1

Hydraulic Components Volume A

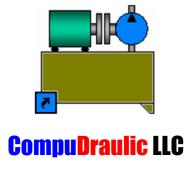
Hydraulic Sealing Elements

Dr. Medhat Kamel Bahr Khalil, Ph.D, CFPHS, CFPAI.

Director of Professional Education and Research Development,

Applied Technology Center, Milwaukee School of Engineering,

Milwaukee, WI, USA.



www.CompuDraulic.com

CompuDraulic LLC

Hydraulic Components Volume A Hydraulic Sealing Elements

ISBN: 978-0-9977634-9-2

Printed in the United States of America First Published by August 2018 Revised January 2019

All rights reserved for CompuDraulic LLC.

3850 Scenic Way, Franksville, WI, 53126 USA.

www.compudraulic.com

No part of this book may be reproduced or utilized in any form or by any means, electronic or physical, including photocopying and microfilming, without written permission from CompuDraulic LLC at the address above.

Disclaimer

It is always advisable to review the relevant standards and the recommendations from the system manufacturer. However, the content of this book provides guidelines based on the author's experience.

Any portion of information presented in this book might not be suitable for some applications due to various reasons. Since errors can occur in circuits, tables, and text, the author/publisher assumes no liability for the safe and/or satisfactory operation of any system designed based on the information in this book.

The author/publisher does not endorse or recommend any brand name product by including such brand name products in this book. Conversely the author/publisher does not disapprove any brand name product not included in this book. The publisher obtained data from catalogs, literatures, and material from hydraulic components and systems manufacturers based on their permissions. The author/publisher welcomes additional data from other sources for future editions. This disclaimer is applicable for the workbook (if available) for this textbook.

Table of Contents

PREFACE, 6

ACKNOWLEDGEMENT, 7

ABOUT THE AUTHOR, 8

Chapter 01: Introduction to Hydraulic Sealing Elements, 9

- 1.1- Functions of Hydraulic Sealing Elements
- 1.2- Applications of Hydraulic Sealing Elements
- 1.3- Classifications of Hydraulic Sealing Elements

Chapter 02: Sealing Rings, 13

- 2.1- Features and Basic Use of Sealing Rings
- 2.2- Configurations of Sealing Rings
- 2.3- O- Rings
 - 2.3.1- O-Rings Construction
 - 2.3.2- O-Rings Sealing Mechanism
 - 2.3.3- O-Rings Main Dimensions
- 2.4- Encapsulated O-Rings
- 2.5- Square-Rings
- 2.6- X- Rings
- 2.7- Custom-Rings
- 2.8- Metallic Sealing Rings

Chapter 03: Hydraulic Seals, 23

- 3.1- Cup Seals
- 3.2- U- Cup Seals
- 3.3- T- Shaped Seals
- 3.4- V-Packings
- 3.5- Spring-Energized Seals
- 3.6- Wear-Rings
- 3.7- Backup Rings
- 3.8- Rod Wipers

Chapter 04: Materials for Hydraulic Sealing Elements, 38

Chapter 05: Properties and Test Methods for Hyd. Sealing Elements, 40

- 5.1- Resilience
- 5.2- Modulus of Elasticity
- 5.3- Elongation

- 5.4- Yield Tensile Strength
- 5.5- Ultimate and Fracture Tensile Strength
- 5.6 -Tear Strength
- 5.7- Compression Set
- 5.8- Swelling
- 5.9- Shrinkage
- 5.10- Surface Hardness
- 5.11- Compatibility with Hydraulic Fluids
- 5.12- Extrusion Resistance
- 5.13- Explosive Decompression Resistance
- 5.14- Hydraulic Seal Friction
 - 5.14.1- Hydraulic Seal Friction Conditions
 - 5.14.2- Friction in Translational Seals
 - 5.14.3- Friction in Rotational Seals
 - 5.14.4- Factors Affecting Seal Friction
 - 5.14.5- Controlling Seal Friction
- 5.15- Wiper Performance Test

Chapter 06: Best Practices for Hydraulic Seals Selection, 64

- 6.1- Selection of Seal Type
- 6.2- Selection of Seal Dimensions
- 6.3- Selection of Seal Lip Geometry
- 6.4- Selection of Seal Crossectional Shape
- 6.5- Selection of Seal Material Based on Working Pressure
- 6.6- Selection of Seal Material Based on Working Temperature
- 6.7- Selection of Seal Material Based on Working Fluid
- 6.8- Selection of Seal Material Based on Hardness
- 6.9- Selection of Seal Material Based on General Properties

Chapter 07: Sealing Solutions for Hydraulic Cylinders, 74

- 7.1- Considerations for Hydraulic Cylinders Reliable Sealing
- 7.2- Sealing Solutions for Cylinder Rods
 - 7.2.1- Unidirectional Rod Sealing Solutions
 - 7.2.2- Bidirectional Rod Sealing Solutions
- 7.3- Sealing Solutions for Cylinder Pistons
 - 7.3.1- Unidirectional Piston Sealing Solutions
 - 7.3.2- Bidirectional Piston Sealing Solutions
- 7.4- Piston and Rod Design for Proper Sealing
 - 7.4.1- Design of Seal Groove and Lead-In Chamfers
 - 7.4.2- Extrusion Gap Design

Chapter 08: Sealing Solutions for Rotational Shafts, 104

- 8.1- Rotational Radial Seals
- 8.2- Rotational Axial Seals
- 8.3- Combined Axial/Radial Sealing Solutions for Rotational Shafts

Chapter 09: Best Practices for Hydraulic Seals Installation, 112

Chapter 10: Best Practices for Hydraulic Seals Storage, 123

Chapter 11: Best Practices for Hydraulic Seals Failure Analysis, 125

- 11.1- Manufacturing Defects Improper Molding
- 11.2- Manufacturing Defects Insufficient Material Properties
- 11.3- Design Defects Extrusion
- 11.4- Design Defects Gland (Groove) Sharp Corners
- 11.5- Design Defects Rough Surfaces
- 11.6- Design Defects Blow-By Effect
- 11.7- Assembly Defects Passing Over Sharp Edges
- 11.8- Operational Defects Overpressure
- 11.9- Operational Defects Pressure Trapping
- 11.10- Operational Defects Overheating
- 11.11- Operational Defects Overspeeding
- 11.12- Operational Defects Contamination
- 11.13- Operational Defects Fluid Incompatibility
- 11.14- Operational Defects Chemical Attack
- 11.15- Operational Defects Hydrolysis
- 11.16- Operational Defects Explosive Decompression
- 11.17- Operational Defects Dieseling
- 11.18- Operational Defects Side Loading
- 11.19- Operational Defects Vibration
- 11.20- Operational Defects Spiral Failure
- 11.21- Operational Defects Seal Wear
- 11.22- Operational Defects Fatigue
- 11.23- Normal Aging Defects Hardening
- 11.24- Normal Aging Defects Splits
- 11.25- Storage Defects Swelling
- 11.26- Storage Defects Ozone Cracking

APPENDIX A: LIST OF FIGURES, 156 APPENDIX B: LIST OF TABLES, 162

APPENDIX C: LIST OF STANDARD TEST METHODS, 162

INDEX, 163

PREFACE

This book provides a knowledge base for fluid power users to become familiar with commonly used seals in hydraulic components. This book presents an overview of hydraulic sealing elements including seal functions, classifications, and materials. This book also presents 15 various properties of hydraulic seals and relevant standard test methods. This book introduces best practices for hydraulic seals selection, installation and storage. This book provides a thorough analysis for failures of hydraulic seals including 26 failure modes with examples and demonstrative pictures. The following table shows some interesting statistics about the book.

Chapters	Pages	Lines	Words	Characters	Figures	Tables	Equations
11	167	1008	23795	133001	182	13	3

ACKNOWLEDGEMENT

The author likes to thank Mr. Thomas Wanke, CFPE Director of the Fluid Power Industrial Consortium at Milwaukee School of Engineering (MSOE), for his effective effort in reviewing the presented technical information.

The author also thanks the administration at Milwaukee School of Engineering and his supervisors who supported the effort to develop this book.

The author thanks the following companies (listed alphabetically) for permitting him to use portions of their copyrighted literatures in this book.

- American High-Performance Seals.
- ASSOFLUID
- Bar Hydraulics
- EPM Seals.
- Ecoseal Co. Ltd.
- Gates Corporation.
- Hallite Seals.
- Hydraulic Specialist Study Manual by IFPS
- MFP Seals.
- Parker Hannifin.
- System Seals Inc.
- Trelleborg.

Lastly, the author extends his thanks to the following sources of public information used to enrich the contents of the book.

- applerubber.com
- astonseals.com
- Caterpillar
- ecosealthailand.com
- hvdrapakseals.com
- marcorubber.com
- mnrubber.com
- news.ewmfg.com
- o-ring-lab.com
- schoolcraftpublishing.com
- skf.com
- wyomingtestfixtures.com

ABOUT THE AUTHOR



Medhat Khalil, Ph.D., Director of Professional Education & Research Development at the Applied Technology Center, Milwaukee School of Engineering, Milwaukee, WI, USA. Medhat got his bachelor's degree in mechanical engineering from Military Technical College (MTC), Cairo, Egypt. He got his master's degree in Mechanical Engineering from Cairo University, Cairo, Egypt. Medhat has been granted his Ph.D. in Mechanical Engineering and Post-Doctoral Industrial Research Fellowship from Concordia University in Montreal, Quebec, Canada. Medhat, published several fluid power textbooks. He participated in many technical conferences, published several reviewed technical papers, and is in the process of registering a number of patents. Medhat has been certified by the

International Fluid Power Society (IFPS) as: Certified Fluid Power Hydraulic Specialist (CFPHS) and Certified Fluid Power Accredited Instructor (CFPAI). Medhat is a member of many grand institutions such as Center for Compact and Efficient Fluid Power Engineering Research Center (CCEFP), listed Fluid Power Consultant by the National Fluid Power Association (NFPA) and listed professional instructor by the American Society of Mechanical Engineers (ASME) and National American Die Casting Association (NADCA). Medhat has been assigned as the chair of the education committee for the International Fluid Power Exposition (IFPE 2017 and 2020). Medhat developed and taught various courses for industry professionals. He has a balanced academic and industrial experience. Medhat has a deep working experience in the field of Mechanical Engineering; more specifically in fluid power and motion control. Medhat had worked for several world-wide recognized industrial organizations such as Rexroth in Germany and CAE in Canada. Medhat has designed several hydraulic systems and developed



analytical and educational software. Medhat also has vast experience in modeling and simulation of dynamic systems using Matlab-Simulink. Medhat was the designer and founder of the Universal Fluid Power Trainers. Medhat was the recipient of the "Otto Maha Pioneers in Fluid Power" in award 2012.