Hydraulic Elevators – Configuring the Power Unit

by Parag Mehta

Learning Objectives
After reading this article, you should have learned about:
- Understanding the power unit of a hydraulic elevator
- Selecting the right components for the power unit
- Important guidelines concerning lift-industry safety regulations
- Power unit configuration techniques
- The types of cylinders used in hydraulic elevators

Summary

Hydraulic elevator manufacturers and, especially, companies specializing in building power units are often confronted with difficult choices of component selection. While important aspects like availability of components, price factor, durability and reliability of components occupy selectors most of the time, functional and operational aspects play an equally important role. This article attempts to provide guidelines in component selection and highlights some of the basic and optional characteristics that products used in power units and hydraulic elevators should have in order to deliver optimally. This article also tends to educate those who do not build hydraulic power units or elevators themselves, but source ready solutions, as to what they should be looking at from their suppliers and OEMs.

Introduction

A hydraulic elevator is powered by a power unit mostly found in the machine room or basement of the building or, sometimes, in the elevator shaft itself. Whichever form the unit may have and how different it may look, it would principally have a tank (oil reservoir), flow control valve, shutoff valve, pump, motor and safety valves in its most basic form (Figure 1).

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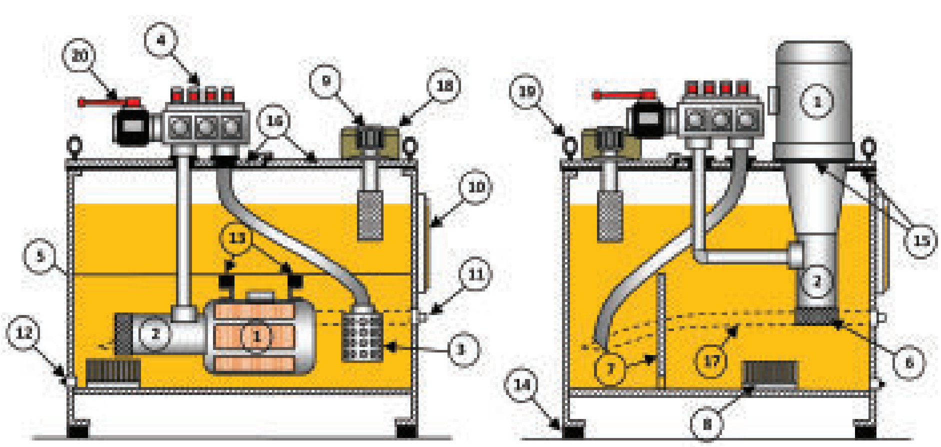

1 Motor	6 Strainer	11 Cooler plug	16 Top lid plates
2 Pump	7 Baffle plate	12 Drain plug	17 Cooler return line
3 Silencer	8 Heater	13 Rubber dampers	18 Electric box
4 Valve	9 Breather cap	14 Rubber feet	19 Lifting hook
5 Diffuser	10 Level indicator	15 Gaskets	20 Ball valve

Figure 1: Power unit of a hydraulic elevator

Value: 1 contact hour (0.1 CEU)

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Depending upon the supplier, cylinders may or may not be part of the power unit. In this article, components used in the power unit will be analyzed individually on the basis of selection criteria, functions and requirements per EN 81-2 codes. After reading this, it should also be clear as to why similar products sometimes available from the industrial hydraulic segment should not be used.

The Pump, the Heart of the Power Unit

Like a human heart that pumps blood through our bodies, a hydraulic pump pumps oil through the hydraulic circuit. As we depend on our heart, so relies the hydraulic elevator on its pump. A hydraulic pump converts mechanical energy into hydraulic energy. When a hydraulic pump is operated, its action creates a partial vacuum at the inlet, while enabling the fluid (oil) to enter the pump. The pump traps this fluid within its cavities, and transports it through and forces it into the hydraulic system, thereby moving the oil and generating flow. Pumps do not generate pressure; pressure is generated by the resistance to the flow in the hydraulic circuit.

A submersible screw pump is the most widely used and best choice for an elevator power unit, since the axial and radial forces on the rotors are hydraulically balanced and there is no metal-to-metal contact between the rotor and the idlers. Screw pumps (Figure 2) are known to produce low mechanical vibration, pulsation-free flow and quiet operation even at high speeds. Gear pumps are mostly used for machine and goods-elevating power units with flow rates less than 30 liters per minute (lpm) and where pump noise is not of prime interest. As flow rate gets higher, gear pumps become costly and noisier, and forfeit their place to screw pumps for passenger and residential elevator applications. A direct comparison between gear and screw pumps is given in Table 1.

It should be noted that the pump output varies with pressure. It's important to check the pump output at peak pressure (maximum loading of the elevator car), as, for example, a screw pump said to offer 75 lpm would give 80 lpm at 10 bar and 68 lpm at 80 bar. The overall efficiency of the pump can be calculated using the following equation:

$$\text{Overall efficiency } (\eta_p) = \frac{P \, . \, Q}{600 \, . \, W} \qquad \text{(Equation 1)}$$

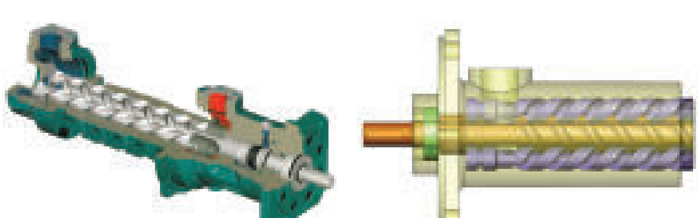


Figure 2: Screw pump

where P = pressure (bar), Q = flow (lpm) and W = input power (kW)

The Valve, the Brain of the Power Unit

Our brain commands our body and instructs our body parts to act. Similarly, a flow control valve in a hydraulic elevator power unit plays an important role in regulating the flow of oil to and from the cylinder moving the cabin up and down. As hydraulic elevator power units use continuous-duty pumps that deliver a fixed output per minute, a control valve to control the flow of oil is necessary; this allows a slow start, gentle acceleration into full speed, traveling in full speed, decelerating into leveling speed and smoothly stopping the elevator at the floor level. In the absence of a control valve, the elevator cabin would shoot like a rocket upon starting the pump motor and stop with a sudden jerk that could feel like an earthquake inside the cabin.

A flow control valve regulates the flow of oil by letting the excess oil flow back to the tank during the bypass, acceleration, deceleration and leveling stages, allowing the pressure to gently build up and gradually fall, giving passengers a smoother ride experience. A control valve used in a hydraulic elevator should be in a position to:

- Control the flow of the oil to and from the cylinder in both the up and down directions
- Have a means to identify shaft switching (generally achieved by using solenoid valves)
- Have a pressure relief and check valve*
- Have a manual lowering function to bring the elevator down in an emergency*
- Have a manometer to monitor pressure and an inspection port for periodic testing by inspectors*
- Offer the possibility to adjust the travel quality by controlling the leveling and stopping speeds in either direction for smoother rides
- Prevent the elevator from overspeeding in the down direction*

Gear pump	Submersible screw pump
Loud	Silent
Smaller flow range	Big flow range
Pulsating output due to gear mechanism	Non-pulsating output
Can be used in high pressure ranges	Not the best choice for high-pressure applications
Cheaper	More expensive
Readily available in the local market	Available from selected manufacturers worldwide
Suitable for smaller-flow/ high-pressure systems	Suitable for wider flow to low-to-moderate pressure ranges
The volumetric efficiency is generally low to medium (approximately 85-93%).	Lower overall volumetric and mechanical efficiencies

Table 1: Gear and screw pump comparison

◆ Include a safety valve to prevent a slack-rope situation in roped hydraulic systems*

(* = Mandatory per EN 81-2 safety directives)

A quality product would offer many other functions/possibilities in addition to these, such as:

◆ Built-in damping
◆ The possibility to connect/mount accessories like additional check valves and down valves
◆ Automatic emergency lowering in case of power failure or system malfunction
◆ The possibility to attach hand pumps (to raise the elevator in an emergency), shutoff valves, pressure switches, etc.

How to Select a Flow Control Valve

◆ Given a piston diameter, the speed of the elevator is derived from the flow of the pump; therefore, flow and pressure are two important factors that decide the type and the size of control valve that can be used. It is important to check if the control valve can handle the maximum flow with minimum pressure loss and the maximum system pressure the hydraulic elevator would have (Table 2).
◆ Travel comfort decides the functions that a control valve should offer. Selecting two speed (leveling and full speed) valves for up and down directions makes sense for passenger elevators, whereas single-speed valves with built in damping are better for goods and car-parking lifts.
◆ Pressure compensation is necessary in applications where the weight ratio of an unloaded to a loaded car exceeds two-and-a-half to three times. Car parking and cargo lifts are classic examples of such installations, wherein the loaded cabin/platform is three to four times heavier than an unloaded one. A hydraulic (mechanical) valve adjusted for such a lift would not give the desired travel characteristics without using pressure compensation methods. Check if the control valve offers the option to compensate for wide pressure variations.
◆ Contamination in hydraulic oil is often the root cause of system failure. Therefore, control valves should offer self-cleaning filters as an extra degree of protection, thereby extending the service and operational life of the valve components. Check if the control valve has built-in and self-cleaning filters for longer service life.
◆ A slack rope valve is an important safety feature; a control valve without this safety should never be used in indirect (roping) installations. Check if the control valve offers a slack rope (safety) valve for indirect installations.
◆ Check if the spare parts of the control valve are readily available at short notice for trouble-free servicing.
◆ Check if the control valve and accessories selected are designed for the vertical-transportation industry and certified and tested as per safety codes and directives.

The practice of using multiple modular valves available in the industrial hydraulic segment to carry out the individual functions mentioned previously results in very high pressure losses, poor travel performance, and difficult adjustment and setup procedures. Remember, such valves could be good for industrial applications but not for the vertical-transportation industry. Moreover, they are not designed for handling passengers, nor for elevators. They lack the safety functions that a proper elevator flow control valve would offer.

Continued

Piston	Speed of the elevator in mps							Weight of the elevator in kg									
Ø mm	0.10	0.20	0.30	0.40	0.50	0.60	0.70	500	750	1000	1500	2000	2500	3000	3500	4000	4500
50	12	24	35	47	59	71	82	25	37	50	75	100	125	150	175	200	225
55	14	29	43	57	71	86	100	21	31	41	62	83	103	124	145	165	186
60	17	34	51	68	85	102	119	17	26	35	52	69	87	104	121	139	156
65	20	40	60	80	100	119	139	15	22	30	44	59	74	89	103	118	133
70	23	46	69	92	115	139	162	13	19	25	38	51	64	76	89	102	115
75	27	53	80	106	133	159	186	11	17	22	33	44	56	67	78	89	100
80	30	60	90	121	151	181	211	10	15	20	29	39	49	59	68	78	88
85	34	68	102	136	170	204	238	9	13	17	26	35	43	52	61	69	78
90	38	76	115	153	191	229	267	8	12	15	23	31	39	46	54	62	69
95	43	85	128	170	213	255	298	7	10	14	21	28	35	42	48	55	62
100	47	94	141	188	236	283	330	6	9	12	19	25	31	37	44	50	56
105	52	104	156	208	260	312	364	6	8	11	17	23	28	34	40	45	51
110	57	114	171	228	285	342	399	5	8	10	15	21	26	31	36	41	46
115	62	125	187	249	312	374	436	5	7	9	14	19	24	28	33	38	43
120	68	136	204	271	339	407	475	4	7	9	13	17	22	26	30	35	39
	Flow (lpm), rounded to nearest decimal							Pressure in bars, rounded to nearest decimal									

Table 2: Flow pressure table for hydraulic elevators with single cylinder and direct (without roping) installation

The Motor, the Power in the Power Unit

In a hydraulic elevator system, the role of the motor is to provide the power to the pump, which (at a given number of revolutions per minute [rpm]) delivers the required discharge (lpm). A hydraulic power pack can have two types of motors: internal (submerged) or external. Irrespective of the type of the motor used, the power (kW) that it has to generate to drive the pump remains the same. Selecting a motor with a correct power rating is important, because an underrated motor would not deliver, stall and wear out, whereas an overrated motor comes at an increase in cost, size and power consumption. Secondly, the common practice of oversizing (overrating) a motor results in less efficient motor operation. E.g., a motor operating at a 35% load is less efficient than a smaller motor matched to the same load; it also generates unnecessary heat.

Quality motors designed for hydraulic power units can usually be overloaded up to 20% for a short period of time without being damaged. If we compare the cost of the motor against the running cost, it would be immediately clear that the cost of electricity to operate a motor over its entire lifespan is generally many times the cost of the motor itself. Even though standard motors operate efficiently, with typical efficiencies of 83-92%, energy-efficient motors perform significantly better. An efficiency gain from 92% to 94% results in a 25% reduction in losses.

Hydraulic elevators do not use any power in the down direction, as they descend due to gravity. One should keep in mind that a motor used in a hydraulic power unit would not be in continuous operation. Also, the elevator is not always fully occupied, nor is the motor always fully loaded.

In warm climates, external motors are usually preferred. A three-phase motor with silent operation is ideal for hydraulic-elevator installation. Depending on the requirement, a two- or four-pole motor can be selected. A two-pole motor with 3,000 rpm is a bit louder than a four-pole motor having 1,500 rpm. It is but obvious that a two-pole motor driving a pump would offer more oil discharge than a four-pole motor driving the same pump due to higher rpm. E.g., to compensate the discharge, a four-pole motor can be used to run a 150-lpm pump to effectively get 75 lpm, instead of running a two-pole motor with a 75-lpm pump.

How to Select a Motor

- Select the correct motor rpm and type (submersible or external).
- Ascertain if the motor sizing is appropriate for the power unit and elevator load.
- Check the motor efficiency at peak load.
- Check up to how long and how much the motor can safely be overloaded.

Motor Starting Methods for a Hydraulic Elevator

While it is true that a motor used for a hydraulic elevator should offer the necessary torque in order to deliver the power to the system, consideration should be taken as to how this is done. Often, starting jerks in a hydraulic elevator find their roots in inappropriate motor-starting techniques. The most common startup methods (Table 3) are:

- Direct-on-line start (DOL)
- Star-delta start
- Soft-starter start

The Cylinder, the Arm of the Power Unit

Push-Type Cylinders

Push-type cylinders used in hydraulic elevators are mostly plunger type (where the piston and piston rod are the same), thus differing a little with their counterparts used in the industrial hydraulics segment. Single-acting push-type cylinders are the most commonly used cylinders for elevator applications. They are cheaper and easy to manufacture. Almost all steel-producing companies have seamless steel tubes available over a wide range of sizes. If quality raw material is available, little machining is required to make the tubes ready and useable. Alternatively, pull-type cylinders can also be seen in elevator installations.

Basic facts to be noted when selecting push-type cylinders are:

- Push-type cylinders are subjected to compressive loading.
- The diameter of the piston is directly proportional to the length of the stroke, which means the longer the stroke of the elevator the larger the piston diameter has to be in order to prevent buckling.
- Pressure in a hydraulic system is inversely proportional to the piston diameter, which means that with increasing diameter, pressure will be less (given constant load).
- The bigger the piston, the larger the pump discharge required to attain a given speed. Hence, pump sizing has a direct relation to the cylinder size.
- An elevator with a direct-acting cylinder can be either a hole or hole-less type. In the latter, the cylinder is above the ground, while in the former, installation the cylinder is buried in the ground, beneath the elevator car. Early designs usually had single-bottom construction and fairly limited corrosion protection. Newer hole-type cylinders have double bottoms and more advanced polymer sleeves, which offer better protection against corrosion and electrolysis problems.

Pull-Type Cylinders

Pull-type cylinders operate fundamentally differently and differ in design from push-type cylinders. Here, the cylinder is used with a counterweight system, and the hydraulic fluid pushes the piston in the cylinder down for the elevator to go up. Thus, the movement of the piston is in the opposite direction of that of push types. An elevator installation with a pull-type cylinder is always indirect (roping). Pull-type cylinders have a piston and a piston rod like a typical hydraulic cylinder. A solid rod is used as piston rod, which is subjected to tensile loading rather than compression, and hence is not subjected to buckling forces. Due to this fact, piston rods with smaller diameters can be used to save material. The counterweight offsets two-thirds of the empty car weight, and the whole concept results in reducing heat losses. This also reduces power consumption and makes the elevator installation eco friendly. Cylinder design is based on the calculation as to how much force the cylinder can produce to lift the load. The counterweight, in this case, adds to the force the cylinder is generating and is very productive. Some of the important criteria to consider when selecting the cylinder are the load, speed and mechanical stability.

Cylinder manufacturers have selection charts for selecting the cylinder size with respect to stroke and load of the elevator. Alternatively, cylinder sizing can be calculated. EN 81-2 very clearly defines how the calculation of rams, cylinders, rigid pipes and fittings should be calculated. From the mechanical strength aspect, the piston diameter has to be selected such that under full load and stroke, the piston should not be subjected to bending or buckling.

The Pipe Rupture Valve,
the Parachute of a Hydraulic Elevator

What a parachute does for an air diver, the pipe rupture valve does for a hydraulic elevator in the event of a hose pipe rupture. In the absence of a pipe rupture valve (and overspeed braking systems), one can expect a free fall of the cabin due to sudden pressure drop occurring when the hose pipe connecting the control valve and the cylinder bursts.

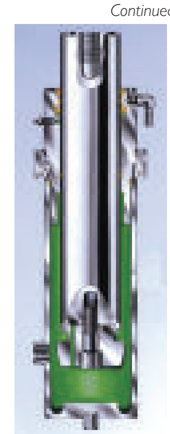
The pipe rupture valve in hydraulic elevators is a lifesaving device and mandatory per EN 81-2. A passenger hydraulic elevator would not be certified by inspection authorities in the absence of this valve. In the event of failure in the main cylinder line or where the down speed exceeds allowable limits, the rupture valve closes, bringing the car to a smooth stop. It should be noted that rupture-valve selection primarily depends on the flow rather than the port size. Valves with optional adjustment for lowering the elevator cabin to the floor level when it has been slowed are also worth considering, as they would safely bring the passengers down without having to wait for rescue.

Continued

	DOL	Star delta	Soft starter
Start	Very high starting torque and current	Low starting torque and current	Voltage and current gradually increase to make the full starting torque available.
Stop	Sudden	Sudden	The pump is gradually made to stop minimizing sudden shocks and hammering effect in pipes.
Cost	Very cost effective	Cost effective	Expensive
Usage	Very small motors	Small to mid-sized motors	Ideal for all motor sizes

Table 3: A comparison of motor starting methods

Single-acting RAM cylinder (courtesy: Kleemann lifts)



Cross-section of single-acting RAM cylinder (courtesy: Leistritz)

Figure 3: Plunger-type cylinders

Things to consider when dealing with an elevator rupture valve:

- Design and certification for the elevator industry: Elevator safety norms clearly outline the design and functions of a pipe rupture valve. In the event of a pipe rupture, the pressure between the control valve and the rupture valve drops to zero, whereas on the other side, the pressure suddenly surges between the rupture valve and the cylinder. The peak pressure after the rupture valve (between the cylinder and the rupture valve) should be in all cases less than or equal to three-and-a-half times the static pressure. It is therefore important to select a product designed and certified for the elevator industry. There may be alternative cost-effective solutions available, but using them would only compromise passenger and elevator safety.
- Mounting the valve: Reputed manufacturers offer a wide range of choices in connections and the way a rupture valve can be mounted on the cylinder. Cylinder manufacturers also usually offer different connection possibilities with their products; .e.g., some may provide a standard pipe-threading port, while some may offer one with National Pipe Thread threads or Society of Automotive Engineers flange connection possibilities. It is therefore crucial to check the coupling options before ordering.
- Suitability of a valve for twin cylinders: Elevator installations in which two cylinders work in tandem require two rupture valves. However, these two safety valves have to be connected to each other so that they can also work in tandem. This is done by connecting the two pressure chambers of the individual valves with tubing to ensure simultaneous closing of both valves in the event of pipe rupture. Comprehensive tests have shown that this very simple system is effective, even when the valves are adjusted to different closing flows. The connection between the two rupture valves ensures that both valves close almost simultaneously. It is usually recommended that the tube diameter be at least as large as those listed in Table 4.

Learning-Reinforcement Questions

Use the below learning-reinforcement questions to study for the Continuing Education Assessment Exam available online at www.elevatorbooks.com or on page ??? of this issue.

- What are the important criteria when selecting pumps, motors, cylinders and flow control valves for a hydraulic elevator?
- How does one differentiate between a typical industrial hydraulic valve and one specially designed for hydraulic elevators?
- What disadvantages do oversized motors bring, and what should be considered when selecting the motor size?
- What advantages do pull-type cylinders have over single-acting push-type cylinders?
- Which rupture valves are best suited for elevator installations with twin cylinders? Why?

Rupture valve size	3/4-1"	1-1/2"	2"	2-1/2"	3"
Tube ID (mm)	6	6	8	8	10

Table 4: Recommended tube sizes for a two-rupture-valve connection

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1. In its most basic form, of what is a hydraulic power unit made?
   A. A tank (oil reservoir), flow control valve, shutoff valve, pump, motor and safety valves.
   B. A tank, rupture valve, pump and motor.
   C. A submersible pump and safety valves.
   D. A tank, flow control valve, motor, pump and two-rupture-valve connection.

2. Which European elevator code is applicable to hydraulic elevators and components used in hydraulic elevators?
   A. ASME A17.1.
   B. ASME A17.7.
   C. CSA B44.
   D. EN 81-2.

3. Which of the following is NOT an advantage of a submersible screw pump?
   A. Silent operation.
   B. Pulsating output.
   C. Wide flow range suitability.
   D. Low mechanical vibration.

4. How is pressure generated in the hydraulic circuit?
   A. The safety valve creates a partial vacuum to enable the introduction of oil into the pump.
   B. The reservoir tank traps oil within its cavities and transports it through and forces it into the hydraulic system.
   C. Resistance to the flow in the hydraulic circuit.
   D. The pumps generate pressure.

5. A screw-pump manufacturer's data sheet shows motor power of 6.9 kW (9.25 horsepower) for a pump delivering 76 lpm (20.07 gpm) at 40 bar (580.14 psi). Calculate the overall pump efficiency.
   A. 0.73
   B. 1.52
   C. 2.07
   D. 5.84

6. What is the role of a flow control valve in an elevator power unit?
   A. To prevent a free-fall condition of the elevator.
   B. To help regulate the flow of oil to and from the cylinder moving the cabin up and down.
   C. To serve as a continuous-duty pump, which delivers a fixed output per minute.
   D. To directly control the leveling ability of the car at each floor.

7. Which is NOT a characteristic a flow control valve used for passenger elevators should have?
   A. Ability to control the flow of the oil to and from the cylinder in both the up and down directions.
   B. A means to identify shaft switching (generally achieved by using solenoid valves).
   C. A pressure relief and a check valve.
   D. A reservoir release for control of pressure compensation.

8. Where is pressure compensation required in hydraulic elevators?
   A. In applications where the weight ratio of the unloaded to loaded car exceeds two-and-a-half to three times.
   B. In applications where the pressure of the loaded cabin/platform is six to seven times higher than that of the unloaded one.
   C. Where a hydraulic (mechanical) valve is used.
   D. In twin-cylinder installations.

9. Which should NOT be a factor in selecting a motor for a hydraulic elevator?
   A. Ensuring correct motor rpm and type (submersible or external).
   B. Ensuring that the rated power of the motor exceeds the maximum work it will have to do.
   C. Whether motor sizing is appropriate for the power unit and elevator load.
   D. Motor efficiency at peak load.

10. Which basic fact is the most important to consider while selecting push-type cylinders?
    A. The tank size and maximum motor rpm.
    B. How much overload the motor can withstand.
    C. The diameter of the piston and pressure in the hydraulic system.
    D. How the rupture valve will be mounted.

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