THE TECHNOLOGY OF FLUID POWER

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Dedication

to Andrea

Preface

The Technology of Fluid Power is devoted to providing the beginning fluid power student with fundamental concepts and basic skills necessary to understand and design a variety of fluid circuits. Emphasis is placed on exercises and assignment, with text to present concepts. The reader is instructed to apply these concepts through problem solving, color coding, schematic development, and component specification in order to develop a greater understanding of the practical applications of fluid power.

Various laws and theories have been devised to describe the nature and actions of fluids under pressure. Many of these are useful in predicting the operation of fluid circuitry under specific environments and conditions. Fluid circuits seldom operate within such limited parameters. Therefore, this text will minimize their usage and will incorporate only those laws and theories required to describe the major variables encountered in designing and understanding fluid circuitry.

The reader will be designing fluid circuitry based on practical applications and typical loads, cycles, or speed requirements. Although specific results will be expected, the variability of fluid components that control pressure and flow of fluids adequately compensates for most of the variance caused by conditional and environmental effects. Such variability is one of the major advantages of fluid power.

Throughout the text emphasis is placed on developing an understanding of the construction of componentry such as pumps, valves, and actuators. With such understanding, the reader will be able to predict how circuits having fluid components will operate. The ability to design fluid circuitry will follow from the logical combination of components rather than rote memorization of standard circuits.

The reader who successfully completes this text should be able to "think fluid power." With further study and application of theories and laws, exposure, and handson experience, vocations in industrial maintenance, machine design or technical sales are possible. Also the casual or interested reader will find these concepts useful in developing an understanding of how fluid circuitry operates.

The author is indebted to the many technologists, scientists, educators, and engineers who have made the study of fluid power a possibility. Gratitude is expressed to three colleagues: F. Theodore Paige, for the inspiration for this book; Menno DiLiberto, for assistance in unwrapping the mysteries of computer-aided drawing and design; and John H. Adams, for reviewing and proofreading the text. Special thanks is also extended to Pat, Ron, Mike, Chuck, Paul, and the rest of the training staff at Aeroquip for timely information on fluid conductors.

This book is possible only because of the patience and understanding of my wife. After thousands of hours of writing, typing, and drawing it is with pride and relief that I can say, "Yes, Barbara, the book is finally finished." However, the study will still go on.

William W. Reeves

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chapter

1

Introduction to Fluid Power

In general, people have little understanding of various fluid power devices that they use every day. They may even be intimidated by fluid machinery that moves tons of soil or raises whole houses while amazed by the accuracy of control available in robots using fluid devices. However, fluid circuits are normally no more complicated than house wiring circuits. With a basic understanding of a few fluid laws and the ability to perform simple algebra, anyone can design basic fluid power circuitry.

1.1 TRADITIONAL FLUID POWER STUDY

Traditionally, the study of fluid power has been a two-phase approach. The technical approach has emphasized the development of understanding of hydraulic component design and operation. The engineering approach has emphasized the development of understanding of hydraulic circuit design and operation. This book will synthesize both approaches in what may best be described as a technological approach. Technicians, technologists, and engineers all need to develop a better understanding of the total concept of fluid power in able to better communicate ideas that will result in improved design, maintenance, and operation of circuitry. Fluid devices rely on the manipulation and control of various liquids and gases. The primary chapters in this book will use oils, both refined and synthetic, as the medium for power transmission. Later chapters include circuit and component design variations necessary to understand power transmission using air as the medium for power transmission.

1.2 DESIGN OF THE BOOK

Most technical texts present a body of information, then require interaction with the reader in a summary at the end of each chapter. Most manuals rely heavily on illustrations and problem solving with little verbal explanation. This book interlaces text, illustrations, and problems, where appropriate, in order of presentation. The result is a reduction in the loss of retention by the reader. Typically, each chapter ends with a design problem that summarizes knowledge gained through practical demonstration of understanding. The illustrations in this book (designated as figures) are primarily used to describe overall design and operation of hydraulic circuits and components. They do not describe specific sizing or construction. For this reason some details may be eliminated for sake of clarity. However, important problems and assignments are frequently included in the figures as well as the text. For this reason, each figure should be thought of as a logical extension of the text as well as a means of clarifying text information. *Therefore, figures in each chapter should be given close attention.*

1.3 CONVENTIONS USED IN THE BOOK

Many different methods exist for presentation of information. Although all methods may be correct, the reader must be informed as to which methods will be incorporated and consistency must be maintained. Many of these conventions exist in designations. Fluid power incorporates the use of distances, areas, and volumes to describe many components. Areas are typically measured in square inches in the English system and may be designated verbally or exponentially. This text will use verbal designation. Areas will, therefore, be designated in square inches or **sq in.** Similarly, volumetric measurement will be designated in cubic inches or **cu in.** In this book linear distances will be designated verbally such as inch **(in.)** or foot **(ft)**. Forces or loads will be designated as pounds **(lb)** rather than #. Ratings will also be made verbally such as gallons/minute **(gpm)** and revolutions/minute **(rpm)** and should be read gallons per minute and revolutions per minute, respectively. Other conventionally used designations will be presented throughout the text and will be explained at those points. Conventions are also used to describe mathematical functions. In this book the following symbols will be used:

+	Addition
−	Subtraction
*	Multiplication
— or /	Division
$\sqrt{\ }$	Square root
$(x)^2$	Square

Note that dual symbols will be used for division. In most cases the line division symbol will be incorporated. However, in more complex formulas both symbols will be used. In these cases the division procedure using the slash (/) symbol should be performed first followed by the major division procedure described by the line symbol. To clarify these situations consider the following formula:

$$\textbf{DIA}\text{meter (in.)} = 2\sqrt{\frac{[\textbf{DEL}\text{ivery (gal/min)} * 0.3208]/\text{Area (sq in.)}}{3.14}}$$

First, notice that the designations such as gal/min are separated from the values, **DEL**ivery, by parentheses. This also affords a natural separation between values. Also note that the first letters in each value are capitalized. After repeated use of the values the first letters will be used alone to describe these values. Finally note that values are grouped through the use of brackets, [ ]. The mathematical operation involved within these brackets should be performed first. The mathematical operations should be performed as follows:

1. Multiply the **DEL**ivery value by the constant 0.3208.
2. Divide the value achieved in step 1 by the Area value.
3. Divide the value achieved in step 2 by the constant 3.14.
4. Take the square root of the value achieved in step 3.
5. Multiply the value achieved in step 4 by the constant 2.

This illustrates what may be called the worst case scenerio. In most cases the formulas used to describe fluid circuitry are relatively simple and straightforward. A final convention used in this book involves the methods of describing fluid condition within a circuit or component. Some excellent hydraulics texts, such as the *Industrial Hydraulics Manual* published by the Vickers Division of the Libby Owens Ford Corporation, illustrate component and circuit operation through the use of assembly drawings using color codes to describe fluid condition. Borrowing from this successful technique, this book will also use assembly-type drawings. However, the condition of the fluid will be designated by using verbal symbols as presented in Figure 1–1.

Early figures in each chapter will include the color codes within the illustrations. Later in each chapter the reader will be given the assignment to color-code the illustrations. Still later, the color codes and assignments will be eliminated. However, the reader will find it to be good practice to color-code each illustration to more fully understand the operation of the component or circuit. Finally, this book will incorporate the use of conventional American National Standards Institute schematic drawings. Although other symbolic systems exist, the ANSI symbols are the current and most often-used system. ANSI symbols will be used as supplements located in the upper corners of some figures and as independent figure illustrations.

ILLUSTRATION CODING

CONDITION	COLOR	CODE
Pressurized fluid	Red	R R R R
Exhaust fluid	Blue	B B B B
Supply fluid	Green	G G G G
Volume or flow controlled fluid	Yellow	Y Y Y Y Y
Fluid under reduced pressure	Orange	O O O O
Fluid drainage or leakage	Brown	N N N N
Inactive fluid	White	
Fluid under intensified pressure	Violet	V V V V

Figure 1-1