FEW MARKETING STATISTICS about hydraulic elevators indicate the wide use of this relatively new entry into the marketplace. Approximately 70% of all elevator units sold for new building structures in the United States are of the hydraulic type; about 70% of all hydraulic elevators for these new buildings are utilized in structures of 4 floors or less. Approximately 95% of all hydraulic elevators operating in the United States today are of conventional direct connected type. Its distinguishing feature is the single plunger jack installed underground directly under the elevator car. The accompanying graphic shows the basic arrangements of conventional hydraulic and geared traction elevators.

The statistics indicate that the hydraulic elevator is widely accepted by U.S. purchasers and is an important factor in the vertical transportation market. It has almost totally displaced the single- and two-speed traction elevator in 2 and 3 floor buildings.

**Hydraulic Elevator Advantages**

The hydraulic elevator offers building designers and users the following advantages:

1. **Substantially lower initial cost of equipment and its maintenance.**
   
   For a given application the traction elevator will cost approximately twice that of hydraulic equipment. Yearly maintenance costs will be in approximately the same ratio. For example a single 3 stop hydraulic passenger elevator having a capacity of 3500 pounds and a speed of 150 feet per minute would cost about $30,000 installed; a comparable traction elevator would cost about $60,000. Yearly maintenance costs would be about $1,200 for the hydraulic and $2,400 for traction.

2. **More efficient building space utilization.**
   
   a) The hydraulic elevator uses about 12% less hoistway area than the traction unit. In the example cited above, the hydraulic elevator would require about 30 square feet less floor space than would the traction. Cleaner roof lines are possible. An overhead machine room is not required for hydraulic units although some extension above the roof line is usually required in order to provide code required clearances above the top of the elevator car.

   b) Since the hydraulic elevator imposes no vertical loads on the building structure, column sizes can be reduced significantly in the hoistway area.

   c) Since the only mechanical connections between the machine room and the hoistway of hydraulic elevators are pipe and conduit, machine room location can be very flexible, usually anywhere within a radius of 40 feet from the hoistway.

3. **Most effective for high load capacity requirements.**
   
   When low-rise elevators are required for capacities of 10,000 pounds or more the advantages of the hy-
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4. Low cost, down speed increase. 
Due to the fact that motive power for a down traveling hydraulic comes from gravity, there are many applications where an increase in down speed is free. Although there are limitations such as control valve flow capacity, car buffer design, and pit depth, this feature can sometimes provide slightly better passenger service.

Hydraulic Elevator Disadvantages
Because of the many advantages offered by the hydraulic elevator, there is a tendency toward its misapplication. The consequences of misapplication can be costly and awareness of these limitations is necessary. The hydraulic elevator does have limitations as outlined:

1. Because of control, power requirement and structural considerations, the conventional hydraulic elevator is seldom applicable for speeds exceeding 150 feet per minute, or for travels over 40 feet although some manufacturers recommend speeds up to 200 feet per minute and travels up to 60 feet.

2. Performance of hydraulic elevators becomes erratic as the oil in the hydraulic system varies in temperature. Oil temperatures can drop in the systems of hydraulic elevators which are lightly used. Temperature will rise in installations subject to heavy use. Machine room operating temperatures must be controlled in order to help reduce oil temperature variation. Ambient temperature control is also very important if microprocessor control is utilized.

3. The underground pressure system of the hydraulic elevator is not accessible for visual safety and leakage inspection. Chemical and electrolytic erosion may result in leakage underground and a “blow-out” is a possibility.

4. Since the hydraulic elevator has no safety device to prevent its falling it depends wholly on the pressure in the hydraulic system to maintain its position in the hoistway. A “blow-out” in the underground system may allow free fall of the elevator car.

5. Leakage in the underground system can inject oil into the ground surrounding the leakage point causing possible pollution of a public water supply.

6. The motor horsepower required for hydraulic elevators is from 2½ to 3 times greater than that required for traction elevators of the same speed and capacity. Despite the fact that the hydraulic elevator motor only runs in the up direction its energy consumption is at least twice that of a traction elevator in an identical application. The electrical service to the hydraulic elevator must be considerably larger than the traction in order to avoid the nuisance of “light dimming” and the even more serious consequences of voltage drop in the building power supply.

7. Unknown costs of installation and maintenance are major considerations in most hydraulic elevator systems. The drilling of the hole required for the hydraulic jack assembly involves risks of encountering underground obstructions and possible added cost general-

ly passed on to the purchaser. Many hydraulic elevator maintenance contracts exclude the costly replacement of underground components.

8. The deceptive simplicity of the hydraulic elevator often attracts new and, possibly, incompetent installation contractors and service organizations. A careful check of previous installations by a prospective contractor and the choice of firms which do good work and provide good products and service is an important prerequisite.

9. The hydraulic elevator is an inherently high heat producing device since all of the energy expended by a descending hydraulic elevator is converted to heat and higher oil temperatures.

Hydraulics Of The Future
Properly applied the conventional hydraulic elevator of today will do a satisfactory and economical job and can be installed and maintained with the normal skills available in the industry. There are, however, increasing pressures from consumers and code authorities for changes in current design to meet new safety and environmental requirements.

Underground Hydraulic System
The underground pressure system of the conventional hydraulic elevator is vulnerable to chemical, mechanical and electrolytic attack which can cause leakage or rupture of the system and the possibility of an elevator fall, or pollution of public water supply. Many preventive measures have been developed and some are currently in use to reduce corrosion of the underground hydraulic system. The most common precautions consist of special wrappings placed on the metal components of the system to isolate them from ground fluids or soil which might cause deterioration. Small electrical charges have also been applied externally to neutralize electrolytic activity. Plastic auxiliary casings and high dielectric strength backfill compounds have also been used successfully for jack protection. The big problem which remains, however, is that there is no effective method of easily and economically inspecting that part of the system which is imbedded in the ground. The obvious approach is to put all of the hydraulic system above ground where its condition can be determined at all times by visual inspection. There is a simple “fix” for the hydraulic piping since it can be installed overhead almost as easily as underground. Installing the jack above ground, however, is more difficult since it must be positioned in such a manner that its lifting force can be applied to the elevator car. For some very short travel applications the conventional single plunger jack is placed above ground at the side, front or rear of the elevator car, and the lifting force applied at the top of the car structure instead of underneath. Although this design has been used successfully for the last 10 or more years, its limited travel capabilities make it impractical as a universal solution to the problem of eliminating the underground jack.

The use of two and three stage telescoping jacks has progressed to the point of practicability despite their relatively high cost. These systems meet most American code requirements, and are available for travels encountered in virtually all low-rise applications. The telescoping jack does, however, require more gaskets and seals thus producing more chances of seal failures and leakage or blow-out.

“Multiple roped indirect hydraulic elevators” have been used in many European countries for some period of time. This arrangement actually lifts the elevator with wire rope powered by the hydraulic jack through a series of compounding sheaves. This same principle was used on high rise water
powered hydraulic elevators in the United States during the late 1800s and early 1900s, many years before the advent of the traction elevator drive. While this design does eliminate the necessity for an underground system, a speed sensing governor and a rail applied safety device are required. The roped arrangement is capable of providing service for higher rises and at higher speed depending upon future development. Cost impacts are unknown at this time.

**Excessive Horsepower**

The horsepower of the conventional hydraulic elevator must be adequate to lift not only the load in the car, but also the entire car weight as well. The traction elevator motor on the other hand must lift only 60% of the load on the car due to counterweighting. For example, a 3,500 pound capacity traction elevator motor would be required to supply adequate torque to lift a net load of about 2,100 pounds. Assuming that a hydraulic elevator of the same lifting capacity (3,500#) has a car weight of 3,200 pounds the elevator motor must handle 3,200 + 3,500 or 6,700 pounds. The hydraulic elevator motor will thus be required to provide approximately 3 times the output of the traction elevator motor, assuming that speeds and efficiencies are the same. (In actuality the efficiency of the hydraulic is somewhat higher.) The approximate horsepower requirements in the example given would be 40 for the hydraulic and 14 for the traction based on a car speed of 150 feet per minute. The yearly cost of electric power for the traction would be about $540 per elevator and $1,700 per elevator for the hydraulic based on an average cost of 8 cents per KWH.

The frequency of starting the elevator motor during a peak period could be as high as 4 times per minute based on each stop requiring about 15 seconds. Such operation on a hydraulic elevator with a 40 HP motor usually requires reduced voltage starting equipment. This leads to a time disadvantage of the performance of a hydraulic elevator since it usually takes about 3 seconds to start the pump motor before elevator movement. Motor starting on elevators is not done until hoistway doors are closed and locked. For a comparable traction elevator this time delay is usually less than one second. High starting currents required by hydraulic motors can cause voltage "sag" in a small building power supply unless the incoming electrical service has adequate capacity to handle very large amperage.

There are several possible approaches to reducing hydraulic elevator horsepower requirements only one of which appears to be cost effective. Hydraulic horsepower requirements are dependent on three factors, the actual weight of the car and its accessories, the lifting capacity and the speed. Specification sets the requirements for capacity and speed. The manufacturers alternatives to reduce horsepower are to reduce car weight through design techniques and use of lighter weight materials, to partially counterweight the elevator car and its accessories or to provide an accumulator system which will store energy produced by the down traveling elevator, and return it when the car travels up. A great deal of work has been done in reducing car weight through better structural design, but much remains to be done in the area

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of lighter materials. Code regulations, however, are a limitation as to the type of materials which can be utilized since they must meet both fire-proofing and structural requirements. Counterweighting appears to be a costly alternative since it will entail major changes in the motive power plus the added cost of the counterweighting system. 

**Temperature/Performance Problem**

Three critical factors in measuring elevator performance are (a) the rapidity and (b) comfort with which it travels from one stop to the next, and (c) the accuracy with which it stops at and maintains floor level under all loads and temperatures regardless of travel direction.

Complete consistency in these characteristics is required in order to achieve high quality elevator operation. Today's hydraulic elevator requires stable oil viscosity in order to provide satisfactory performance. Since oil viscosity varies with temperature hydraulic elevator performance unfortunately does likewise. On busy elevators it is not uncommon to find oil temperatures varying from 50 degrees to 170 degrees F or more. Such variations produce widely fluctuating quality of elevator performance at different times of the day depending on the use of the elevator. One manufacturer has alleviated the temperature variation problem to some degree by supplying heat energy to the oil in order to eliminate lower temperatures. The heat energy, however, is supplied by operation of the elevator motor to recirculate the oil whenever thermostats indicate a drop in oil temperature in the reservoir. This approach obviously increases the number of motor starts required resulting in higher operating costs, more wear and tear on the equipment and other undesirable factors.

A second approach to the solution of this problem lies in the use of a flow control valve which will produce constant oil flow regardless of oil viscosity change by use of closed loop servo control. Such devices have been used in foreign markets with varying degrees of success. They have been introduced in the United States by an American manufacturer.

**Summary**

The modern oil/hydraulic elevator is currently an excellent, low cost solution to the problem of vertical transportation in small low-rise buildings, and in those applications requiring very large capacities, slow speeds and short travel. It does not seem likely at this point in its development that it will ever be suitable for high-rise, high speed installations, although some development is being done which may permit modest increases in travel, and perhaps speeds.

It would be short sighted not to consider the possibility that new lower cost geared traction elevators may ultimately replace hydraulic equipment in the low-rise market unless solutions to some of the hydraulic problems are found. This is particularly true in light of the increasing restrictions and demands in the environmental control and energy conservation practices in the United States.

In conclusion, it might be helpful to provide examples of good and poor applications of hydraulic equipment with the realization that special situations should always be explored where advantages seem possible.

**Good Application Examples**

1. Two, three, and four floor office buildings with net leasable space up to 100,000 sq. ft.
2. Two, three, four and five-floor apartment buildings with up to 200 apartments.
3. Small hospitals, clinics and medical buildings up to three floors.
4. Low-rise industrial buildings requiring freight or automated material handling elevators of from 1,000 to 125,000 pound capacities.
5. Governmental office buildings up to four floors and 150,000 net sq. ft.
6. Basement or garage shuttle elevators in major buildings.
7. Passenger/Service elevators in malls.
8. Handicapped elevators supplementing escalators.
9. Stage lifts.

**Poor Application Examples**

1. Most department stores.
2. Hospitals over four floors.
3. Structures requiring over 45 feet of elevator travel.
4. Structures where hole drilling has obvious high risks.
5. Buildings where power costs are very high, or where power supply is limited.
6. Buildings where the elevator is exposed to the elements.
7. Buildings where continuous and severe demands for elevator service will exist.

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