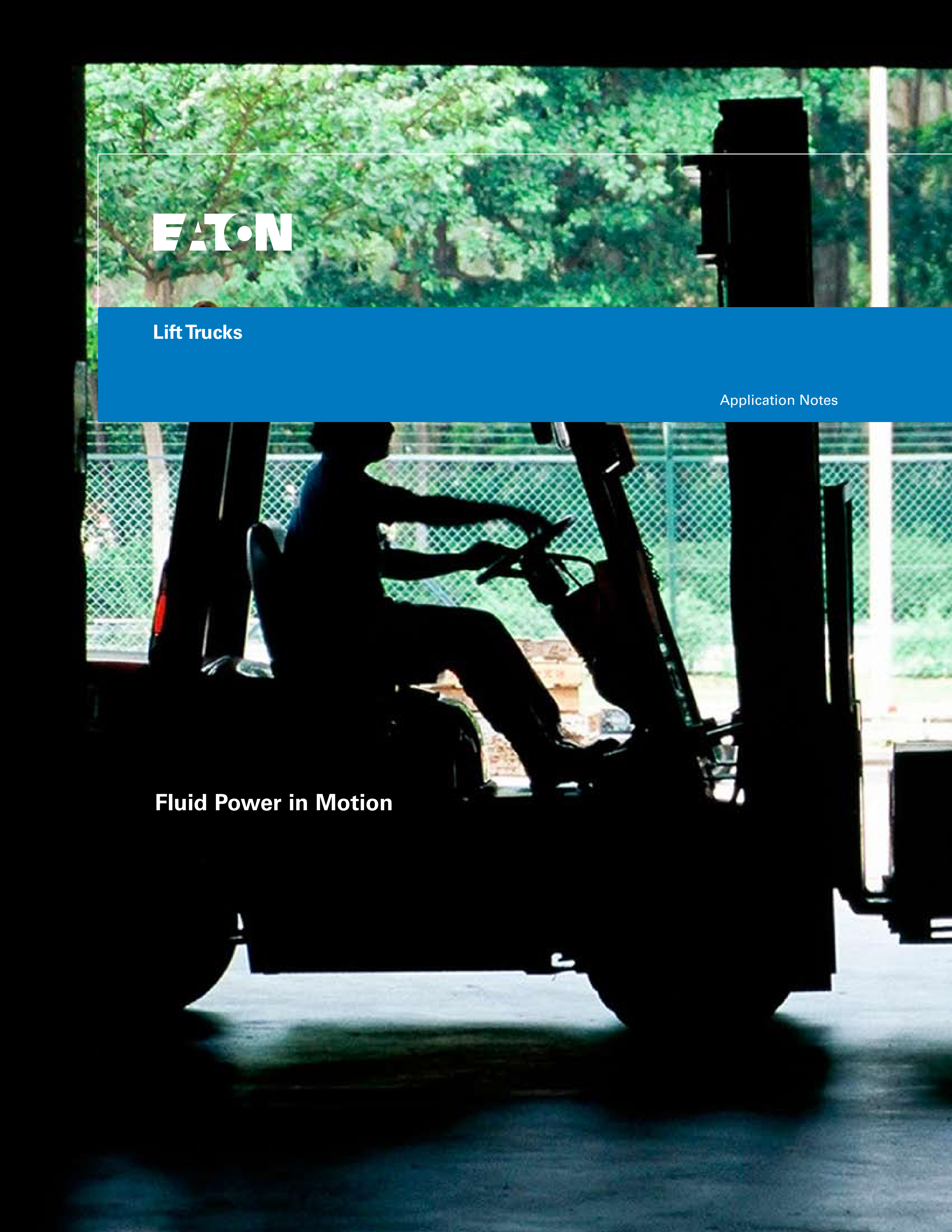


Lift Trucks

Application Notes

Fluid Power in Motion

Solutions for Lift Trucks.

Eaton has the products and capabilities to provide complete system solutions for your application needs. World class hydraulic components, electronic controllers and software are just part of the value Eaton brings to make your applications deliver the power, in fluid power. Tough applications require the experience and knowledge that Eaton can provide and this application information will help you get started. Contact your Eaton representative for further information or visit us on-line at www.hydraulics.eaton.com.

Forklift Truck Applications

The standard forklift, also commonly known as a counterbalanced sit-down lift truck, is the vehicle most people think of when they think Lift truck or Forklift truck. They are available in smaller sizes with battery operation but the majority are run from several different fuel types especially as the vehicle gets larger and the lift capacity increases. There is quite a range of weight capacities, lift heights, and attachment options available in the market, many with their own special needs from the hydraulic system in order to provide smooth reliable operation when handling various types and sizes of loads. The system requirements will be different for a smaller lift truck with a low lift height versus a machine pushing 40 tons lift capacity or one with a significant lift height capability.

The lift capacity of a truck is affected not only by the load, but also by the lift height and the physical size of the load. A larger size load moves the center of gravity of the load further from the wheels effectively reducing the lift capacity as does the height the load is being lifted. The lift truck mass and center of gravity determines the maximum lift capacity and how far from the mast a given load center can be located and still provide a stable platform. Caution must be used in selecting the lift truck system components and attachments since the load and the load center must be determined under all operating conditions to ensure that the truck is stable. This same caution applies to any hydraulic controls used to operate the mast or tilt on a typical forklift truck. With low lift heights centered close to the mast a simple on-off control valve can be used. This simple inexpensive approach is often seen on small electric powered trucks. As the load capacity increases, or the load center is further from the truck mast, or the lift height is increased, the precision of the hydraulics must be improved. Any sudden movement caused by an on-off valve with a heavy load high in the air can be very uncomfortable to the operator and also potentially cause the truck to tip because of a high inertia load extended so far out in the air. Smooth, controllable operation is absolutely necessary as heavier loads and higher lift heights are utilized. The same can be said for the propel circuit. If a heavy load must be inched into location at some significant height the operator must have the capability to smoothly inch the machine without jerking the load.

Many types of hydraulic propel circuits have been used over the years. They can range from a simple gear pump and Low Speed High Torque (LSHT) motor circuit with a valve controlling the direction and speed of travel, to complete closed loop hydrostatic transmissions with variable displacement piston pumps and fixed or variable displacement motors. Using high-speed piston motors for propel will require the use of a gearbox to provide the necessary gear reduction and output shaft bearings to support the weight of the machine. This design provides very smooth operation and high efficiencies, but comes at a cost penalty. Where the displacement and loading conditions permit, the use of Geroler® type low speed high torque motors can provide a compact, cost effective drive motor and, in many cases, without the need for a gearbox.

Hydraulic steering systems can range from open center systems to closed center load sensing systems, and today steer by wire is also being

actively investigated. With the availability of two speed steering units and options like Eaton's Q-amp®, almost any desired steering characteristic can be provided today. At low steering speeds the steering is slow to provide precise position control, but when making sharp turns rapidly the speed of the steering is sped up to provide rapid response and limit the number of turns that the operator has to apply to the steering wheel.

There are a lot of options and features available within the steering offerings today and careful consideration should be given to the compromises in order to provide the best operator comfort and productivity. Most of the steering systems applied today do not synchronize the steering wheel to the actual steering angle on the wheels, but systems are available that can give the same feedback and feel as your car. If it is desired to have the steering wheel return to the same position as in your car, then the Eaton "EPACS" steering control system should be investigated. There are certain markets in the world where this type of system has become the standard.

Control valves for lift trucks can be a simple open center valve, closed center, or closed center with flow and load sensing. Operation can be by a manual lever, remote hydraulic operation, or electro-hydraulic with either simple on-off operation or complete proportional control, or any combination of these. One important factor is to consider the load holding requirements, especially with so many different attachments utilized with lift trucks. Typically on the smaller trucks, only a spool valve might be used for holding the load from drifting down. A counter-balance valve or tilt-lock load holding valve is typically used for the tilt function. This prevents the tilt function from being inadvertently operated if the engine is off and the load was left up, thereby preventing a load from sliding off the forks. Certain markets may demand a flow control valve to limit the maximum lowering speed or a counterbalance valve to precisely control the lowering velocity.

Today, with the advent of numerous reliable electro-hydraulic components and controls options available, there is a noticeable shift to using more electro-hydraulics in forklift truck systems. Electronic controls provide numerous benefits in improving the operation of the machine. A lot of functions can be easily automated or semi-automated. If the vehicle is inching to place a load at the same time an operator is asking for maximum lift speed, the electronics can make the decision to up the engine speed, maintain a low pump displacement for the propel, and provide maximum lift speed without the operator needing to handle multiple controls simultaneously. Power management and automotive drive control is readily available with our electronic control systems. This significantly increases operator comfort and productivity. Electronics also makes the addition of load monitoring and restricting the operating envelope of the machine possible reducing the opportunity for the operator to pick up or position a heavy load beyond the machines design capabilities. It is also possible to completely automate the machine function for densely packed warehousing applications.

Hydraulic Functions

Functions typically driven and operated by the hydraulic system:

- Steering
- Ground drive / propel
- Mast lift
- Mast tilt
- Mast lift and tilt load holding
- Auxiliary attachment controls
- Cooling fan drive on larger systems
- System design considerations
- Review all applicable standards
- Define operating envelope
- Evaluate performance / cost compromises
- Select and properly size all components
- Evaluate ergonomics

Product families typically used for hydraulic systems

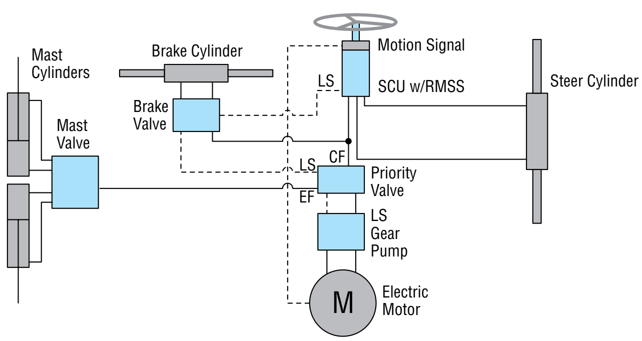
- Open loop steering control unit
- Closed loop steering control unit
- Medium or heavy duty closed loop piston pump
- Medium or heavy duty closed loop piston motor
- Open loop piston pump
- Open loop gear pump
- Open loop disc valve motor
- Open loop VIS motor
- Open loop spool valve motor
- Open center directional control valve
- Flow and load sensing directional control valve
- Cartridge valves
- Cartridge valve manifold assembly
- Filtration
- Oil cooler
- Fluid conveyance

Basic formulae for sizing*

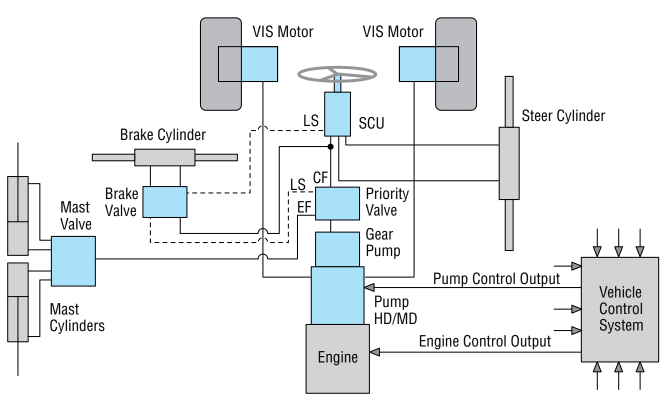
Pump Output Flow	(GPM)	= RPM x Displ (cid) / 231
	(LPM)	= RPM x Displ (cc) / 1000
Pump Input Power	(HP)	= GPM x PSI / (OAL Eff x 1714)
	(KW)	= LPM x BAR/(OAL Eff x 600)
Hydraulic Motor Speed	(RPM)	= GPM x 231 x Vol Eff /Disp (cid)
	(RPM)	= LPM x 1000 x Vol Eff /Disp (cc)
Hydraulic Motor Torque	(in-lb)	= PSI x Displ (cid) x Mech Eff / (2π)
	(N-m)	= BAR x Displ (cc) x Mech Eff / (20π)
Cylinder Force	(lbs)	= Area (in^2) x PSI
	(N)	= Area (mm^2) x BAR x 10
Cylinder Speed	(in/min)	= GPM x 231 / Area (in^2)
	(mm/min)	= LPM x 1000 /Area (mm^2)
Steering unit disp	(cid/rev)	= Cyl Vol (cubic inches) / Number of Revs
	(cc/rev)	= Cyl Vol (cc) / Number of Revs
Vehicle Ground Speed	(MPH)	= RPM x 60 x Tire Radius (ft) x PI / 5280
	(KPH)	= RPM x 60 x Tire Radius (m) x PI / 1000

Typical Circuits

Electric Trucks - Four Wheel



IC Trucks - Hydrostatic Propel



***The following calculations may also need to be considered with regards to sizing:**

- Basic formulae are general in nature and do not take into account efficiency losses for individual components.
- Cylinder pressures and speeds for mast lift, tilt, and aux., functions
- Torque and displacement calculations for propel loop
- Gradeability and travel speed calculations
- Over speed calculation
- System Hp calculations under all operating conditions
- Power range calculation
- Mechanical and volumetric efficiencies
- Product life
- Cooling capacity
- System pressure drop calculations
- Line flow velocity calculations

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