Frequency controlled lift with counterweighted roped hydraulic system

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Abstract

Changes in the lift market have lead to the development of new systems, which meet new demands such as: space (no machine room), power consumption, ride comfort, etc. A new concept for a hydraulic lift is presented that combines these requirements in a single system. A counterweighted roped hydraulic lift is driven by a differential cylinder. The power unit motor is not immersed in the oil and is driven by a frequency converter. The known advantages of hydraulic lifts can thus be increased to include high efficiency and the integration of the power unit and the controls in a single cabinet.

New development targets for the hydraulic lift

The hydraulic drive for elevators is well established on the market due to reasonable advantages:

⇒ Rugged and low-maintenance technology
⇒ Flexibility in the position of the machine room
⇒ Good price to performance ratio

Over the years, the hydraulic principle has increased its maket share. For example in germany.

Number of order intakes for lifts according to TRA200

Year	Traction	Hydraulic
1992	46,8 %	53,2 %
1996	33,9 %	66,1 %

(Source: VDMA- Association of German Mechanical Engineering Establishments)

The first design principle of a dircet acting hydraulic cylinder was followed by roped applications where the cylinder operates with a 1:2 transition to the car. This principle allows to double the stroke of the car with the same cylinderstroke as the direct acting drive. In addition, no cost driving borehole is required with this design.

But what are the new developments for the future ?
Nowadays the demands of the market are giving more importance to
⇒ ride comfort,
⇒ quiet operation,
⇒ low operating costs,
⇒ a minimum space for the machinery, no separate machine room

It quickly becomes apparent that only partial successes can be realized by improving single components. The lift must be viewed and optimized as a complete system. This applies to the hoistway equipment, the cylinder, the controls and the power unit. In analyzing the requirements, it becomes clear that solutions have to be found for the following points:

⇒ Energy consumption, reduction of power waste
⇒ Space requirements, reduction of the power unit size
⇒ Ride comfort, reduction of travel noises, compensation of effects due to load, temperature etc.

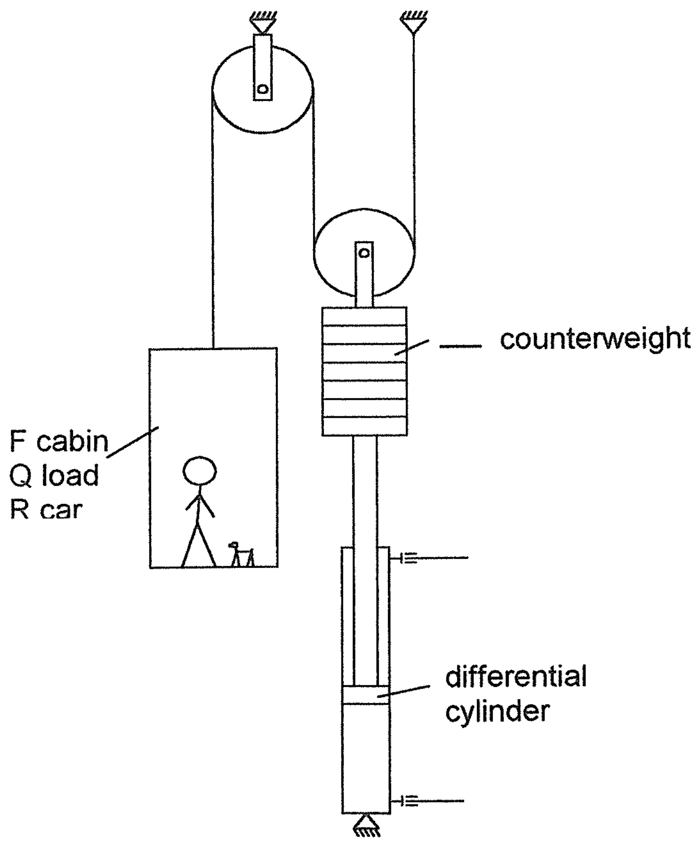
THE HYCO SYSTEM

The mechanical principle

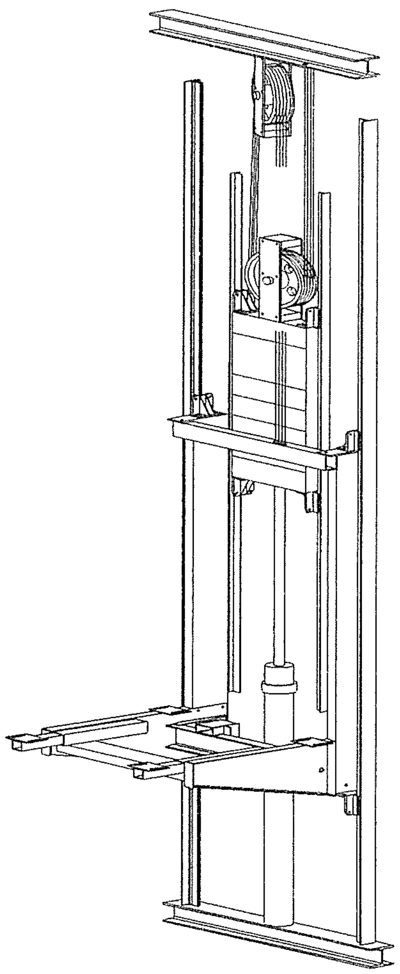
The amount of power drawn by a lift will depend upon the specific transportation task and is calculated by the values for power drawn during acceleration and during steady-state travel, regardless of which drive principle might be used. Losses of the pump and the electric motor are not taken into account at first.

Steady-state power: $P_b = m * g * v$
Acceleration power: $P_a = m * a * v$

The situation can be improved by using a counterweight since this reduces the accelerated mass „m“ for the drive. The counterweight is mounted directly on top of the cylinder`s piston rod and works on the cab by way of 1:2 roping.



This „counterweighted roped system" has already been introduced to the market for lifts with hydraulic drive. This technology is characterized by the space-saving location for the counterweight and the fact that the car can be accessed from three sides.



The weight compensation for a common hydraulic counterweighted system must take into account the pressure loss which is required for the operation of the hydraulic control valve. Therefore the weight compensation usually will only reach about 30 %.

A weight compensation of 50 % of the rated load in addition with 100 % of the cabin and frame and would be ideal. But in detail, some circumstances have to be further investigated . First, when no power is applied, a car carrying less than 50 % of the load would be drawn upward by the counterweight. Additional safety devices would be required to avoid this situation. Second, the piston rod of the cylinder has to be calculated for resistance to buckling.

Therefore, the HYCO system uses a weight compensation of about 90 % of the mass of the cabin and the frame.

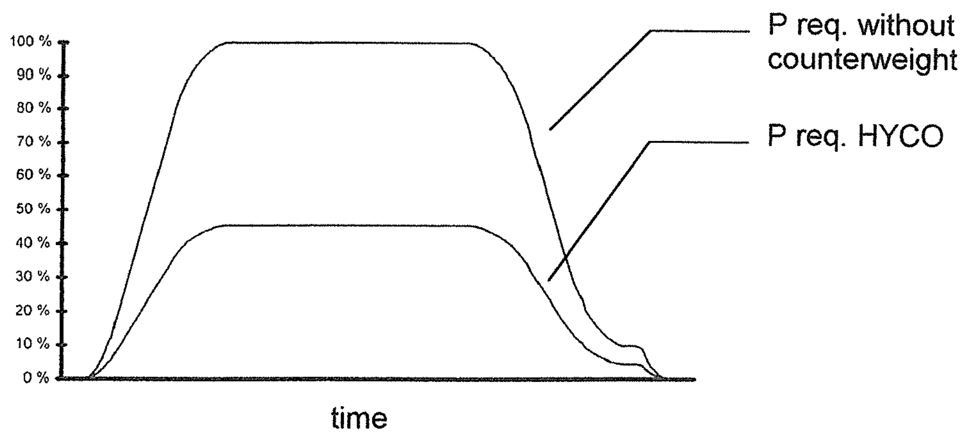
	Hydraulic 1:2	Pulling piston	HYCO
Load		630 kg	
Car and frame		820 kg + 150 kg	
Counterweight		500 kg	870 kg
accel. mass (fully loaded)	1600 kg	1100 kg = 69 %	730 kg = 45 %
accel. mass (50% load)	1285 kg	785 kg = 61 %	415 kg =32 %
accel. mass (empty)	970 kg	470 kg = 48 %	100 kg =10 %

As shown, the HYCO system makes sure, that even empty cars will always be pulled downward. The rest position and safety devices correspond to those found in the pulling piston system. An example shows the advantages of a counterweighted: system.

Conventional 1:1 or 1:2 system: $m = 1600$ kg, $g = 9.81$ m/s², $v = 1$ m/s,
$a = 0.3$ m/s²
$P_a = 15{,}6$ kW + $P_2 = 0{,}4$ kW = 16 kW

HYCO: $m = 730$ kg, $g = 9.81$ m/s², $v = 1$ m/s,
$a = 0.3$ m/s²
$P_a = 7.16$ kW + $P_2 = 0.22$ kW = 7.38 kW

The following diagram shows in principle the required power of a lift during upward travel. The advantages of the counterweight are easily recognized. The areas below the curves represent the amount of energy required, in kWh.



The HYCO solution, using an optimized counterweighted system for the mechanical design gives the following advantages:

- Reducing the required power for acceleration and steady-state travel to about 45 %,

⇒ The power consumption of the drive is reduced

- Known and proven technology of the pulling piston system,

⇒ recognized safety concept,
⇒ access to the car from three sides,
⇒ low space requirements for mechanical components in the hoistway

The cylinder

Beside the pure mechanical aspects, the functioning and efficiency of the installed drives have to be taken into account. Usually a hydraulic pump generates the pressure for the cylinder to raise the car ether in direct acting or by a 1:2 roped application. In downward motion the car`s weight displaces the hydraulic fluid from the cylinder. In both cases a valve regulates excess flow into the tank. The piston rod of the cylinder is designed to prevent buckling.
As shown above, the HYCO counterweighted system favors the use of smaller cylinders. In addition, a double-acting differential cylinder is used which enables the oil interchange between piston chambers AO and A1 via a hydraulic valve array.

For example: Q + F = 1600 kg, v = 1 m/s

Principle, car travel	Piston diameter	Oil flow	Oil interchange tank-cylinder
Roped 1:2, 12 m	100 mm	235 l/m	47 l
Roped 1:2, 20 m	130 mm	397 l/m	132 l
HYCO 12 m	70/28 mm	97 l/m	3,6 l
HYCO 20 m	70/28 mm	97 l/m	6 l

The HYCO solution, using a double-acting cylinder as the pulling piston gives the following advantages:

- Impressive reduction of the volume and the flow of the operating liquid.

⇒ Noise level is reduced,

⇒ Tank size is reduced

- The cylinder requires less space,

⇒ The use of hoistway space is optimized

Tank, pump and electric motor

To fullfill the demands for a hydraulic power system which needs no additional machine room, all system components have to be designed, that their heat exchange as well as their size allow the installation in a small cabinet. Therefore, and in addition to the net energy savings, it is also required to reduce the wasted energy. Otherwise the area for the heat exchange will result in a big size tank and sometimes the need for an additional oil cooler.

The efforts of the design principles described above are quite impressive:

- Reduction of power required for acceleration and steady-state travel to about 45 %
- Reduction of the volume flow to about 25% to 40 %
- Reduction of the oil interchange between tank and cylinder to about 25% to 40 %

These efforts make it possible to reduce the rated sizes of the pump and motor to the values indicated. Since the efficiency levels always represent a percentage share of nominal power, it is naturally possible to also reduce half of the actual losses from the pump and motor.

In the past the typical efficiency of submerged motors was 75 % while pump efficiencies were usually 80 %; this represents power losses of 9 kW for a 24 kW motor. In the interest of improving efficiency, the HYCO system uses an air-cooled industrial motor. When driven by a frequency inverter, these motors will typically achieve about 85 % efficiency. This reduces the wasted power of the pump and the motor in our example from 9 kW to about 3.5 kW.

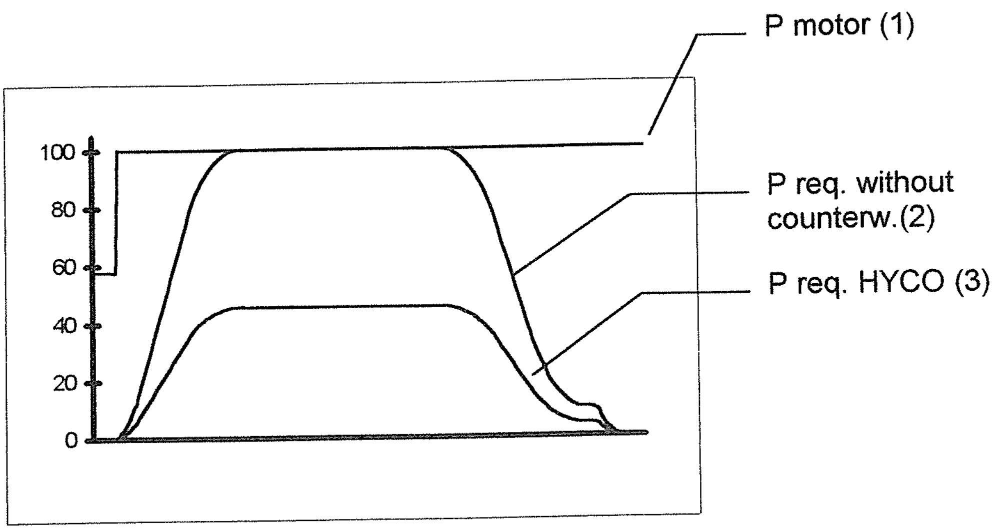
Now the size is a result of the electric motor mounting plate dimensions and the physical size of the pump an not longer a result of the hydraulic fluid`s capacity to absorb heat.
In example, the power unit of a 1:2 roped hydraulic system will require a tank of about 800 liters. The tank in the HYCO system is just 60 liters and total system volume is about 90 liters.

Control of the travel speed

The function of a common hydraulic power unit is based on a motor and pump assembly running at constant speed and output. The system calculation is made for the desired maximum travel speed. For the smooth acceleration and deceleration, excess power is normally transferred to the hydraulic fluid in the form of heat. The required volume flow is regulated via a common hydraulic valve array or via a close-loop-control system. Excess volume flow is diverted to the tank as wasted energy. This wasted energy can be drastically reduced by using a frequency converter controlled motor. In the past the costs were often too high for hydraulic lifts. Now, the described advantages of the HYCO system are reducing the total power consumption of the hydraulic lift in a way, that the size of the cost driving frequency converter can be drastically reduced as well.
The frequency converter controls the speed of the motor and pump, following a programmed speed curve. The feedback is the actual cabin speed, measured by the volume flow to the double-acting differential cylinder. The pump will feed pressure either the ring area or the piston area of the double-acting cylinder, depending on the travel direction. Even for downward operation a hydraulic valve array ensures that the motor does always operate as a motor, not as a generator. Therefore, there is no need for an intermediate circuit resistor in the frequency converter, which usually converts the braking power into heat. The current drawn by the frequency converter is proportional to the motor`s moment. Therefore the current spike typical for star/delta start-up can be avoided.

The advantage of the frequency converter is the control of the travel speed without the wasted energy of a common motor pump unit running at a constant speed. The HYCO counterweighted system reduces the cost driving size of the converter to allow the economical use in lift power systems.

The drawing shows in principle the power output of the electric motor (1), the power requirements for a conventional system without counterweight (2) and for the HYCO system (3). The area under curve 1 shows the energy supplied by the electric motor running at constant speed in the conventional configuration. The usage of the frequency converter reduces the energy consumption to the area below curve 2. With the combination of frequency converter, improved efficiency and counterweight, the energy required by the HYCO system is reduced to the area below curve 3.



The control cabinet

The above described design features make it possible to mount all the lift control components inside a single control cabinet. The wasted heat can be interchanged by convection at the surface areas of the cabinet and cylinder even in heavily frequented lifts. The dimensions allow the mounting of the control cabinet into hoistway walls (1200 mm * 365 mm * 1900 mm).
The system is fitted with a hand pump and an emergency descent. All operating controls for maintenance and passenger rescue are easily accessable. The cabinet is fitted with a splash protection panel and a drip pan. Local building codes as well as the codes for passenger lifts and fire protection have to be observed.

Comparison roped hydraulic1:2 / HYCO

	1:2 roped	HYCO
load [kg]	630	630
v [m/s]	1	1
travel [m]	20	20
total oil volume [l]	ca. 900	ca. 90
motor size [kW]	28	7,5
power consumption [A]	61	24
Req. space [m^2]	0,9 + control cabinet	0,4

Summary

The HYCO design fullfills the new requirements for a modern lift system and is still keeping the advantages of the hydraulic principle by improving part sizes and efficiency levels so drastically that it is possible to house all the control components in a small equipment cabinet. This cabinet can be integrated into the building in such a way that the need for a separate machine room is eliminated in many cases. The fluid volume and the associated costs for the initial fill can be cut by as much as 80 %. The electrical power consumption is only 45 % of a comparable conventional hydraulic system.

Author biographical details

The author Dipl.Ing.(FH) Dieter Klitzke is born in 1957 and the Manager Bochum Branch of the Division Hydraulic at Leistritz since 1996. He has experience in the development of electronic controlled hydraulic systems since 1981 in various applications.