

# TABLE OF CONTENTS.

Rather than using the, more or less, “standard” layout for an index (alphabetical, at the end of a book), I have chosen to give a short description of the contents of each chapter whilst giving the page number on which the subject starts. My thoughts were that that would be handier than listing the pages on which a specific word can be found.

For obvious reasons one of the most frequently used word throughout the book is “seal(s)”. That word is used around 1.500 times of which it is preceded around 500 times by the word “mechanical”. Listing each and every mention would only create confusion.

Chapter	Subject	Starts Page
-	<b>PREFACE.</b>	
I	<b>INTRODUCTION.</b>	
	An historic overview of when seals were first developed. This includes information on 3 patents (1 Swedish, 1 German and 1 American) of which the first was granted in the late 19 <sup>th</sup> century with the other 2 requiring some imagination to see them as a mechanical seal.	2
	Description of what a mechanical seal is and what the (presumed) thoughts were behind its design.	6
	2 Definitions of a mechanical seal and the conditions to which they are exposed.	9
	The 3 most asked questions with regard to mechanical seals and the (attempts to) answer them.	12
	The 3 C’s, i.e. the 3 issues that determine the success (or lack of) a mechanical seal.	20
II	<b>VARIOUS METHODS OF SEALING ROTATING EQUIPMENT.</b>	
	Stuffing Box Packing.	1
	Condensate Injection Sealing.	3
	Floating Ring Gland.	5

Chapter	Subject	Starts Page
<b>II</b>		
<b>CONT.</b>	Labyrinth (Breakdown) Bushing.	6
	Wind Back Scroll, Wind Back Seal or Visco Seal.	7
	Lip Seal.	8
	Ferro Fluidic Seal.	9
	Expeller Device.	10
	Cost Comparison Packing versus Mechanical Seal.	11
<b>III</b>	<b>PUMPS AND OTHER ROTATING EQUIPMENT</b>	
	A brief history of the development of pumps including the Shaduf and the Archimedean Screw.	1
	Short description of Positive Displacement Pumps divided into Reciprocating and Rotating.	3
	Centrifugal Pump Nomenclature.	7
	Horizontal Centrifugal Pumps, various types.	10
	Vertical Pumps, various types.	13
	Seal chamber pressure. A discussion on how to determine the pressure in the seal chamber per pump type.	14
	Further Points of Interest such as:	37
	De-staging.	38
	Trimming of impellers.	39
	Volute Inserts.	40
	Variable Drive.	40
	Description of Sealless Pumps subdivided into Canned Motor and Magnetic Drive Types, including drawbacks and advantages in relation to Mechanical Seals.	41
	Amphibious Pump.	53
	Power Recovery Turbines.	54
	Compressors.	55
	Steam Turbines.	57

Chapter	Subject	Starts Page
<b>III</b>	Mixers.	58
<b>CONT.</b>		
	Centrifuges.	64
	Refiners.	65
	Reactors.	66
	Propeller Shafts.	69
	Future Developments.	74
<b>IV</b>	<b>HOW DO MECHANICAL SEAL WORK?</b>	
	The concept of Unbalanced and Balanced Seals and the need for a spring arrangement.	1
	The workings of a mechanical seal using an unbalanced mechanical seal as an example, including:	5
	Pressure Gradient across the Faces.	6
	Why the Pressure Drop is hardly ever linear.	9
	Mechanical Distortion.	9
	Hydraulic Distortion.	11
	Thermal Distortion, Static and Dynamic.	13
	Influence of Converging and Diverging Gaps.	15
	Full Fluid Film and Boundary Lubrication.	16
	The Balanced Mechanical Seal.	17
	Different Balance Ratio's.	18
	Relationship between Balance Ratio and S.G.	19
	Equation to Calculate Balance Ratio.	21
	Varying Terminology for Balance Ratio explained.	23
	Why one Face is nearly always wider	25
	How to determine whether a seal is balanced or not.	27
	Why (metal) Bellows Seals are always balanced.	29
	The States of Matter and what that has to do with mechanical seals.	32
	Explanation as to the need for a minimum vapour pressure margin in the seal chamber and what happens when that condition is not met (including proof that there is no such thing as a mechanical seal that does not leak).	34
	API 682 and seal vendor recommendations on minimum vapour pressure margin.	37

Chapter	Subject	Starts Page
<b>IV</b>	Introduction of the concept of Hydrodynamic lift	40
<b>CONT.</b>		
	The influence of out of flatness and face roughness on hydrodynamic lift	41
	The influence of viscosity on hydrodynamic lift.	42
	The influence of shaft speed on hydrodynamic lift.	42
	The influence of face width on performance	43
	Special face designs	45
	Double Balanced seals and their application	47
	Reverse Pressure Capability	52
<b>V</b>	<b>SEAL DESIGN AND APPLICATION</b>	
	Arbitrary division of mechanical seals into 7 “categories”.	1
	Unbalanced and balanced seals (a short reiteration).	2
	Spring arrangements, various types and pros and cons.	2
	Rotating and stationary spring arrangements.	9
	Specials	14
	Seals for boiler feed applications.	15
	Seals for extreme temperatures both + and –.	24
	Seals for slurry applications.	35
	Seals for low emissions.	40
	Gas- or “non-contacting” seals.	42
	Split seals.	50
	Dry running seals.	52
	Outside and inside mounted seals.	53
	Single/Double/Tandem/Multiple Seals.	55
	Single seals.	55
	Double seals.	56
	Reasons for use (6).	59
	Selection criteria barrier fluid (13).	64
	Discussion various barrier fluids.	73
	Tandem seals.	81
	Reasons for use (4).	

Chapter	Subject	Starts Page
<b>V CONT.</b>	Liquid-Liquid tandem seal.	82
	Liquid-Gas tandem seal.	86
	Differences Liquid-Liquid -v- Liquid-Gas.	89
	Differences between Double & Tandem.	89
	Multiple Seals.	96
	Component/Cartridge Seals	99
	Future Developments	103
	Other Points of Interest	104
	Basic and adaptive seal components.	104
	Seal faces properties and materials.	105
	Seal face configurations (5)	108
	Pros and cons of the 5 configurations.	111
	Face configuration versus distortion.	112
	Drive & anti-rotation mechanisms.	114
	Adaptive parts.	117
	Shaft sleeve.	117
	Seal flange.	122
	Pumping devices	124
	Materials of construction.	126
	Gaskets (configuration and materials).	130
	The seal chamber	137
	The throat bushing	141
	Cooling jacket	142
	Seal performance (is dependent on 4 issues)	143
<b>VI</b>	<b>EQUIPMENT PREPARATION</b>	
	Explanation with regard to the need for carrying out a number of checks prior to installing a mechanical seal and the tolerances one is normally expected to adhere to.	1
	A mention of the time worn excuse not to perform all the necessary checks: "I haven't got the time"	4
	Some advice on the "tools" required to carry out the checks.	5
	The measuring of the rotating components. Shaft run out.	7

Chapter	Subject	Starts Page
<b>VI CONT.</b>	Shaft + shaft sleeve run out.	10
	Shaft diameter and finish.	11
	Axial shaft movement (3 checks).	13
	Axial play or end float.	13
	Mid position.	14
	Thrust bearing clearance.	15
	Radial shaft movement (4 checks).	17
	Centre position shaft.	17
	Wear ring clearances.	20
	Bent shaft.	23
Radial movement in bearings.	24	
	Balancing of the rotating element.	27
	The measuring of the seal chamber.	27
	Squareness seal chamber face.	28
	Concentricity shaft to seal chamber.	32
	Fit flange spigot to seal chamber bore.	36
	Seal Setting	38
	Setting of a component seal.	40
	Setting of a cartridge seal.	42
	“Golden rule” of seal setting.	42
	Setting on vertical multi stage pumps.	45
	Influence of thermal expansion shaft -v- pump casing on hot pumps.	46
	The “walk around” (9 points).	49
	Additional issues to be aware of with regard to seal setting	50
	Pressure testing (the sense and nonsense thereof).	53
	Dynamic testing (and what to be aware of).	57
	Balancing of the rotor (see also page 27).	58
	The alignment (a description of various methods and what can go wrong.	58
	Vibration.	63
	General rules (8 points).	64
	(Re)commissioning (including a further explanation of the most important points of the “walk around: checking the setting on hot pumps at operating temperature.	71

Chapter	Subject	Starts Page
<b>VII</b>	<b>Assembly and Reconditioning of a Mechanical Seal.</b>	
	Assembly, general tips and tricks (9)	1
	Things to watch out for when assembling a seal.	4
	Single spring seals.	4
	Multi spring seals.	6
	Tandem and double seals.	7
	Inverted seals.	8
	Bellows seals (rotating and stationary).	9
	Non-contacting seals.	15
	Installation.	17
	Repair and reconditioning.	19
	Lapping (various methods of).	19
	Checking flatness of seal faces.	22
	Cleaning (various methods of).	25
	Bellows testing (on site method)	26
<b>VIII</b>	<b>Environmental Control.</b>	
	What is API?	1
	The API 682 piping plans, objectives	2
	The basic rules in successfully applying the API piping plans.	3
	The symbols used in the piping plans.	6
	The introduction of PDN plan 00 and why I feel that is necessary.	7
	An important quote/unquote from BRRR to support the need for plan PDN 00.	12
	The API piping plans for clean products.	12
	The API piping plans for dirty products.	24
	The API piping plans for systems.	31

Chapter	Subject	Starts Page
<b>VIII</b>	The API piping plans for auxiliaries.	56
<b>CONT.</b>		
	The API piping plans which are seldom used	66
	Other points of interest regarding Environmental Control.	68
	Seal chamber cooling and/or heating.	68
	ΔT between coolant in & outlet.	69
	Auxiliary equipment.	70
	The magnetic separator.	71
	The cyclone separator.	72
	The orifice.	74
	The heat exchanger.	77
	Switches and transmitters.	80
	The injection point.	84
	Throat bushings.	84
	<b>NOTE.</b> In chapter VIII, the piping plans have not been discussed in numerical order but rather in a logical sequence based on their use. That makes it somewhat difficult to find a particular plan for which you are seeking information. On the last page of the chapter you will find a numerical overview of the piping plans with the page number on which they can be found.	86
<b>IX</b>	<b>TROUBLESHOOTING I.</b>	
	General introduction into the subject of trouble shooting including the definitions of theory and practice	1
	The “Troubleshooting Cake”. In other words, which ingredients, or rather skills, are required to be a good trouble shooter.	3
	A rough guide to troubleshooting: various tips and tricks.	5
	Why do seals fail? The definition of troubleshooting.	10
	What do people regard as a seal failure?	10
		10
	As a reminder: keep records.	13
	66 items which in some form or other have to do with trouble shooting are told from this page onward:	14
	An alphabetical list of these items is shown from page on	150



Chapter	Subject	Starts Page
<b>X</b>	<b>TROUBLESHOOTING II</b>	
	This chapter contains a number of case histories (21). Names of firms, persons, exact locations and dates have been omitted; they are not relevant.	1 thru 48
	Case History no.1 relates to a bearing problem which was responsible for heavy seal leakage. The problem affected seals of at least 2 suppliers but had nothing to do with the seal itself.	1
	Case History no. 2 is about cavitation which was created by an unusual problem.	5
	Case History no. 3 is about excessive wear of, in particular, the carbon face due to something in the product of which the client was not aware that it was an abrasive substance.	7
	Case History no. 4 is a story about seals which the MTBR dropped dramatically from > 4 years to as many weeks following an overhaul of the pumps in which they were installed.	9
	Case History no. 5 is similar to Case History no. 4 albeit that in this case the seals had performed for more than 20 years, achieving MTBR figures of >8 years.	12
	Case History no. 6 relates to an installation of seals in a boiler feed pump where the maintenance people who had installed the seal had not followed up the instructions correctly.	14
	Case History no. 7 is about an 'A' and a 'B' pump of which the former was favoured by the plant operators as "it never gave any problems". The 'B' pump drew a higher amperage, its delivery was below the rated capacity and the free end seal always leaked.	16
	Case History no. 8 tells the story of what can happen when carbon seal faces are incorrectly lapped	19
	Case History no. 9 occurred at a refinery which had built an extension to their existing plant and took a last minute decision to upgrade the seals from rotating to stationary bellows for which the seal chamber bore had to be enlarged. On a few pumps this created problems of an unexpected nature.	20

Chapter	Subject	Starts Page
<b>X CONT.</b>	Case History no. 10 is most likely one of the weirdest case histories in this chapter. The root cause was a perfectly normal piping arrangement which created a problem with the level indicator on the vessels of an API plan 52. It is a typical example of a cause which was regarded as “impossible”.	22
	Case History no. 11 is about seal failures created by a “less than fortunate” piping lay out combined with operator error. The problem occurred every time the plan 52 vessel was re-filled.	25
	Case History no. 12 was perceived by everyone as a seal problem which started to occur following the de-staging of a number of pumps.	26
	Case History no. 13 is a perfect example how a little bit of luck is welcome in a trouble shooting exercise. Seals were deemed to be “worthless” as they were leaking heavily one moment and seen to be “bone dry” the next.	28
	Case History no. 14 shows that denying that there are differences or changes in process conditions, working methods, etc. can cause serious problems certainly when the end user insists that they have not changed anything.	30
	Case History no. 15 shows that a pump which has been built in accordance with the latest specifications does not necessarily guarantee a better performance of the seals. In addition, there were other contributing factors to the poor performance of the seals.	33
	Case History no. 16 is about the shortest seal life I have ever experienced: 30 seconds. Again, the root cause was something far removed from anything to do with the seals or the installation thereof.	37
	Case History no. 17 was all about the anomalous temperature readings recorded on the circulation loop of seals equipped with API plan 53B. Several modifications were made to the seal and piping with little or no effect. At the end of the day it turned out that the oil used as a barrier fluid was not suitable for this kind of application.	38
	Case History no. 18 is about MTBR and demonstrates that, although a specification may call for a minimum MTBR, there are applications where it cannot always be achieved without some “out of the box thinking”.	41

Chapter	Subject	Starts Page
<b>X CONT.</b>	Case History no. 19 is about dry running seals which emitted high pitched squeaks during operation. That was simply solved by using an alternative material for one of the faces. The interesting thing about the Case History is that whilst carrying out the modification not a single squeak was heard coming from the other units in the production hall. The “why not” is a perfect example of one of the basic rules of trouble shooting: “looking for the difference”.	44
	Case History no. 20 is about seal failures which were the result of the shutdown of the otherwise continuous production process over the weekends. The failures would invariably occur on Monday morning when the process was re-started.	46
	Case History no. 21 is another story about the barrier fluid being responsible for the seal problems.	47
	Case History no. 22 is about a “commodity” which I have called “Preventive Knowledge” which helped me solve a problem before it actually occurred.	48
<b>XI</b>	<b>TROUBLESHOOTING III</b>	
	This chapter begins with a “Quick Reference Chart” spread out over 9 pages each containing 6 columns listing: Cause of Failure – Symptoms – Affected Parts – Side Effects – Possible Cause – Possible Cure.	2
	Secondly there is a “Mechanical Seal Checklist” which can be helpful in recording many details of a particular application so as to build up a historical data base which can be used to monitor performance and, if required, can be used in a troubleshooting exercise.	11
<b>XII</b>	<b>GLOSSARY</b>	
	An A to Z description of words, terms, abbreviations etc. which I have “encountered” during my working life. Throughout the pages you will find <i>references in Italics</i> which point to a more elaborate explanation at some point in the book.	