

More Essential Hydraulics

Introduction	12
About this Seminar	12
Safety	12
Pre-Evaluation	14
Foundation Principles	18
Fluid Power Rules-of-Thumb.....	18
Area	19
Pressure.....	20
Pascal’s Law.....	20
Characteristics of Pressurized Fluid	20
Heat and Horsepower	21
Schematics & Symbols	22
Reading and Drawing Schematics.....	22
Schematic Symbol Elements.....	22
Complete Symbols.....	24
Complete Schematic.....	25
Hydraulic Pumps.....	26
Fixed Displacement	26
Variable Volume, Pressure-Compensated	26
Relief Valves.....	27
Direct Acting Relief Valve	27
Pilot-Operated Relief Valve.....	27
Pilot Stage	27
Main Stage	27
Series Circuits	28
Parallel Circuits	28
Directional Controls.....	29
Common Center Conditions & Applications	29
Open Center.....	29
Tandem Center.....	29

Closed Center.....	29
Float Center	29
Flow Controls	30
Flow Control Application.....	30
Meter-In.....	30
Meter-Out	30
Bleed-Off	30
Hydraulic Actuators	31
Hydraulic Motors	31
Cubic Inch Displacement.....	31
Cubic Inches Per Minute.....	31
RPM	31
Torque.....	31
Differential Cylinders.....	32
Area	32
Area Ratio	32
Performance Characteristics	32
Force	32
Stroke Time.....	32
Inches Per Minute	32
Lab: Review of Foundation Principles	33
Schematic: Review of Foundation Principles.....	35
Review: Review of Foundation Principles.....	36
Hydraulic Manifold Technology	37
General	37
Inline	37
Selection.....	37
Installation	37
Sandwich.....	38
Advantages	38
Application.....	38

Installation	39
Procedure	39
Cartridge Valves	40
General	40
Advantages	40
Operation	40
Application	40
Custom Manifolds	42
Application	42
Pressure Controls	43
Cross-Port Relief Valves	43
General	43
Application	43
Lab: Cross-Port Relief Valves	44
Bench Setting Cross-Port Relief Valves	45
Setting Cross-Port Relief Valves	45
Schematic: Cross-Port Relief Valves	47
Schematic: Cross-Port Relief Valves, Schematic #2	48
Review: Cross-Port Relief Valves	49
Pressure Reducing Valves	50
General	50
Operation	50
Application	50
Lab: Pressure Reducing Valves	51
Schematic: Pressure Reducing Valves	55
Review: Pressure Reducing Valves	56
Sequence Valves	57
General	57
Application	57
Lab: Sequence Valves	58
Schematic: Sequence Valves	60
Review: Sequence Valves	61

Accumulators	62
General	62
Safety Considerations	62
Unloading.....	62
Hydraulic Pilot Signal.....	62
Electrical Signal.....	63
Manual Control	63
Mechanically Loaded	64
Weight-Loaded.....	64
Spring-Loaded.....	65
Gas-Charged	66
Piston	66
Bladder	67
Applications	69
Energy Storage	69
Emergency Power	70
Shock Absorption.....	70
Adiabatic & Isothermal Exchange.....	70
Sizing Accumulators	71
Accumulator Calculations.....	71
Isothermal.....	71
Adiabatic	71
Fluid Requirements	71
Considerations.....	71
How to Size an Accumulator.....	72
Lab: Accumulators – Part 1	73
Schematic: Accumulators – Part 1	74
Lab: Accumulators – Part 2	75
Schematic: Accumulators – Part 2.....	78
Review: Accumulators	79
Load Control Valves.....	80
Counterbalance Valves	80
General	80

Operation	80
Direct Acting	81
Pilot-Operated	81
Four Port (Vented) Option	81
Pilot-Operated Check Valves	82
General	82
Pilot To Open	82
Pilot To Close	82
Four Port (Vented) Option	83
Application	83
Calculations: PO Check – Pilot Pressure, Blind End	84
Lab: Counterbalance Valves – Part 1	85
Schematic: Counterbalance Valves – Part 1	87
Application	88
Calculations: Direct Acting Counterbalance	90
Calculations: Externally Piloted Counterbalance	92
Lab: Counterbalance Valves – Part 2	95
Counterbalance Valve Bench Setting Procedure	98
Schematic: Counterbalance Valves – Part 2	99
Review: Counterbalance Valves – Part 2	100
Lab: Counterbalance Valves – Part 3	101
Schematic: Counterbalance Valves – Part 3	102
Lab: Pilot-Operated Check Valves	103
Schematic: Pilot-Operated Check Valves	105
Lab: Counterbalance Valves – Part 4	106
Schematic: Counterbalance Valves – Part 4	108
Review: Counterbalance Valves – Parts 3 & 4	109
Review: Pilot-Operated Check Valves	110
Heat Exchangers	111
Heat Reduction	111
Calculation: Heat Reduction	112
Heat Exchanger Circuit Locations	114

Return Line Cooling – Full Time	114
Return Line Cooling – Periodic	114
Offline Cooling.....	115
Air Over Oil	116
Water Over Oil	116
Sizing Heat Exchangers.....	116
Load Sense	117
Overview.....	117
The DFR Compensator	118
Lab: Load Sense – Part 1	119
Schematic: Load Sense – Part 1	120
Lab: Load Sense – Part 2.....	121
Schematic: Load Sense – Part 2	123
Lab: Load Sense – Part 3.....	124
Schematic: Load Sense – Part 3	125
Review: Load Sense.....	126
Regenerative Circuits	127
Characteristics	127
Types of Regenerative Circuits	128
Fulltime Regenerative	128
Automatic Kickdown	129
Controlled Kickdown	130
Regenerative Circuit Calculations	131
Lab: Regenerative Circuits – Part 1	133
Schematic: Regenerative Circuits – Part 1.....	134
Lab: Regenerative Circuits – Part 2	135
Schematic: Regenerative Circuits – Part 2.....	136
Review: Regenerative Circuits	137
Lab: Regenerative Circuits, D08	138
Schematic: Regenerative Circuits, D08	139
Review: Regenerative Circuits, D08	140

Flow Rate vs. Pressure Drop	141
Lab: Flow Rate vs. Pressure Drop	141
Schematic: Flow Rate vs. Pressure Drop	142
Review: Flow Rate vs. Pressure Drop	143
Lab: Final Project	144
Introduction	144
Current System	144
Current System Specifications	144
Feed Roll	144
Schematic: Final Project, Current System	146
Proposed System Specifications	147
Clamp Cylinder	147
Feed Cylinder	147
Saw Motor	147
Bill of Materials: Final Project, Proposed System	148
Schematic: Final Project, Proposed System, Final	150
Review: Final Project	151
Post-Evaluation	152
Appendix	155
Schematic Symbols	155
Pumps	155
Hydrostatic Pumps	156
Pressure Controls	157
Flow Controls	158
Directional Controls	159
Actuators	161
Accessories	162
Fluid Lines	163
Common Directional Valve Mounting Patterns	164
Types/Locations of Hydraulic Filters	166
Reservoir Breather	166
Suction Strainer	166

Suction Filter	167
Pressure Filter	167
Return Line Filter	168
Offline Filtration	169
Filter Selection	170
Selection Considerations.....	170
Surface Media	170
Wire Mesh.....	170
Depth Media.....	171
Cellulose:.....	171
Fiberglass:.....	171
Pressure Differential Across Element	172
Filter Flow Rate	172
Filter Bypass Valve	172
Filter Housings	173
Selection Considerations.....	173
Hydraulic Formulae.....	174
Quick Reference.....	174
Cylinder Math	174
Pump Math	175
Motor Math	175
Fluid Line Sizing Math	175
Pumps.....	176
Cubic Inches Per Minute, Gallons Per Minute	176
Horsepower	176
Motors	177
RPM	177
Torque	177
Cylinders.....	178
Blind End Area	178
Rod End Area	178
Cylinder Area Ratio.....	179
Regenerative Cylinder Area Ratio	180

Force	181
Pressure	181
Rod Speed	182
Stroke Time	182
Fluid Lines.....	183
Fluid Velocity	183
Fluid Line Diameter.....	183
Fluid Lines.....	184
Line Sizing	184
Glossary	185
A	185
Annulus	185
ANSI	185
Area.....	185
Atmospheric Pressure.....	185
B	185
Balanced Spool	185
Bernoulli's Principle	185
C	185
Closed Circuit	185
Conservation of Energy.....	185
Cushions.....	186
Cylinder Displacement	186
Cylinder Mounting Styles	186
Cylinder, JIC Type	186
Cylinder Rod	186
D	186
Displacement.....	186
Double Acting Cylinder, Single Rod	186
Double Acting Cylinder, Double Rod	187
E	187
Expanded Hydraulic Symbol.....	187
F	187
Finite	187
Force	187

G	187
H	187
Head Pressure	187
Horsepower	187
Hydraulic Horsepower	187
Hydraulic Motor, HSLT	188
Hydraulic Motor, LSHT	188
Hydraulic Schematic	188
Hydraulic Symbols	188
Hydrodynamic	188
Hydrostatic	188
I	188
I.D.	188
Inches of Mercury	188
Infinite	188
J	188
K	188
Kinetic Energy	188
L	189
Laminar Flow	189
Load Pressure	189
M	189
N	189
O	189
O.D.	189
Oil Flow	189
Oil Flow Paths	189
Oil Velocity	189
Open Circuit	189
Overhung Load	189
Overrunning Load	190
Orifice	190
P	190
Parallel Flow	190
Pascal’s Law	190

Piston	190
Positive Displacement	190
Power	190
Pressure	190
Pressure Drop (ΔP)	190
Prime Mover	190
PSIA	190
PSIG	191
$P_t = P_s + P_v$	191
Q	191
R	191
Resistive Load	191
S	191
Series Flow	191
System Pressure	191
T	191
Turbulent Flow	191
Torque	191
U	191
V	192
Vacuum	192
Valve Poppet	192
Valve Spool	192
Valve Spool Positioning	192
Venturi	192
W	192
Work	192
X	192
Y	192
Z	192
Course Evaluation	193