Why hydraulic elevators are so popular? Part II

Dr Ferhat ÇELİK[1] & Dr. Banu KORBAHTI[2]
[1] *Blain Hydraulics GmbH, 74078-Heilbronn, Germany.*
[2] *Department of Mechanical Engineering, Istanbul University, Turkey.*

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Abstract
In the application of vertical transportation systems, a major decision is, which drive system to use, hydraulic or traction? Each type has characteristics which makes it particularly well suited for a specific application. In general, hydraulic elevators are suitable for low-rise buildings (up to 6 floors) whereas, the roped (traction) elevators are best suited to higher buildings.

Over the last forty years hydraulic elevator has been accepted world wide. As the Machine-room-less (MRL) traction elevator system was introduced to replace the hydraulic elevator, strong competition for the low-rise market started. Aggressive market strategies have been applied solely to grasp the market and decline popularity of the hydraulic elevator. These efforts created the MRL trend at the expense of safety. Purchasers however, should be informed about the merits and shortcomings of both elevator systems to ensure the most suitable and safe application of each type.

In this paper, mainly hydraulic and MRL traction elevators are discussed and compared in order to enlighten consumers.

1. Introduction

In the first part of the present paper[1] the development of the elevator market as well as the present situation in the European and the Turkish markets were discussed. Suitability of various elevator types, i.e., hydraulic, traction and machine-room-less (MRL), was also highlighted there. It was concluded that the percentage share of the hydraulic elevator in the elevator market reduced to approximately 40% however, this did not decrease hydraulic elevator production world wide due to a total increase in the number of elevator installations. It was also concluded that the hydraulic elevator is the safest elevator type against seismic movements, and that efforts to promote MRL traction elevators in earthquake endangered areas would result in more damage and injuries.

Misleading arguments against the hydraulic elevator are mainly limited to exaggerated energy consumption and environmental risk. Such exaggerated claims are evaluated for the end user.

2. Drawbacks of traction MRLs

1- **Genuine installation costs for the same performance** are estimated to be 15-25% higher than the hydraulic units[2] (MRL installations might be initially offered at low prices to win contracts with overblown service charges later).

2- **Maintenance is**

Difficult: Because the machine is located in the headroom of the shaft or, on or under the cab, reaching it can be complicated. Serious accidents during construction and servicing of the elevator are more likely. In case the car is stuck and cannot be moved, the machine cannot be serviced from the top of the car, insecure methods may need to be attempted.

Costly: All major elevator manufacturers as well as the major motor manufacturers specializing in lift technology now offer their own MRL solutions based on the permanent magnet synchronous (PMS) motor

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concept. The present traction MRL solutions have been patented and therefore, it is difficult to introduce further new MRL solutions that would be more cost effective, without infringing on existing patents[3]. The patent's reserved rights also ban other qualified companies to service traction MRLs. As a result, a group of multinational companies are increasingly controlling the low and medium-rise elevator market. The traction MRL solutions are initially offered with competitive prices and the low revenue is later made good through frequent servicing and high-priced spare parts. Obtaining the spare parts of MRL units is difficult, since servicing may only be performed by the original installer or by their service partners.

Disregard of safety requirements: Rescue of passengers during an emergency situation becomes complicated, since each type of MRL machine requires expertise and the machine is difficult to reach in the shaft[4,5]. Temperature and humidity conditions inside the shaft are detrimental and can easily affect the electronic components which might cause more frequent break-downs and servicing. A short circuit to the motor or fire can make the lift unable to move and passengers may be entrapped in the elevator. The fire itself might not be deadly but rather the smoke within the shaft. Installation of traction MRLs in seismic regions and natural endanger areas is obviously irresponsible on the part of the owner, the architect and the elevator company itself[4].

3. The argument on high energy consumption of hydraulic elevators

The argument on the energy consumption of elevators should be carefully dealt with otherwise; unrealistic results can be interpreted. The fact is the cost of operating an elevator is considerably less than the cost of servicing it[6]. Therefore, knowing servicing and spare-parts costs in advance are important, but at the same time, difficult to determine.

The energy consumption of a hydraulic elevator is said to be 2 to 5 times more than that of traction elevator without explaining on which basis these numbers were produced. It is well known that reduced energy consumption of the traction elevator results from the counter-weight. The hydraulic elevator generally does not use counter weights, and are consequently safer at the expense of a small increase in motor power. On the other hand they can be constructed with the counter-weight balance under suitable conditions (in earthquake free regions) so that similar energy savings like traction elevators can be obtained. Table 1 shows the motor power of a hydraulic elevator for 8 people with and without a counter-weight. It can be seen that by reducing 2/3 of the car weight (by means of a counter-weight) the motor power can be reduced 29%. In Figure 1 another configuration of the counter-weight for the hydraulic elevators is shown, where the counter-weight is placed on a pull ram. By doing so, smaller diameter rams and smaller pumps can be used. Such a configuration can prevent the counter-weight from swinging in the shaft. Therefore, claiming hydraulic elevators to be uneconomical is inaccurate and misleading. The majority of hydraulic elevators are without counter-weights because of better safety records and ease of installation. Logically higher motor powers would increase energy consumption however, the increase is less than might be expected since the hydraulic elevator does not consume energy in down travels.

Table 1. Reduced energy consumption of the hydraulic elevator with the counter-weight.

Counter weight	Piston length [m]	Piston diam. [mm]	Suspension ratio	Cylinder pressure [bar]		Speed [m/s]	Flow rate [lt/min]	Motor power [kW]
				Empty	Full			
No	4.5	70	2:1	22.9	55.1	0.64	74	8.5
Yes	4.5	60	2:1	10.4	54.1	0.64	54	6

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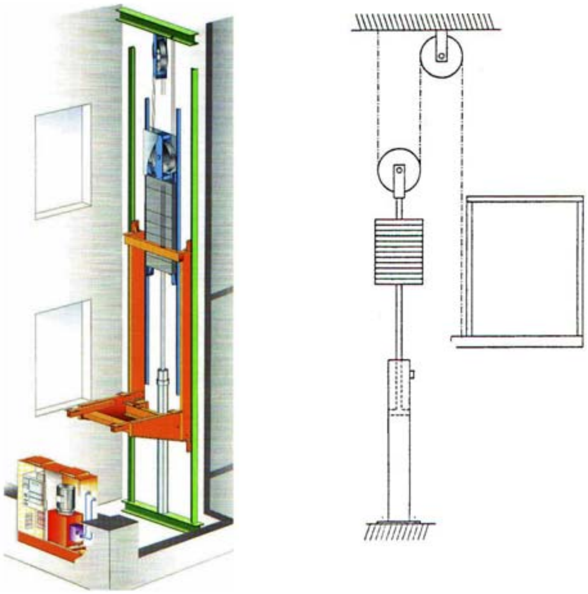

Figure 1. Hydraulic elevator with a counter-weight.

Cooper[7] performed tests on energy consumption of five different elevator drives in hospitals where elevator usage is high. He used a power demand recorder to measure the energy consumption of the elevators. The elevators had different speeds depending on the number of stops (3 to14). As a result, he stated that running cost of even a busy elevator was very little. His results are given in Table 2. It can be seen from Table 2 that when a hydraulic elevator (even without a counter-weight) is installed, its energy consumption is negligible.

Table 3 below also gives annual energy consumption of some household equipment as well as the typical energy consumption of a hydraulic elevator for a 6 family-house[8]. As the energy consumption of an elevator will be shared by the occupiers, the monthly share per family will be as low as between 9 to 12 kWh. In this example, the elevator uses 4 to 6 percent of the total energy consumption of the building. As a result, avoiding hydraulic elevators eventually may result in higher energy consumption due to wrong traffic estimation, expensive servicing and frequent break-downs.

Table 2. Comparison of energy consumption of various drives (based on a kWh rate of 3.2cents, all results adjusted to reflect 3000 stops over 24 hours) [7].

Drive Type	**kWh consume**	**Cost/day $**	**% of Max.**	**Speed [m/s]**	**Stops**	**Total Weight [kg]**
Hydraulic	49.9	1.60	39.9	0.63	3	1134
Otis MRVF	51.9	1.66	41.4	1.78	8	1134
Gearless SCR	55.3	1.77	44.1	2.54	14	1588
Geared MG	103.8	3.32	82.9	1.78	6	1588
Gearless MG	125.2	4.01	100	2.54	11	1588

Table 3. Comparison of the energy consumption of an elevator with various household equipment [8].

Goods	**Refrigerator**	**Dish washer**	**Washing machine**	**Television**	**Iron**	**Gas Oven**	**Lights**	**A typical residential hydraulic lift**
Yearly energy consumption [kWh]	350-500	400-600	445	230	250	25	750	600-800

The most important component affecting elevator performance is the motor, because its efficiency and size affect the overall efficiency of the entire elevator system. This means that it’s important to choose the most efficient motor and make sure it is sized properly for its intended use. It is also a known fact that energy consumption rises dramatically with the increase in speed. Because of the fact that hydraulic elevators do not consume energy in down travels (because the car descends by gravity and controlled oil flow), they are especially suitable for balancing the elevator traffic speed without additional cost. This can be done by simply increasing the down speed and at the same time decreasing the up speed. Thus, a smaller size motor can be

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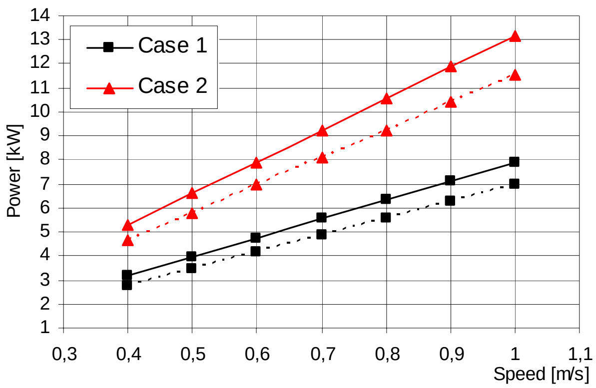

Figure 2. Selection of motor power versus elevator speed.
Case 1: Car loaded weight: 650kg (4 people), Max. Static Pressure:33bar.
Case 2: Car loaded weight: 1080kg (8 people), Max. Static Pressure:55bar.

utilized and energy consumption can be lowered. In Figure 2, the motor power graphics are shown for two different cases. The motor power can be chosen between the solid and dashed line depending on the characteristic of the electrical motor.

In Table 4, percentage reduction in motor power (for the Case 1 in Figure 2) is shown after balancing the up and down travel speeds in order to obtain the same travel time. Reductions of 10-28% in motor power are attainable. The annual energy consumptions (AEC) for 300 starts a day are approximately calculated by means of Doolard's and Schroeder's equations[9,10]. Since the code allows the velocity of the elevator to be as high as 1m/s for hydraulic elevators, the down speed can be increased to 1m/s so that maximum energy saving and better travel times can be obtained. As a result, applying counter-weight and down travel speed-balance, the electric motor power can be approximately reduced 50%. Schroeder's equation is as follows;

AEC=Typical trip time (TP)*No.of starts*Motor power*Working days/3600.

This is a generalized equation that was developed as a result of a large number of measurements for calculating the daily energy consumption of a lift installation. In the formulation the TP (typical trip time) can be taken as between 5 (small motors) to 7 (large motors) for hydraulic elevators without counterweight. Similarly, another formulation was developed by Doolard[10] who introduced a graph form which energy consumption can be formularized energy/kg per journey. In practice, Schroeder's equation is found to underestimate the energy consumption whereas the Doolard's method gives higher estimates (a factor of two)[11]. These methods can be used as the upper and lower limits of the energy consumption of an elevator, where the actual value lays between. Here, the average value of both methods is given as the consumed energy of the elevator.

Table 4. Balancing the travel time. Travel distance:12m, TP:6 , 2:1.

Travel speed [m/s] Up and Down	Modified travel speeds [m/s]		Modified travel	
	UP	DOWN	Reduction in motor power [%]	Daily energy consumption [kWh]
0.8	0.66	1	17.5	3.9
0.8	0.72	0.86	10	4.3
0.7	0.53	1	24.3	3.2
0.7	0.6	0.84	14.3	3.6
0.6	0.43	1	28.3	2.6
0.6	0.5	0.75	16.7	3.0

In Table 5, energy consumption of a 4 people elevator, speed of 0.6m/s, in a residential building with respect to number of starts a day is given. It can be seen from Table 5 that energy consumption of a residential elevator is insignificant in terms of cost.

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Table 5. Daily energy consumption in a residential building versus number of starts, TP:6, Motor:5kW

No of starts	10	50	100	150
Energy Consump. [kWh]	0.125	0.625	1.25	1.88
Cost (10 cents/kWh)	1.25 cents	6.25 cents	12.5 cents	18.8 cents

Oversized motors will run at low efficiency causing unnecessary energy consumption. Proper planning for projected occupant usage will ensure that the elevator system uses energy efficiently. Reducing motor losses is possible by choosing the submersible pump motor with about 20% smaller output and in consequence overloading the motor when the car is lifting full load. It must be guaranteed that the motor can withstand this situation from torque performance as well as thermal overload[12]. Sometimes exaggerated comparisons of hydraulic elevator are given intentionally by using such over sized elevator systems to compare hydraulic elevators with the others. For example, the speed of 0.63m/s, 8 person elevator may be calculated to have 11 kW motor power where as an 7.5 kW or 8.5 kW motor would be sufficient.

The number of break downs introduces another kind of energy consumption for elevator systems. The energy spent in traveling between the site and the servicing company should obviously be added on to the total energy consumption of the elevator. On top of that, there will be servicing and component cost, which might be very expensive if the required component and service are not available freely apart from the original installer. In this respect, hydraulic elevators are well known for their low servicing requirements besides which their components are readily available from the hydraulic component trade. The number of components in a hydraulic drive are much less than in an equivalent traction drive and therefore, the chances of failure are also less.

4. The argument on danger to the environment

Accusing hydraulic elevators being dangerous to the environment is a false case. It is needles to say that the environmental awareness has always been the ultimate condition of hydraulic practice as it is in every manufacturing practice. Application of the existing Elevator Code EN 81-2 and related standards, as it should be, would sufficiently eliminate environmental problems. Liability of any incident regarding contamination of the environment belong to unqualified and amateurish constructers but not the hydraulic elevators itself. Besides, controlling proper application of the elevator code, not only for hydraulic elevators but also for the MRL systems, is the responsibility of the notifying bodies and the local authorities.

There are also developments such as jack leak monitoring systems and jack corrosion protections that can be applied by free will to increase preventative measures. While criticizing the use of 100 to 200 liter mineral oil, being stored inside the jack and the tank for the life time of approximately 10 years or more, it should be remembered that the same amount of fuel is used by only one vehicle in 1 month-time.

It is obvious that the use of biodegradable and fire proof hydraulic fluid eliminates completely the drawbacks of mineral oil due to unforeseen accidents. Today, biodegradable hydraulic fluids are available and the traditional mineral oil can be replaced by such environmental-friendly fluids, when it is required for particular environmental conditions, without regard for the initial cost.

Hydraulic elevator manufacturers also developed energy saving MRL systems in which a traction's mechanical counterweight is substituted by a hydraulic accumulator (hydraulic counterweight)[13]. With such a system energy consumption is found to be the same than the best traction MRL. In such a system, accumulators are utilized to collect pressurized oil during down travel and later this energy is used to help up travel with a smaller size motor. A biodegradable fluid is also replaced the mineral oil and the weight of the entire system is kept comparatively low. The energy saving hydraulic MRL system eliminates the arguments like high energy consumption and environmental concern totally at the expense of increased initial cost.

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5. Why hydraulic elevators are popular?

After 10 years, since MRL type traction elevators were introduced to the market with the intention of replacing hydraulic elevators, it appears that the use of hydraulic elevator is not declining but rather increasing. The popularity of hydraulic elevators not only comes from their inherent advantages but also their reliability and safety that they provide to their customers.

Even the technicians from major MRL traction manufacturers accept the complexity of their systems under emergency circumstances. Arming the elevators with local or global communication networks for rescue purposes would obviously fail when there are mass numbers of enquires after natural disasters. In comparison, the care-taker or the house-maid can be taught in minutes, how to release persons from a hydraulic elevator.

Other grounds for the popularity of hydraulic elevators may be listed in terms of the needs of installers and customers as below;

In terms of installers;

1- For low-rise buildings, installation takes less time.
2- The complete hydraulic system is available for installers to purchase and install at a competitive price.
3- Procurement of the replacement parts is easier and there is no monopoly to complicate servicing.
4- Hydraulic elevators consist of fewer components than traction elevators requiring less servicing.
5- Risk of accidents during installation is less with the use of safe machine room at the basement or at the first floor.
6- Hydraulic elevators with motor-pump drives are submersed in lubricating oil operate smoothly with minimum wear. Servicing intervals between repairs are longer then with traction type elevators.
7- Most effective for high load capacity requirements.
8- The load is carried by the foundations of the building and not by the less stable structure of the elevator shaft, a major factor in earthquake endangered areas.
9- Noise in the shaft is reduced with the existence of the machine room.
10- They are less sensitive to fire sprinklers and fire hoses in the hoistway.
11- Down speed can be increased at no cost since, the motive power for the down travel comes from gravity. This feature can provide faster passenger service.

In terms of customers;

1- Substantially lower initial cost of equipment and its maintenance: It is generally estimated that for elevators of comparable specifications, the initial investment is from 15 to 25% less than for traction installations[2]. A further economy is realized in the maintenance cost of the hydraulic elevator.
2- More effective building space utilization:
- The hydraulic elevator uses about 12% less hoistway area than the traction unit since, the extra room for the counterweight is not required for hydraulic units[14].
- Since the hydraulic elevator imposes no vertical loads on the building structure, column sizes can be reduced significantly in the hoistway area.
- Machine room location can be very flexible.
- It can be easily applied to the buildings without a shaft.
- It is suitable for installing in old buildings, where structural reinforcements to support the overhead loads imposed by traction elevator equipment would be costly and impractical.
- Hydraulic elevators are well suited for installations where future floors may be added to the building.
3- High reliability on failure free operation.
4- Involves no experts for rescue operations. Most emergency measures can be taken without entering the shaft or climbing to the top floor. Elevator controls can be adjusted without working in the shaft.
5- Considering the savings in fuel through fewer service calls required by hydraulic elevators, the total energy requirements of hydraulic and traction elevators are similar. The limited amount of heat

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generated by the hydraulic power unit during down travel can serve to temper the lower temperature in the basement of buildings, in which case there is potentially no waste of energy.

6. Conclusions

High energy consumption and environmental issues raised by MRL traction manufacturers against hydraulic elevators are not entirely reflecting the reality. The energy consumption difference between hydraulic and traction is insignificant provided that the number of floors and elevator traffic have been correctly assessed, and the power unit capacity of the hydraulic elevator has been properly selected. Using a counter-weight (where it is suitable) and balancing the travel time can bring the hydraulic elevator energy consumption to MRL level.

Applications of hydraulic systems are inevitable in many industrial practices. Unreasonably finding hydraulic systems hazardous to environment would also result in forbidding all industrial applications. Instead, more attention should be paid to inspection of the vertical transportation systems in use. Biodegradable-fire resistant fluids are other alternatives to the mineral oil and can be used easily if required.

Hydraulic elevators have unbeatable properties such as break-down free operation, low initial cost, easy installation and high comfort. Hydraulic elevators also have the best records in safety and servicing costs.

Finally, it must be remembered that the cost of servicing an elevator is much higher than the cost of operating an elevator. Services and spare parts for hydraulic elevators are freely available in the market without having enforcing contracts.

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