

# **Basic Hydraulics**



# **Basic Hydraulics**

*Fluid Power Workhorse*

**Jay F. Hooper**

Carolina Academic Press  
Durham, North Carolina

Copyright © 2012 Jay F. Hooper  
All Rights Reserved

Library of Congress Cataloging-in-Publication Data

Hooper, Jay F.  
Basic hydraulics : fluid power workhorse / Jay F.  
Hooper.  
p. cm.  
ISBN 978-1-59460-835-3 (alk. paper)  
1. Fluid power technology. 2. Hydraulic fluids.  
I. Title.

TJ843.H68 2010  
621.2--dc22

2010023557

Carolina Academic Press  
700 Kent Street  
Durham, NC 27701  
Telephone (919) 489-7486  
Fax (919) 493-5668  
[www.cap-press.com](http://www.cap-press.com)

Printed in the United States of America

# Contents

<b>Preface</b>	xi
<b>Introduction</b>	xiii

## **Section One**

<b>1 · Hydraulic Fundamentals</b>	3
The Four States of Matter	3
Change of State	3
STP	5
Normal Air	5
Free Air	5
Relative Humidity	6
Dew Point	7
FPS [MPS or mps or m/sec.]	8
Scales	8
Absolute Pressure Scale	8
Gauge Pressure Scale	8
Vacuum Pressure Scale	9
Major Constituents of Air	9
Compressibility	10
<b>2 · Hydraulic Fluid Treatment or Conditioning</b>	13
Primary Fluid Treatment	13
Strainers	13
Suction Line Filters	14
Pressure Line Filters	14
Return Line Filters	14
Hydraulic Fluid Cooler	14
Hydraulic Fluid Heater	14
Separation of Water	15
Separation of “Big” Dirt	15
Breather Adsorption Filter	15

**Contents**

Micron	16
Secondary Treatment and Protection	18
Separator	18
Filters	19
Wipers	19
Boots	19
<b>3 · Distribution Systems</b>	<b>21</b>
Reservoir	21
Piping Systems	21
Pitch	22
Take Offs	23
<b>4 · General Schematic Symbols</b>	<b>25</b>
Connected and Non-connected Lines	25
Cylinders	26
Flow Control	26
Variable Symbol	27
Compensated Flow Control Valves	27
Check Valves	29
Fluid Treatment	29
Pressure Relief Valve	29
Motors and Pumps	30
Reservoir or Tank	31
Accumulator	31
Pilot Lines, Exhausts, and Enclosures	32
Hydraulic or Hydraulic Arrowhead	34
<b>5 · Valve-Related Schematic Symbols</b>	<b>35</b>
Self-Test #1	43
<b>6 · General Force Equation for Cylinders</b>	<b>47</b>
<b>7 · Hydraulic Fittings</b>	<b>51</b>
Barbed Fittings	51
Tubing Sizes	51
Hose Sizes	52
Quick Disconnects	53
Hose Clamps	53
Nipples	54

Straight Couplings	55
Reducers	55
Ferrule or Sleeve, and Nut	56
Manifold	57
Strain Relief	58
Swivel	59
Tee	59
Elbow	60
Valves	60
Plug	62
Runs and Branches	62
Male & Female	63
Union	64
Flow Control with Integral Check	64
Straight Connector	66
Pipe Thread	66
Summary	67
Self-Test #2	68
<b>8 · The Ideal Gas Law and Solved Problems</b>	<b>71</b>
Solved Problem	73
Solved Problem	74

**Section Two**

<b>9 · The Hydraulic Side of Fluid Power</b>	<b>75</b>
Friction	75
Viscosity	75
Distance, Area, Volume	76
Distance, Speed (Velocity), Acceleration	76
Flow, Pressure	77
Momentum (a 5th level tech. term)	77
Force, Weight (6th level tech. terms)	77
Energy, Torque (7th level tech. terms)	78
Power, HP (8th level tech. terms)	78
<b>10 · Hydraulic Terms and Concepts That Help Your Understanding</b>	<b>81</b>
Efficiency	81
Pressure Differential	82
Dissolved and Entrained Air	82

**Contents**

Cavitation	82
Actuator Speed, Pressure, Flow, Force, and Torque	83
Intensifiers	84
Fire Points	84
Fire Resistant Fluids	85
Hydraulic Cylinder Terminology	85
Hydraulic Accumulator Terms	90
<b>11 · The ABCs of Hydraulic Relationships</b>	<b>93</b>
<b>12 · Hydraulic Motors</b>	<b>97</b>
Positive Displacement Hydraulic Motors	97
Vane Motors	97
Gear Motors	98
Piston Motors	98
Variable Displacement Hydraulic Motors	98
Axial Piston Swashplate Motor	99
RPM	99
Torque	100
Horsepower	101
Freewheeling	101
Items & Terms	102
Self-Test #3	103
<b>13 · Pressure Control Valves</b>	<b>105</b>
Pressure Relief Valve	106
Sequence Valve	106
Brake Valve	107
Counterbalance Valve	108
Unloading Valve	108
Pressure Reducing Valve	109
Summary	110
<b>14 · Proportional and Servo Valves</b>	<b>111</b>
Six General Areas of Valve Control in Hydraulics	111
Electro-mechanical Control (Levers and Solenoids)	115
Hydrostatic Drive Control (Hydrostatic Drives)	115



Proportional Valve Control	116
Single Stage and/or Instrument Servo Control	117
Two Stage Servo Control	118
Three Stage Servo Control	119
<b>15 · Discussion of Self-Test Answers</b>	<b>121</b>
Test #1	121
Test #2	125
Test #3	128
<b>16 · Exercises</b>	<b>131</b>
Exercise 1	134
Exercise 2	135
Exercise 3	137
Exercise 4	139
Exercise 5	141
Exercise 6	143
Exercise 7	145
Exercise 8 (no build—from print only)	148
Exercise 9 (optional) (no build—from print only)	151
Exercise 10	153
Exercise 11	156
Exercise 12 (optional)	159
Exercise 13	163
Exercise 14	166
Exercise 15	169
Exercise 16	172



# Preface

This book was developed to instruct people who want to troubleshoot hydraulic machinery and hydraulic circuits. The material in this book assumes no prior knowledge of hydraulics and could be used by anyone who has an interest in this particular area of fluid power. This book does not cover the rebuilding of hydraulic components.

In order to firmly plant the concepts of what is going on in hydraulics, this information has an orientation to a “hands-on” approach. The text uses some generalizations and other approximations. This book is directed at the hourly worker on the factory floor or out in the field.

The objective of this basic hydraulics course is to train the current or prospective maintenance mechanic or technician in the basic hydraulic building blocks to be used in troubleshooting. This is done in a two-step fashion. If you have had no previous experience with pneumatics or hydraulics, then start right at the beginning of section one. If you have had previous experience with troubleshooting pneumatics, then look over and review the first section of the text, do all of the exercises (1–8) in the first section, and then start in earnest on section two. This hydraulic text is oriented to what you will run into in the field. Technical specs and other values are given in the text and then followed by their {standard} and [metric] equivalent, as you should be able to work in either measuring system in this field.

Jay. F. Hooper  
Salisbury, N.C.  
December 2011



# Introduction

This book is part of a course that prepares the student to display a working knowledge of hydraulic systems and to troubleshoot hydraulic problems. Upon successful completion of this course, the student will be able to:

- Read schematic prints
- Understand the components of hydraulic systems
- Recognize the names of hydraulic components and fittings
- Determine probable causes and solutions of problems
- Troubleshoot standard hydraulic circuits

