deviation must be approved by the owner.
- This selection procedure assumes that API 7th or 8th edition pumps will be used. If pump does not comply with API 7th or 8th edition, the seal and seal support system must be approved by the owner.
- Seals and seal support systems for non-API pumps must be approved by the owner.
- Primary and secondary support plan codes follow API Standard 682 (Current Edition) coding.
- Fluoroelastomer O-rings are the standard for all hydrocarbon services covered in this procedure with the exception of the following services:
 - Hydrocarbons services above 350 degF
 - Aromatic hydrocarbon services above 150 deg F
 - Hydrocarbon services with high concentration of H₂S

Table. D.3

Mechanical seals for pumps in hydrocarbon service - selection procedure.

Service No	Service	Pumping Temperature Range	Comments	API 682						Notes
				Seal Code						
				Category	Type	Arrgm	Config	Primary	Secondary	
1	Fresh water, condensate	0-100 °C		2	Aa	1	CW-FL	11	61M	
2	Sea Water	0-80 °C		2	Aa	1	CW-FL	11	61M Note	62 May be required
3	Boiler Feed Water	80-290 °C		2	Aa	2	CW-FL	23	61M	
4	Sour Water H ₂ S >50 ppm	0-80 °C		2	Aa	1	CW-FL	11	61M	
5	Sour Water H ₂ S >200 ppm	0-80 °C		2	Aa	2	CW-CW	2	52	
6	Sour Water H ₂ S >500 ppm	0-80 °C		2	Aa	3	CW-FB	2	53	
7	Sour Water H ₂ S >2000 ppm	0-80 °C		3	Aa	3	CW-FB	2	53	
8	Brine	0-80		2	Aa	1	CW-FL	11	62	
9	Oily Water - Sump applications		VS4 Pumps	2	Aa	1	NC-FX	2		Packed Gland, Dry Running Contacting Seal
10	Storm Water - Sump applications		VS4 Pumps	2	Aa	1	NC-FX	2		Packed Gland, Dry Running Contacting Seal
11	Sea Water - Sump applications		VS4 Pumps	2	Aa	1	NC-FX	2		Packed Gland, Dry Running Contacting Seal
12	Hydrocarbon - Non Flashing - Sump applications		VS4 Pumps	2	Aa	1	NC-FX	2		
13	Hydrocarbon - Flashing - Sump applications			2	Aa	1	CW-BB	2	53	
14	Hydrocarbon - Non Flashing with H ₂ S (low levels below 200 ppm)			2	Aa	1	CS-FX	2		
15	Sea Water - Vertical Lift			1	Aa	1	CW-FL	32		Clean Water flush
16	Cooling Water	0-80 °C		2	Aa	1	CW-FL	11	61M	
17	Process Water	0-80 °C		2	Aa	1	CW-FL	11	61M	
18	Hydrocarbons - Non Flashing	-40 °C to -5 °C		2	Aa	1	CW-FL	11	61M	

19	Hydrocarbons - Non Flashing	-5 °C to 175 °C		2	Aa	1	CW-FL	11	61M		
20	Hydrocarbons - Non Flashing	176 °C to 259 °C		2	Ca	3	CW-BB	11	53		
21	Hydrocarbons - Non Flashing	>260 °C	possibly above auto ignition temperature	2	Ca	1	CW-BB	11	53		
22	Hydrocarbons - Non Flashing	to a max of 450 °C	Above auto ignition temperature	3	Ca	1	CW-BB	23	53		
23	Hydrocarbons - Flashing	-5 °C to 59 °C		2	Aa	2	CW-CS	11	76		
24	Hydrocarbons - Flashing	60 °C to 175 °C		2	Aa	3	CW-BB	2 Note	53	Consider Plan 23	
25	Hydrocarbons - Flashing	176 °C to 259 °C		2	Ca	3	CW-BB	2 Note	53	Consider Plan 23	
26	Hydrocarbons - Flashing	>260 °C		2	Ca	3	CW-BB	23	53		
27	Hydrocarbons - Flashing	to a max of 450 °C	Above auto ignition temperature	3	Ca	3	CW-BB	23	53		
28	Hydrocarbons		Contaminated with H2S	as a minimum follow Sour Water with ppm H2S or hydrocarbon at operating temperature							
29	Hydrocarbons		Contaminated with Benzene	2	Aa	3	CW-BB	2	53		
Examples of Hydrocarbon Services											
30	Naphtha	0-80 °C		2	Aa	1	CW-CS	11	76	Check with process for H2S or Benzene present	
31	Propane / Butane	0-80 °C		2	Aa	3	CW-FB	11	53		
32	Crude Oil	0-80 °C		2	Aa	1	CW-FL	11	65		
33	Crude Oil	>200 °C	Possibility of Coking	2	Aa	3	CW-FB	2	53		
34	Diesel Oil	0-80 °C		2	Aa	1	CW-FL	11	61M		
35	Kerosene	0-80 °C		2	Aa	1	CW-FL	11	61M		
36	Molten Sulphur	127 C		2	Aa	1	CW-FL	11	62	Steam Quench	
37	Corrosive Acid	0-80		2	Aa	3	CW-FB	2	53		
38	Sulphuric Acid	0-80		2	Aa	1	CW-FL	11	61		
39	Hydrofluoric Acid	0-80			Work with Pump Vendor / Seal Vendor						
40	Caustic Acid (Low concentrations)	0-80		2	Aa	1	CW-FL	11	62		

41	Caustic Acid (High Concentrations)	0-80		2	Aa	3	CW-FB	2	53	
42	Benzene			2	Aa	3	CW-BB	2	53	
43	Amines	0-240 °C		2	Aa	3	CW-BB	2	53	
44	Lean MEG			2	Aa	3	CW-BB	2	53	
45	Rich MEG			2	Aa	3	CW-BB	2	53	
46	Slurries			Work with Pump Vendor / Seal Vendor						

- Perfluoroelastomer O-rings are the standard when fluoroelastomer O-rings are not an acceptable choice.
- The use of per fluoroelastomer O-rings as an alternative to fluoroelastomer O-rings is acceptable when it is justified by standardization reasons.
- Metal bellows seals may also use flexible graphite secondary seals in place of fluoroelastomer or per fluoroelastomer O-rings.
- Additional attention must be given to issues not covered by this procedure like: availability of vapor recovery systems (flare) for a dual seal equipped with an API Plan 52, availability of Nitrogen for a dual seal equipped with an API Plan 53, availability of cooling water, containment areas for seal leakage to reduce / eliminate the risk of environmental incidents, etc. EH & S concerns should be evaluated on a case by case basis.
- For abrasive or corrosive services in which the process fluid cannot be utilized as flush for the inner seal, an external flush API Plan 32 is an acceptable option. Cost of introducing an external product into the process stream and compatibility issues must be evaluated in a case by case basis.
- Dry non-contacting gas seals with API 682 Plan 74 support system should not be used in the pump applications when available Nitrogen pressure is less the 30 psig over maximum seal chamber pressure.

2.2 Mechanical seal selection procedure-B

Another alternatively checking the right seal selection will be based on Service and Temperature range of Pumping. Table D.3 below

illustrates the selection procedure for primary and secondary seal type for a given pump with particular set of conditions (service type and temperature range).

2.3 Work process flow diagram- seal selection /co-ordination

Work process flow diagram for the mechanical seal selection/coordination for OG & C plant along with brief information on various Seal types for Pumps per API 682. TABLE D.5 below illustrates the Process Map which help in Mechanical Seal Selection/coordination between the Pump/Seal vendor, End User and Design Department Interco-ordination (Engineering, Procurement), Process Safety and Licensor (wherever applicable). Below notes are to be referred in line with Table D.5.

NOTES:

- 1) Refer 1a) & 1b) below:
 - a) End User Inputs/Comments are required where applicable, per the prime contract applicable from project to project.
 - b) Review / comments from EPC Contractor/Consultants Sub-Disciplines shall be as-required based on document type and scope of seal and auxiliaries specified.
- 2) Specific fluid properties that must be advised shall be:
 - a) Specific Gravity
 - b) Specific Heat
 - c) Vapor Pressure
 - d) Viscosity (Including any significant viscosity increase when fluid is cooled)
 - e) Temperature – Minimum/normal/maximum

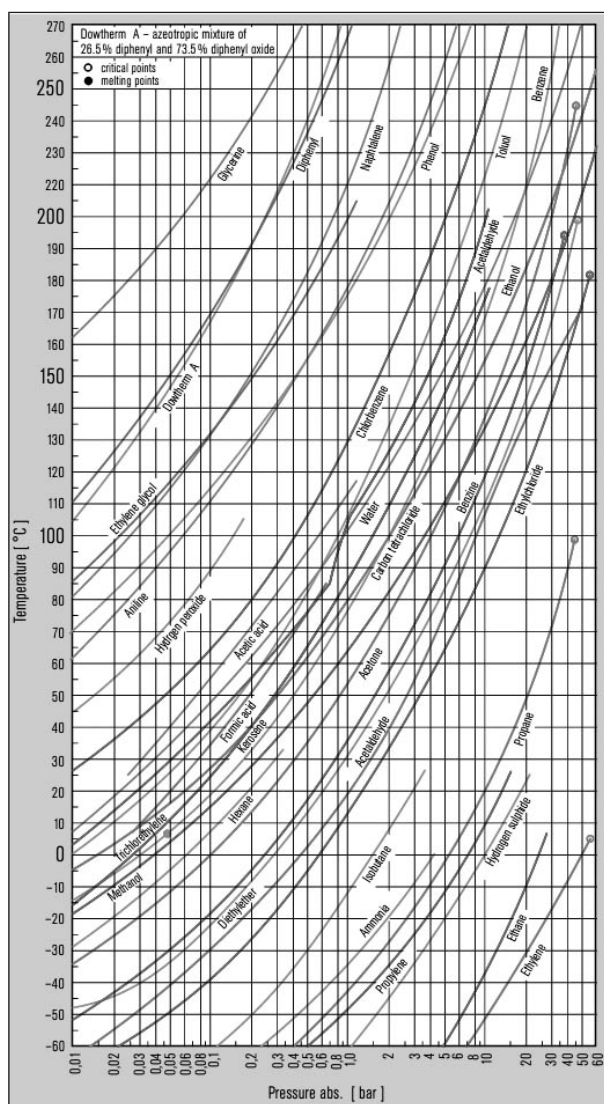


Fig. D. 4. Vapor curves of hydrocarbons.

- f) Potential for coking or crystallization when process fluid cools or reaches atmospheric pressure.
 - g) Whether fluid will completely flash or if condensable may be present.
 - h) Whether fluid is considered hazardous and / or flammable
 - i) Presence of hazardous components in fluid (e.g. H₂S, caustic, etc.)
 - j) Properties of available flushing utilities (e.g. water, steam, nitrogen, etc.)
 - k) Compatibility of buffer/barrier fluids and Plan 32 flushing liquid with process fluid.
- 3) Seal documentation deliverables for review (via the pump vendor) shall include at minimum:
- i) Seal performance data included on Seal Data Sheet and /or Pump Data Sheet (Note 4)
 - ii) Seal Drawing with operating conditions

- complete (Including seal chamber pressures
 - iii) Seal Flush (Including Auxiliary Flush Plan) Arrangement Drawings (Complete with flushing flow rates and pressures)
 - iv) Seal Flush P&ID for each service with instrument tags and alarm / set points
 - v) Seal IOM Manual (Marked specifically for the seal supplied for each service)
- 4) Some projects combine seal data on the Pump Data Sheet and others require a separate Seal Data Sheet.
- 5) Seal vendor shall recommend buffer and/or barrier flush fluid. Process and Project Engineering shall review and approve recommended fluid.
- 6) Seal flush P&ID's shall detail field connections for vents and drains with their termination locations.
- 7) Mechanical Seal Quote shall list all operating condition assumptions, as provided on pump/seal data sheets. Quote shall also include Seal Chamber Pressure and Vapor Pressure Margin (or state N/A if not applicable) for each service to receive consideration as complete bid.
- 8) Start-up representative should be consulted at Hazop Review Stage (IFH) for lessons-learned / recommendations regarding:
- a. Typical seal flush plan selections.
 - b. Spare mechanical seal quantities by service.

2.4 Vapor curves of hydrocarbons

Above Figure D.4 depict the temperature vs Pressure graph (Vapor Curves) of Hydrocarbons namingly; Acetaldehyde, Acetone, Formic acid, Ammonia, Aniline Benzene Benzene Chlorobenzene Diethyl ether Diphenyl, Dowtherm A, Acetic acid, Ethanol, Ethane, Ethylchloride, Ethylene, Ethylene Glycol, Glycerine, Isobutane, Hexane, Kerosene, Methanol, Naphthalene, Propane, Propylene, Hydrogen Sulphide, Carbon tetrachloride, Trichloroethylene, Toluol and Water

3. Conclusion

Systematic efforts to upgrade seal selection are possible through increased involvement of experienced application engineer working for capable seal manufacturers. These efforts are further assisted by a seal selection strategy presented in this paper which identifies those design features which promise to lead to reduced

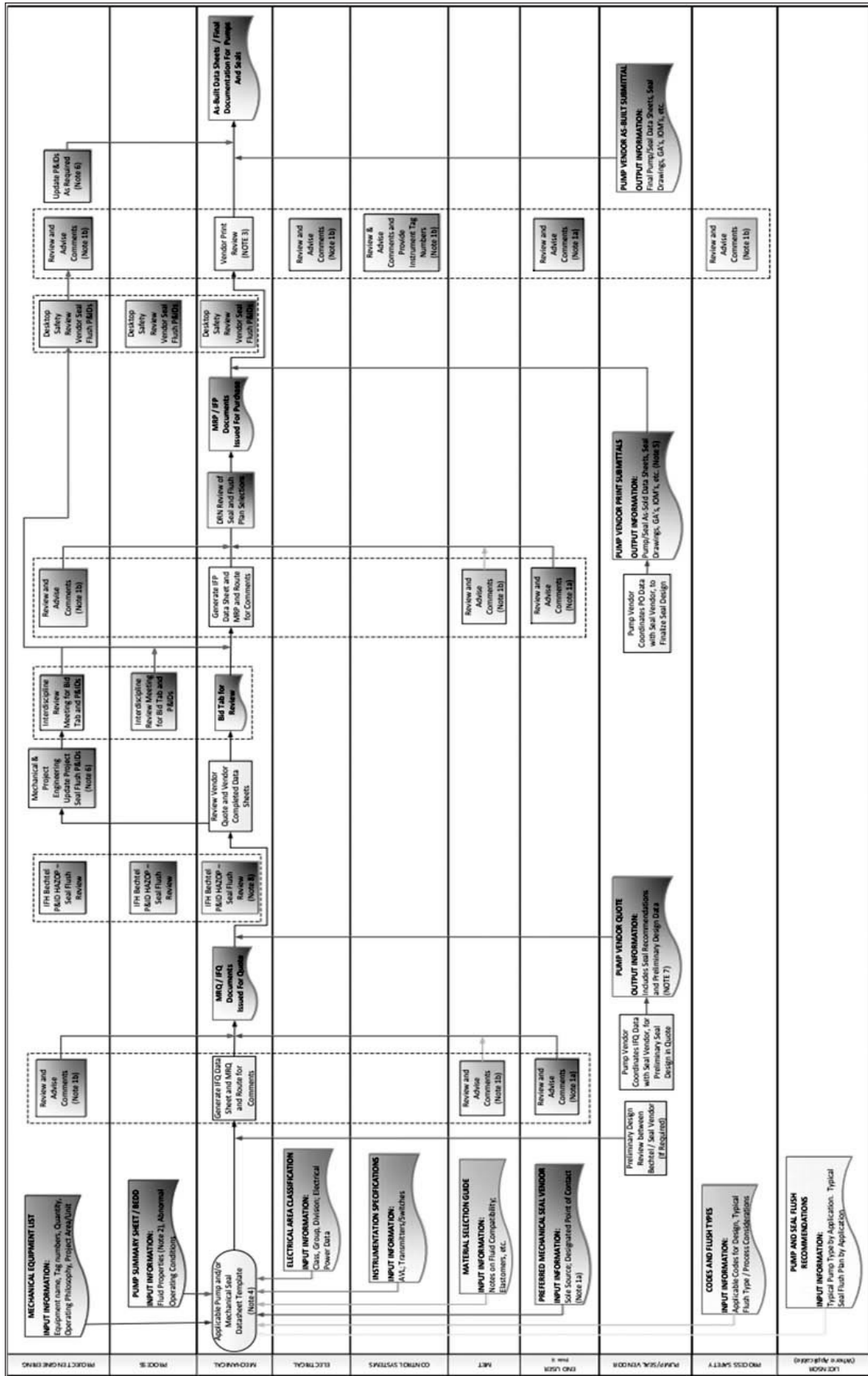


Fig. D. 5. Process MAP- mechanical seal selection/ coordination.

failure risk, greater ease of maintenance, better understanding by operators and mechanical work forces. It is believed that 98% of the pumps used in typical petrochemical plant can be assigned service severity categories from 1 (least severe) to 9 (most severe). Selection of only 3 types to cover all 9 categories will accomplish the goals we have set for ourselves. The selection strategy presented also outlines, which makes maximum use of the capabilities of knowledgeable seal manufacturers and is perfect road map for ideal seal selection. Additionally, the Work process flow diagram depicted in this paper helps in right path following for coordination between different parties while seal selection for the pumps in a typical plant.

4. Acknowledgement

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