

Design & Development of Double Acting Cylinder to Prepare Hydraulic Test Rig

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Abstract - Fluid power systems, particularly hydraulics, play a critical role in industrial applications, yet there is often a disconnect between theoretical education and practical skills. This paper presents the design, fabrication, and validation of a modular Hydraulic Trainer Kit focused on demonstrating the operation of a double-acting hydraulic cylinder (DAC) through basic control circuits. The kit integrates a hydraulic power pack, directional control valves, pressure relief valves, and quick-release couplings (QRCs) mounted on an aluminium T-slot profile plate for ease of reconfiguration. Key calculations for cylinder sizing, force, speed, and flow rates were performed at a design pressure of 50 bar, yielding an extension force of 6.28 kN. and retraction force of 4.71 kN. The system emphasizes safety, modularity, and educational value, bridging the gap between classroom theory and industry practice. Validation confirms reliable bidirectional motion control, making it suitable for engineering laboratories.

Key Words: Hydraulic Trainer Kit, Double-Acting Cylinder, Fluid Power Education, Directional Control Valve, Modular Design

1. INTRODUCTION

Hydraulic systems are essential in sectors such as manufacturing, construction, and aerospace, leveraging pressurized incompressible fluids to transmit power with advantages like high force-to-weight ratios and precise control. However, engineering students often lack hands-on experience, leading to a gap between theoretical knowledge and practical application. Training equipment like hydraulic trainer kits

addresses this by enabling students to assemble, test, and troubleshoot circuits in a safe environment.

This research focuses on developing a modular trainer kit centered on a basic DAC control circuit, which serves as the foundation for advanced hydraulic systems. The kit demonstrates bidirectional linear motion, force variations, and speed differences between extension and retraction strokes. Drawing from foundational principles like Pascal's Law, the design ensures simplicity, safety, and educational relevance. Objectives include component specification, fabrication, circuit validation, safety integration, documentation, and cost analysis. Similar educational tools have been developed to enhance fluid power curricula, such as benches for pump and actuator testing and virtual labs for hands-on simulation. This work builds on these by emphasizing modularity with QRCs and low-pressure operation for student safety.

2. Literature Review

A comprehensive review of fluid power literature informed the kit's design. Esposito's *Fluid Power with Applications* [1] provides core principles like Pascal's Law and actuator characteristics. Majumdar's *Oil Hydraulic Systems* [2] emphasizes practical aspects such as fluid selection and maintenance. Merritt's *Hydraulic Control Systems* [3] analyses valve dynamics, justifying the use of a 4/3 closed-center directional control valve (DCV) for stability.

Sullivan [4] and Bolton [5] highlight industrial circuits and educational experimentation, supporting the choice of a basic DAC circuit for simplicity. Dudley [6] and Parr [10] offer technician guides on installation and troubleshooting. Standards

like ISO 1219-1 [7] and ANSI/B93.3M [8] ensure uniform schematic representation. Manufacturer guidelines from Eaton [9] aided component selection.

The survey underscores the pedagogical value of modular trainers, aligning with needs for hands-on learning in fluid power education

3. Design Calculations

3.1 Area Calculations

a. Piston Area (Extended, A_E)

$$A_E = \frac{\pi D^2}{4}$$

$$A_E = \frac{\pi(40)^2}{4}$$

$$A_E = 1256.64 \text{ mm}^2$$

b. Annulus Area (Retract, A_R)

$$A_R = \frac{\pi(D^2 - d^2)}{4}$$

$$A_R = \frac{\pi(40^2 - 20^2)}{4}$$

$$A_R = 942.48 \text{ mm}^2$$

3.2 Area Ratio

The ratio of the effective areas dictates the force and speed relationship:

$$\alpha = A_R/A_E = 942.48 / 1256.64 \approx 1.33$$

(This ratio indicates that the extension force is 1.33 times greater than the retraction force, and the retraction speed is 1.33 times faster than the extension speed.)

3.3 Force Analysis

The cylinder's maximum force capability is determined by the design pressure of $P = 50\text{bar}$ (5N/mm^2).

a. Extension (Push) Force (F_E)

$$F_E = P \times A_E$$

$$F_E = 5 \frac{\text{N}}{\text{mm}^2} \times 1256.64 \text{ mm}^2$$

$$F_E = 6283.2 \text{ N}$$

$$F_E = 6.28 \text{ KN}$$

b. Retraction (Pull) Force (F_R)

$$F_R = P \times A_R$$

$$F_R = 5 \frac{\text{N}}{\text{mm}^2} \times 942.48 \text{ mm}^2$$

$$F_R = 4712.4 \text{ N}$$

$$F_R = 4.71 \text{ KN}$$

3.4 Cylinder Speed and Time Calculations

The flow rate Q_{max} (equivalent to $5.97 \times 10^{-5} \text{ m}^3/\text{s}$) determines the time required to complete the 150mm stroke.

a. Extension Speed (V_E)

$$V_E = \frac{Q}{A_E}$$

$$V_E = \frac{5.97 \times 10^{-5} \text{ m}^3/\text{s}}{1.257 \times 10^{-3} \text{ m}^2}$$

$$V_E = 0.0475 \text{ m/s} = 47.5 \text{ mm/s}$$

b. Extension Time (t_E)

$$t_E = \frac{0.150 \text{ m}}{0.0475 \text{ m/s}}$$

$$t_E = 3.16 \text{ s}$$

c. Retraction Speed (V_R)

$$V_R = \frac{Q}{A_R}$$

$$V_R = \frac{5.97 \times 10^{-5} \text{ m}^3/\text{s}}{9.42 \times 10^{-4} \text{ m}^2}$$

$$V_R = 0.0634 \text{ m/s}$$

$$V_R = 63.4 \text{ mm/s}$$

d. Retraction Time (t_R)

$$t_R = \frac{L}{V_R}$$

$$t_R = \frac{0.150 \text{ m}}{0.0634 \text{ m/s}}$$

$$t_R = 2.37 \text{ s}$$

4. Assembly and Implementation

The frame uses mild steel trolley and aluminium plate. Power pack at base, components mounted via T-slots. Hoses connect via QRCs for modularity. System bled and leak-checked at 40 bar.

Circuit schematics follow ISO 1219, showing flow paths in extend, retract, and neutral positions.

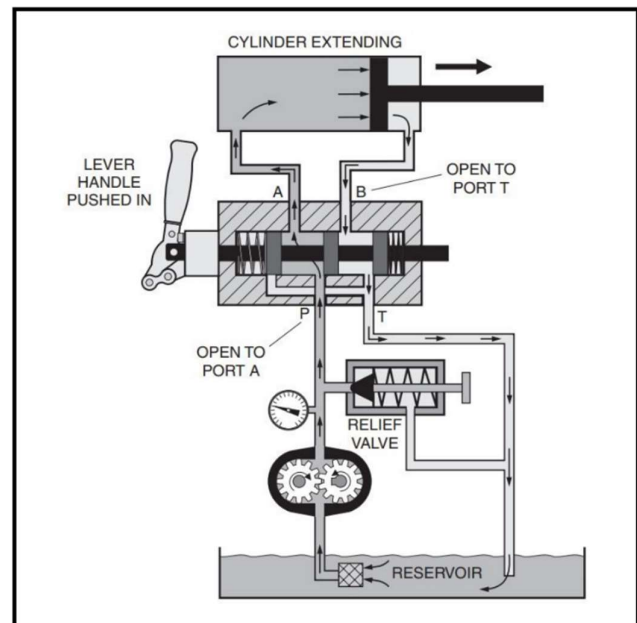


Fig -1: Diagram of a 3-position, 4-way DCV with the cylinder rod extension

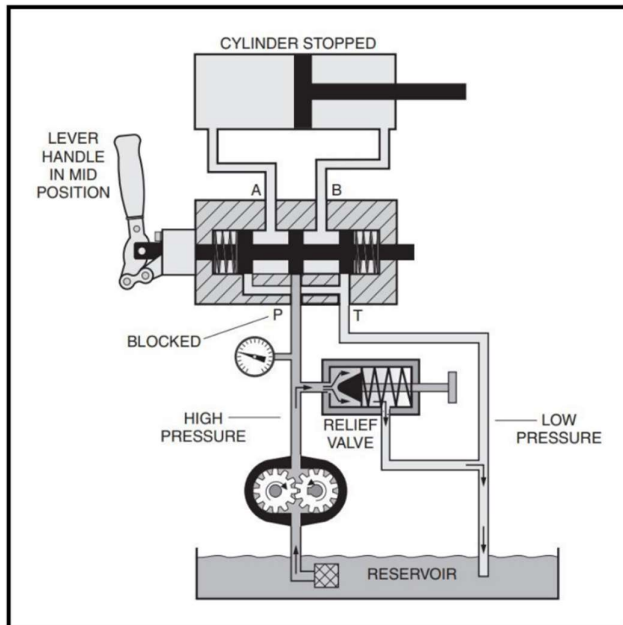


Fig -2: Diagram of a 3-position, 4-way DCV in a neutral state

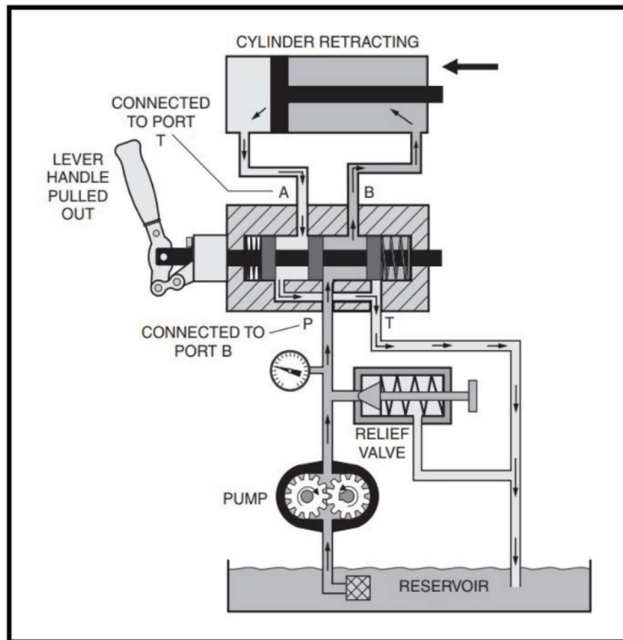


Fig -3: Diagram of a 3-position, 4-way DCV with the cylinder rod retraction

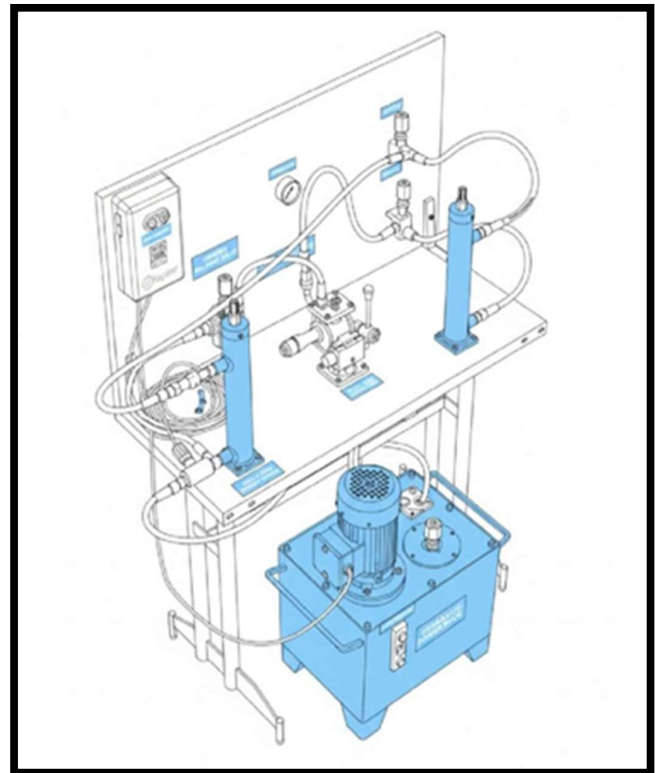


Fig -4: Assembly Drawing

5. Results and Discussion

The kit successfully demonstrates DAC control: In extension, fluid to piston side yields slow, high-force motion; retraction faster with lower force due to area difference. Neutral locks the cylinder via closed-center DCV, with PRV diverting flow.

Performance aligns with calculations: Observed forces and speeds match theoretical values, validating design. Modularity allows quick reconfiguration, enhancing educational utility. Advantages include hands-on visualization and safety; limitations: manual control, single actuator, sensitivity to fluid viscosity.

Compared to existing trainers, this kit's low-pressure operation and QRCs improve accessibility for undergraduates.

6. CONCLUSIONS

The developed Hydraulic Trainer Kit meets objectives by providing a safe, modular platform for teaching hydraulic principles. It bridges theory-practice gaps, with validated circuits demonstrating key behaviours. Future enhancements: Integrate electro-hydraulics, PLC control, additional circuits (e.g., regeneration), and data acquisition sensors.

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