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PREFACE

The National Conference on Fluid Power has been held each year since its founding in 1945 by the Illinois Institute of Technology in cooperation with leaders in the field of industrial hydraulics. Currently overseen by a Board of Governors, comprised of leaders from industry, education, and fluid power organizations, it is administered by IIT and organized by an Annual Conference Committee, whose membership consists of individuals active in all phases of fluid power.

These Proceedings contain most of the papers presented at the 37th Annual Conference, October 21, 22, 23, 1981, at McCormick Place, in Chicago, Illinois. They represent the state-of-the-art in hydraulic and pneumatic fluid power, with particular emphasis toward satisfying the theme of the Conference, which is "Productivity - The Challenge of the 80s."

Particular appreciation is expressed to the session chairmen, the Board of Governors, the Illinois Institute of Technology, the Industrial Sponsors, and most importantly, the authors for their respective contributions toward the furtherance of fluid power technology through the 1981 National Conference on Fluid Power.

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A special note of thanks to the chairmen and co-chairmen of each session for their assistance in the editorial work of the Proceedings

C O N T E N T S

INDUSTRIAL ROBOTS

Hydraulics and Programmable Controllers in Materials Handling Robots
Ron Shields.......................... 1

MOBILE HYDRAULICS

Add-On Electrohydraulic Control for a Variable Pump/Variable Motor Hydrostatic Transmission
R. V. Burton......................... 7

An Electrohydraulic Remote Proportional Control Pump and a Productive Application
Kenneth F. Frank..................... 15

Hydraulic and Pneumatic Systems on the G3R Hydraulic Excavator
Gerard M. Palmersheim................ 25

The Development of Hydraulic Rock Drills
R.E. Murray and R.K. Tessman......... 27

FLUID POWER EDUCATION

Fluid Power Technology - Granite Falls Area Technical Institute
Duane Olson.......................... 31

Fluid Power Education at C.S. Mott Community College
J. W. Ortiz.......................... 43

Fluid Power Education at Iowa State University
Arthur Akers......................... 45

A Report on the Fluid Power Program at Gateway Technical Institute
Stuart Vorpagel...................... 49

Fluid Power Education at the Waukesha County Technical Institute
Dick Minch........................... 53

NOISE AND VIBRATION

Acoustic Signatures - A Feasible Diagnostic Technique for Hydraulic Systems
Don E. Stremme........................ 55

Computer Aided Designing of Quiet Hydraulic Pumps
Roy Taylor........................... 61

Effects of Pipes and Hoses on Hydraulic Circuit Noise and Performance
H. R. Martin......................... 71

An Introduction to Noise Control on Existing Equipment
Robert H. Grefe...................... 77

TECHNOLOGY TRANSFER

Finite Element Method Part I - Evolution and Overview
Kolar L. Seshasai.................... 81

Finite Element Method Part II - Example Problems
Kolar L. Seshasai.................... 91

Finite Element Computational Analysis for Fluid Power Applications
A. J. Baker.......................... 99

The Development of a Seawater Hydraulic Vane Motor
Stanley A. Black and
William D. Kuehler, Jr............... 111

AGRICULTURAL HYDRAULICS I and II

A Microprocessor-Based Steering Controller for Over-the-Row Harvesters
B.L. Upchurch, B.R. Tennes and
T.C. Surbrook........................ 119

Variable Torque Hydraulic Wheel Assist
Richard A. Beck...................... 131

AGRICULTURAL HYDRAULICS (continued)

Design and Development of a Low Speed High Torque Hydraulic Motor
R. J. Recker........................ 137

Reliability Growth Methodology in Hydraulic Component Testing.
Richard A. Hoveland.................. 141

Hillside Axial-Flow Combine Hydraulic Systems
N.G. Stroup and E. J. Krukow......... 145

Agricultural Tractor Hydraulic Power Use
Ron Burke............................ 155

Hydraulic Systems on Four Wheel Drive Agricultural Tractors
Darrell Svendsen..................... 159

PNEUMATICS SYSTEMS I and II

Why It Pays to Use Air Wisely
Henry Fleischer...................... 161

Small-Compressor Air Supplies
Robert Moffatt....................... 169

Programmable Air Controller
Robert Ryan.......................... 177

The Economics of Air Drying
Charles A. Henderson................. 179

VALVES AND CONTROLS

A Simple Design Modification for Improved Accuracy of Piston Type Flow Diver Valves
Roger Chan, Greg Schoenau, and Richard Burton...................... 189

Considerations for Applying Servovalves to Robots
Robert T. Banfield................... 193

VALVES AND CONTROLS (continued)

A Low Power Electro-Pneumatic Servovalve
C.K. Taft, B.M. Herrick and T.S. Burke........................ 197

A Load Sensing Hydraulic Valve for Mobile Vehicles
Robert Breeden........................ 203

ELECTROHYDRAULIC SERVOSYSTEMS

Using Servohydraulics to Control Hi-Rise Building Motion - The Citicorp TMD System
Niel R. Petersen...................... 209

Hydraulic Servomechanisms in Flight Simulation
G. M. McKinnon........................ 215

Designing Hydraulic Actuators for Low Friction and Long Life
Larry Hall............................ 227

TESTING

A Comparative Study of Accelerated Life Test Methods on Hydraulic Fluid Power Gear Pumps
Thomas S. Wanke....................... 231

The Testing of Hydraulic Pumps and Motors
Graham J. Toogood..................... 245

Remote Coupler Testing
G. B. Randall......................... 253

MICROPROCESSORS IN FLUID POWER

On-Board Data Acquisition Systems on Farm Combine
J.K. Schueller, M.P. Mailander, G.W. Krutz, and L.F.Huggins........... 255

MICROPROCESSORS IN FLUID POWER (continued)

Utilizing a Microprocessor to Achieve Indirect Feedback Control in Hostile Environments
R.K. Chan, R.T. Burton, G.J. Schoenau, and P.R. Ukrainetz..... 259

Remote I/O PLC Programmable Controllers
Jack Andres.............................. 267

MARINE HYDRAULIC SYSTEMS

Marine Environments Condition Hydraulic System Designs
Russ Henke............................. 271

Hydraulic Controls for SCARAB (An Unmanned Submersible)
J.W. Broome and P.A.Yeisley........... 273

HYDRAULIC FLUIDS

Synthetic Based Aerospace Hydraulic Fluids
Carl E. Snyder, Jr.................... 275

Development of Antiwear Hydraulic Oils
John N. Horstman, John F. Hedenburg, and J. T. Mann............. 281

Fire Resistant Hydraulic Fluids - State-of-the-Art Review
Julian Louie, Richard T. Burton, and Paul R. Ukrainetz................. 285

PUMPS, MOTORS AND HYDROSTATIC TRANSMISSIONS

Reducing Hydrostatic Transmission Costs by Using Multi-Flo Pumps
G.E. Maroney.......................... 291

Sound Reduction of Hydraulic Pumps
William F. Marshall................... 299

PUMPS, MOTORS AND HYDROSTATIC TRANSMISSIONS (continued)

Hydraulic Power Assist: A Way to Boost Performances of Standard Transmission
Claude Pinson 301

Control Variations for Hydrostatic Applications
Thomas Canfield and James Ross 303

Energy Conscionable Transmission Selection for Mobile Equipment
Walter E. Hull and Gary D. McConeghey 305

Direct Hydrostatic Variable Speed Drives
Michael Clifford 307

CONTAMINATION CONTROL

A Practical Guide to Hydraulic Filter Application
Harold L. Robinson 309

Measurement of Hydraulic Filter Performance During Cyclic Flow
James N. Gehrking 311

PRODUCT LIABILITY FORUM

On Classification of Safeguard Devices
Ralph L. Barnett and Peter Barroso, Jr. 313

HYDRAULICS AND PROGRAMMABLE CONTROLLERS IN MATERIALS HANDLING ROBOTS

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Summary

The utilization of hydraulics in conjunction with a programmable controller provides optimum flexibility in various linear and rotating functions that a materials handling robot must perform. The scope of this paper is to cite practical examples and some basic calculations pertaining to hydraulic components, programmable controllers and how they are effectively interfaced with a materials handling robot. Special emphasis is placed on the importance of a reliable and diversified control circuit package to provide a wide range of programming capability.

Introduction

The science of hydraulics dates back several thousand years when water wheels and dams were used to control the flow of water for irrigation and domestic use. The term "power hydraulics" refers to fluid used under controlled pressure to accomplish useful work. A fluid is infinitely flexible. It can transmit a force in any or all directions; it has a yield strength similar to steel and can readily change its shape. Fluid must be supplied and controlled in a materials handling robot application. Pumps & valves such as directional control, flow control, and check are commonly used to accomplish this goal. The fluid is then conveyed from the pump to the appropriate valve or valves to components such as cylinders and motors to produce useful work.

In order for these items to function at the proper time, a control circuit must be implemented. The materials handling robot discussed in this paper uses a programmable controller (P.C.) to synchronize each individual function.

Materials Handling Robot

The robot that will be discussed in this paper is shown in Figure 1. It is basically a four (4) axis robot. Each function that this robot performs is powered by hydraulics. Let us begin by identifying each one of these functions.

I. Part Carriage
II. Main Carriage
III. Vertical Lift
IV. Traverse
V. Rotation

The following is a description of the task each function must perform and how it is accomplished.

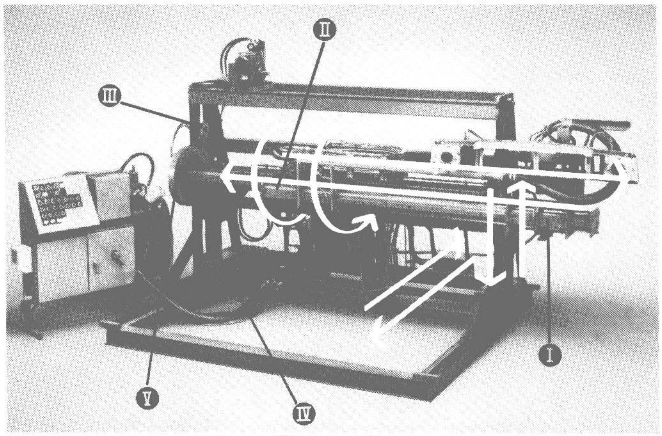

Figure 1

Shown above is the new programmable materials handling robot manufactured by Lynch Machinery for heavy duty applications. It has a reach/load capacity of 300 lbs. at 11 feet from center. Axes of movement are indicated by arrows.

I. PART CARRIAGE

The part carriage's primary purpose is to provide means to adapt a wide variety of tooling. The tooling used will depend upon product size, shape and weight.

The part carriage can be programmed to extend in the plus (+) or minus (-) direction (see Figure 2).

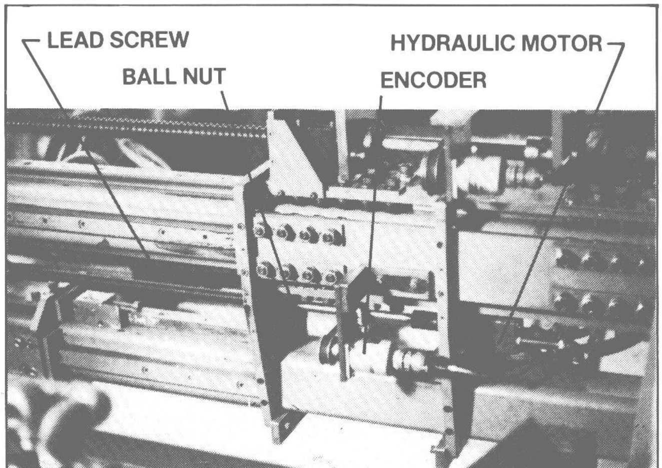

Figure 2 Part Carriage Drive Assembly

The stroke of the carriage will vary and depends upon "home" position of the robot and location of products orientation position (pick-up position).

The part carriage is powered by a hydraulic motor. The motor is coupled to a lead screw and ball nut mechanism. The ball nut is fixed to the part carriage.

Since the motor and lead screw are directly connected, then one (1) revolution of the motor will result in one (1) revolution of the lead screw. Let us assume that the lead screw has a one (1) inch pitch, then one revolution of the motor and lead screw would equal one (1) inch of linear movement of the part carriage.

In order to select a hydraulic motor to drive the part carriage, we must know the hydraulic system pressure, driving torque and velocity.

<u>Example problem (assumed parameters)</u>

P (Total weight or load)	=	400 Lbs.
Part carriage velocity	=	12 in/sec
Hydraulic system pressure	=	1000 P.S.I.
Ball screw lead	=	1 in/turn

<u>SOLUTION:</u>

<u>Driving Torque</u> = the amount of effort required, measured in pound-inches to turn the ball screw and move the given load.

T = Direct torque (LB-IN)
P = Load (LBS.)
L = Screw lead (Inches/turn)
E = Ball screw efficiency (90%)

then

$$T = \frac{P \times L}{2\pi e} = .177 \; P \times L$$

$$T = .177 \times 400 \times 1$$

$$T = 70.8 \text{ LB-IN}$$

<u>Velocity</u> - 12 IN/SEC

In terms of revolutions/min. of lead screw and hydraulic motor.

$$\text{RPM (Rev./Min.)} = \text{Velocity (IN/SEC)} \times \frac{1}{\text{L (IN/TURN)}} \times 60$$

$$\text{RPM} = 12 \times \frac{1}{1} \times 60$$

$$\text{RPM} = 720$$

<u>HYDRAULIC MOTOR SELECTION</u>

D = Displacement of hyd. motor (CU-IN/Rev)
T = Driving torque (LB-IN)
PSI = System pressure (LB/IN^2)

$$D = \frac{T \times 2\pi}{PSI}$$

$$D = \frac{70.8 \times 2\pi}{1000}$$

$$D = .445 \; IN^3/REV$$

Most hydraulic motors are based upon cubic inches per revolution in reference to flow rate. With these basic calculations, we can select the proper motor to suite this application using various vendors' selection curves.

<u>II. MAIN CARRIAGE</u>

The main carriage supports the part carriage mechanism and adds additional extension capabilities due to the telescoping feature. The main carriage can also be programmed to extend in the plus (+) or minus (-) direction (see Figure 3)

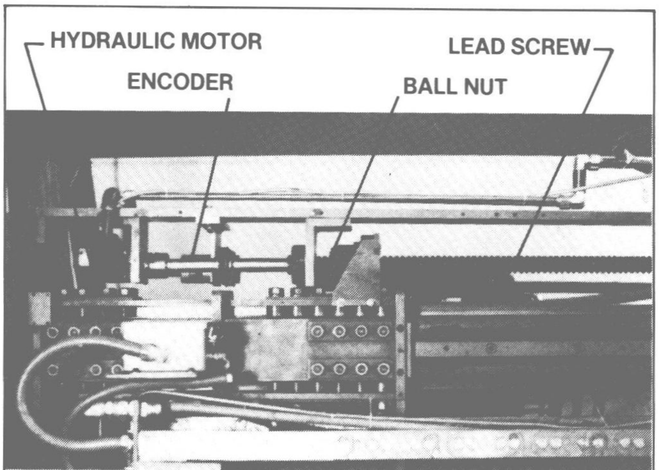

Figure 3 Main Carriage Drive Assembly

The stroke will vary in the same manner as the part carriage and is based upon the same basic criterion. In order to select a hydraulic motor to drive the main carriage, we must know the hydraulic system pressure, driving torque, and velocity, just as we have done on the part carriage.

<u>III. VERTICAL LIFT</u>

The vertical lift supports the part carriage and main carriage mechanism. The stroke of the vertical lift will vary and depends upon "home" position of the robot and elevation orientation of product (pick-up position). The vertical lift is powered by a hydraulic motor. The motor is directly coupled to a gear reducer. The gear reducer is connected to the vertical lift drive shaft through a drive chain and sprocket combination. (See Figure 4).

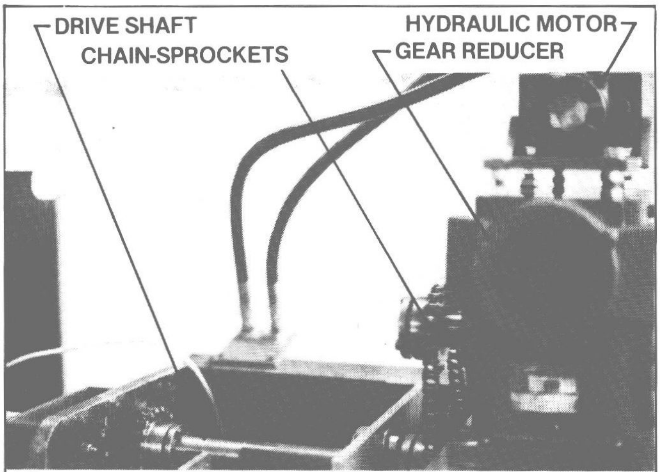

Figure 4 Vertical Lift Drive Assembly

The vertical lift mechanism can be moved up or down, depending upon application.

In order to select a hydraulic motor to drive the vertical lift mechanism, we must know the hydraulic system pressure, driving torque and velocity - just as we have done on the part and main carriages.

Example problem (assumed parameters)

P (Total weight or load)	= 1500 Lbs.
Vertical lift velocity	= 12 in/sec
Hydraulic system pressure	= 1000 PSI
Pitch dia. of sprockets	= 3.831 in.
No. of sprocket teeth	= 24
Sprocket pitch	= .5 in.
Gear reduction (Gear Box)	= 20:1

SOLUTION:

Driving Torque = the amount of effort required, measured in pound-inches to move the load.

$$T = P \times R \times \frac{r}{R} \times \frac{1}{Ratio} \times \frac{1}{e}$$

where

T = Direct Torque (LB-IN)
P = Load (LBS)
R = Radius of Driven Sprocket (IN)
r = Radius of Drive Sprocket (IN)
Ratio = Gear box reduction
e = Efficiency (85%)

then

$$T = 1500 \times 1.916 \times \frac{1.916}{1.916} \times \frac{1}{20} \times \frac{1}{.85}$$

T = 169 LB-IN

Velocity = 12 IN/SEC

In terms of revolutions/min. of hydraulic motor.

$$RPM = V \times \frac{1}{\pi D} \times \frac{R}{r} \times Ratio \times 60$$

where

RPM = REV./MIN.
V = Vertical lift velocity (IN/SEC)
D = Pitch dia. of driven sprocket (IN)
R = Radius of driven sprocket (IN)
r = Radius of drive sprocket (IN)
Ratio = Gear box reduction

then

$$RPM = 12 \times \frac{1}{\pi\, 3.831} \times \frac{1.916}{1.916} \times 20 \times 60$$

RPM = 1196.5

HYDRAULIC MOTOR SELECTION

$$D = \frac{T \times 2\pi}{PSI}$$

where

D = Displacement of Hyd. Motor (CU-IN/REV)
T = Driving torque (LB-IN)
PSI = System pressure (LB/IN^2)

then

$$D = \frac{169 \times 2\pi}{1000}$$

$D = 1.06\ IN^3/REV.$

Use vendors' selection curves to select proper hydraulic motor.

IV. TRAVERSE

The traverse supports the part carriage, main carriage, vertical lift and rotation mechanism. It can be programmed to travel either forward or backward. The stroke will vary and depends upon "home" position of the robot and location of products orientation position (pick-up position). The traverse is powered by a hydraulic motor. The motor is connected to the traverse drive shaft through a drive chain and sprocket combination (See Figure 5).

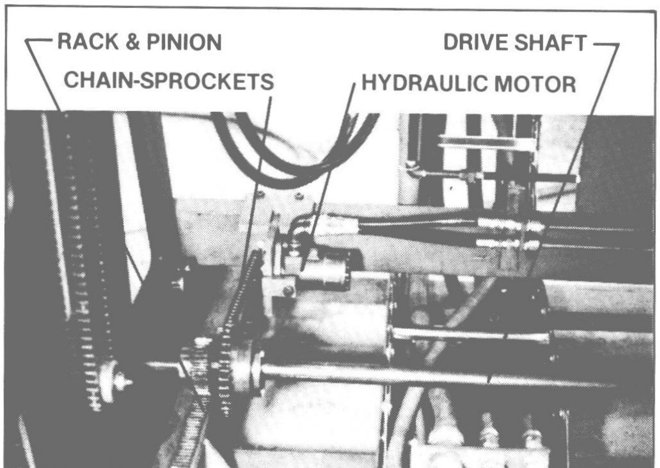

Figure 5 Traverse Drive Assembly