EXPERIENCE WITH MODIFICATIONS TO PATERNOSTER TYPE LIFTS

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1. Introduction

The "paternoster" lift was invented in the country where the industrial revolution began.

In 1876 a precursor was used to transport post and parcels through the various floors of the General Post Office in London.

Seven years later, in 1883, so much progress had been made that it was used for conveying passengers. In 1885 the Hamburg merchant Freiherr von Ohlendorff built the first paternoster in a Hamburg company building.

Using a paternoster meant emancipated travel free from state patronage. The general introduction of paternoster lifts required a petition from the Association of German Engineers (VDI) to the Chancellor of the Reich and the state governments in 1907: "The Association advocates the more general introduction of paternoster lifts as the conventional passenger lifts where a single cell moves up and down are no longer able to cope with the large volume of passengers!".

The gazette of the building authorities was still able to write in 1908: "Moreover, paternoster lifts are not only more efficient than single lifts but also safer and cheaper to install and operate!".

The paternoster lift does not require a lift-man.

In addition, it does not need a safety gear.

It is not suspended by ropes but rather the individual cells are attached to heavy band chains. They run in closed guideways and in an emergency, such as breakage, they become load-bearing support elements. A special sliding stirrup prevents the drive chain from slipping if it breaks. The paternoster lift does not produce any significant dynamic inertia forces as is the case with other lifts.

The electric drive rating required for the motor is small, amounting to about 2.5-5.0 kW.

The acquisition costs of paternoster lifts were higher but the running costs much lower.

After 31st December 1973 passenger circulation lifts were no longer allowed to be built in accordance with paragraph 28 of the Federal Lift Regulations dated 28th March 1972.

In 1972 when paternoster lifts were banned, there were roughly 800 paternosters in daily service. This compared with 120,000 lift installations in Germany between 1960 and 1970, the proportion of paternoster lifts accounting for only half a percent.

The ban on new installations did not mean that the existing paternoster lifts had to be suddenly shut down; the paternoster is suffering a slow death and dying out gradually.

Measured per one thousand lift installations, the accident rate for paternoster lifts is ten times higher according to TÜV statistics.

As a consequence these figures meant the death knell to paternoster lifts, the official death-blow.

Altogether we have eight paternoster lists, and most of them have coped excellently with vertical passenger transport for over 40 years.

During the maintenance and TÜV inspection of one paternoster lift installation substantial defects were discovered in the drive chain and in the drive gear wheel. A cost comparison - repair of the existing old paternoster against a new passenger lift - clearly showed that in the long run it appeared advisable to dismantle the old paternoster and install a new passenger lift.

Then the key question arose: "Do we build two small passenger lifts in the existing lift shaft or do we take the opportunity to install merely one larger passenger and goods lift?".

I personally had the opportunity of talking to Dr. Joris Schröder from Schindler in Lucerne about this problem.

Dr. Joris Schröder had been very involved for many years in transport calculations for lifts.
After considering numerous ideas and holding discussions with the works engineer and the porter it was decided to install one large lift in the old shaft.

It became a wide-car lift. A two-part, centrally opening automatic shaft and car door with a width of TB = 1200 mm and a height of TH = 2,100 mm was selected.
This new lift can now be used to transport stretchers, desks and cupboards.

2. Rail Attachment

After inspecting the old paternoster shaft, we were confronted with the following problem: "Can we re-use the old rail attachment stirrups in the brickwork for the new lift?"

How do you check these old attachments in the brickwork?

If the old attachments can no longer be used, what solutions are currently available?

An order was placed for a passenger and goods lift with a load capacity of 1500 kg, corresponding to 20 people, and an operating speed of 1.6 m/sec.
The Technical Directives for Lifts TRA 204.3 states:
"The guide rails must be dimensioned so that they withstand the operating loads and the catching forces. In the case of brake catching gears (which we need and use) a two-fold factor of the weight force of the car and useful load is to be taken as the catching forces when safety gears are installed on the car".

The same is demanded in the European Standard EN81-1 only in different wording:
Our question was:
"What forces act from the guide rails on the attachment stirrups in the wall?".
We did not obtain a direct answer from the safety guidelines for lifts "SR guide rails".

I still remembered from my previous experience with the design and calculation of shaft frames for lifts that about 8-10% of the vertically acting force is taken as the horizontal force.

Therefore:	carrying force	Q =	15000 N
	car	F =	15000 N
	Q + F	=	30000 N
	10% of (Q + F)	=	3000 N

We build a pulling gear for ourselves. We slung a rope around the left and right attachment stirrups. We installed a pressure gauge on the rope and produced a tensile load of 3000 N using the mechanically activated pulling gear. During the initial tests we even achieved a pull of 6000 N. (Fig. 1).

All the frame stirrups were tested for tension in this way.
All tensile tests on the old stirrups showed that they were still fastened stably enough in the wall to accommodate the new potential loads.

When the frame stirrups in the wall withstood the optimum tensile load, we were able to assume that any possible compressive and shear loads on the stirrups would also be withstood as the compressive and shear loads on the brickwork would be accommodated considerably better.

This tensile test is only an aid but it does provide an approximate reference basis for testing an old stirrup in the shaft wall.

An additional study of the forces in accordance with the "SR - guide rails" showed that we had an adequate safety margin with our loads for this paternoster modification project.

We assumed that the loads of the lift car and the useful load are introduced directly onto the rails and then directly onto the stirrups, which means that the guide shoe and the safety gear act at the level of the rail stirrup (refer to Figs. 2 and 3).

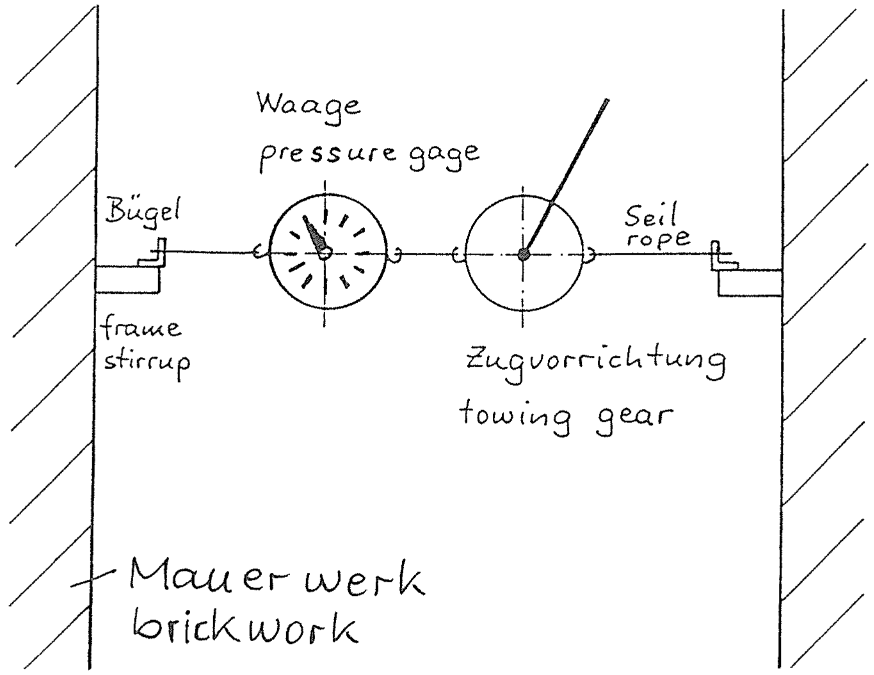

Figure 1: Tensile test

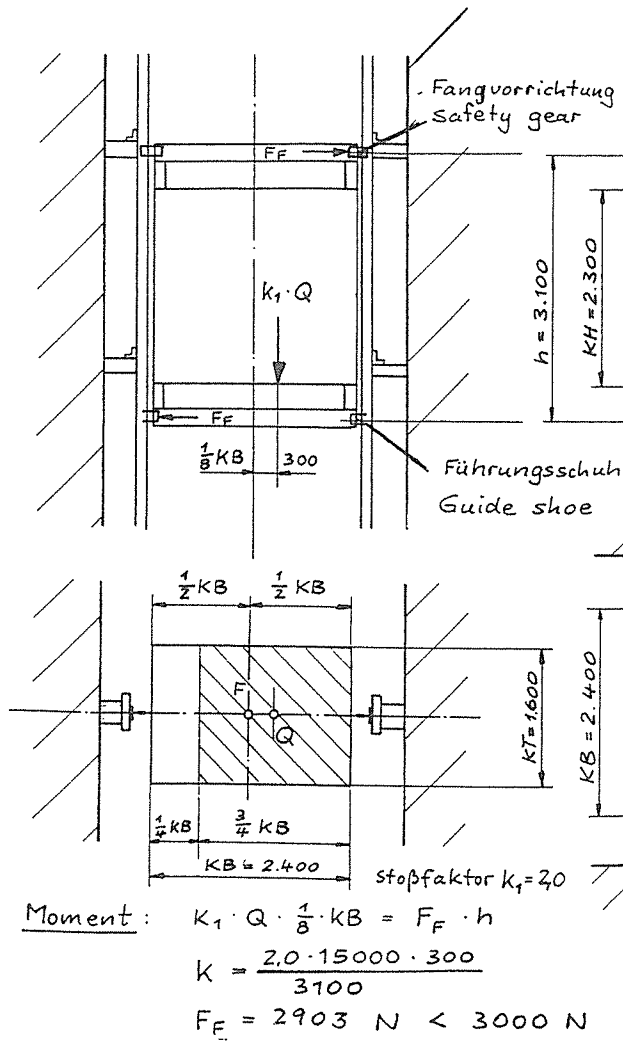

Figure 2: Loads during operation

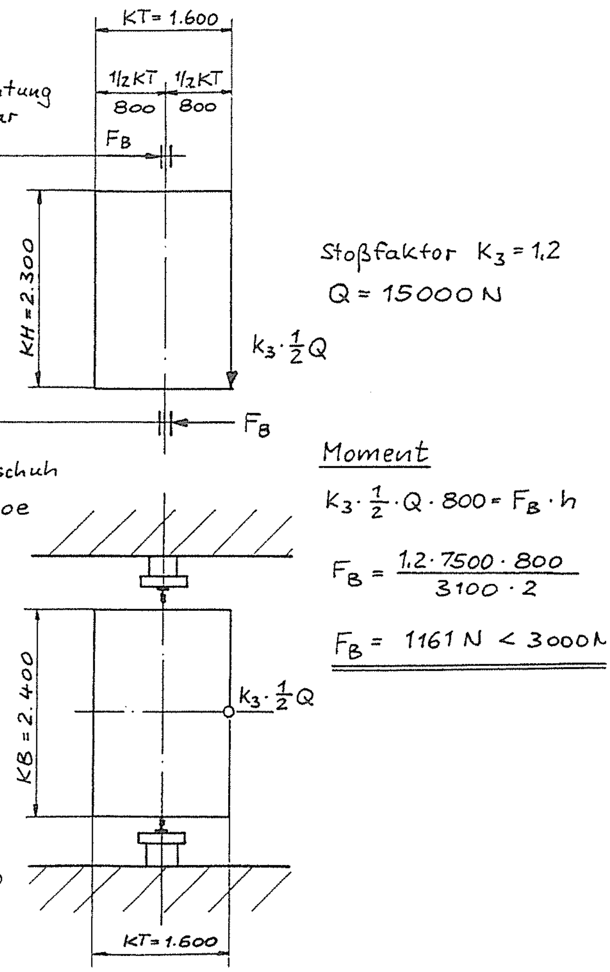

Figure 3: Loading

3. Results

With the aid of this tensile test on the old rail attachment stirrups we were able to say for each stirrup that it would withstand the loads of the new goods lift. After the TÜV acceptance test with the successful catching test we heaved a sigh of relief as we had thus saved a lot of time and unnecessary expense.

If our tensile tests had failed (and the rail stirrups had become detached from the brickwork), we would have had to develop other attachment possibilities for the stirrups.

1st possibility
A shaft frame with four corner angles is installed in the old lift shaft. The frame stirrups can be bolted or welded to the vertical connection girders required.
This would have entailed a longer installation time with substantial additional costs.

2nd possibility
Instead of the old attachment stirrups the brickwork is joined on the right and left with two steel plates and four bolts. The new stirrup can be then bolted or welded to the steel plate.

This method is very expensive and we would have been confronted with considerable difficulties in our modification project.

In Germany plugging in brickwork for dynamic loads is not permitted, forbidden, which means that this possibility was not even considered.

4. New Rails

Three loading possibilities for the lift car guide rails are to be considered for the lift car.

1. Normal travel
The car is loaded with the maximum load. During car travel only minimal forces act on the guide rails through the four guide shoes in the case of slideways or the four roller guideways.

If the car is well balanced and the lift ropes are suspended at the centre of gravity of the car, the loads acting on the guides rails and thus on the rail attachments are low and can be disregarded.

2. Loading of the lift car

If the car is loaded from one side, the loads are always in one direction only. In the event of through-loading, i.e. loading from two sides, the loads act on the rail and thus on the attachment stirrups on both sides.

We were able to establish that in the case of lift cars with high load capacities of about 6.0-7.5 t the short rail stirrup in the brickwork loosened slightly after many years. Surprisingly, the large stirrup for the counterweight with its counterweight rails withstood the loads much better when the car was loaded. Perhaps the counterweight stirrup is, after all, slightly more elastic and thus the impacts which occur during loading are not so severe and are not transferred directly to the two stirrups on the counterweight.

3. Catching the lift car

The highest load on the guide rails and thus on the pertinent rail stirrups occurs during the prescribed catching tests.

In our example the attachment stirrup was designed and installed in 1940 for the paternoster lift with Q = 150 kg.
In 1991, roughly 50 years later, these stirrups withstand ten times this load (new installed lift Q = 1500 kg).
We also modified a goods lift which in 1951 had a load capacity of Q = 500 kg.
In 1991 the lift was modified and given a new and higher load capacity of Q = 2100 kg in accordance with the TRA and EN81.

We also checked the attachment stirrups using to the tensile method described before.
We were able to establish that both attachment stirrups in the wall readily withstood a roughly four-fold increase in the load capacity during catching.
It is quite amazing what a well-secured stirrup in brickwork can withstand and what loads it can absorb.

5. Safety Gear

In 1743 a lift was used for the first time to convey people from one floor to another.
The safety lift, which comes to a standstill when the rope attached to the lift car breaks, was invented by the American engineer Elisha Graves Otis in 1853 and demonstrated by him in the New York Crystal Palace. Otis said at that time: "All safe, gentlemen, all safe!".
The wire rope was invented in 1834 by the senior mine inspector Albert from Claustal in the Harz Mountains.
As can be seen from the photograph, one of Otis's assistants broke the rope attached to the lift car in two with an axe. It can be assumed with great certainty that the attachment rope was a hemp rope.

Mice and rats used to bite these ropes, weakening their cross section. As a result Elisha G. Otis invented the first so-called safety gear for the lift car.
If Elisha Otis had used a wire rope for his lifts, which he could not have cut in two with an axe and which could not have been bitten by mice and rats, I believe that developments would have taken a different turn.

Elisha Graves Otis personally demonstrated his automatic safety gear in 1853.

Today, after almost 140 years, we still use the same safety gears in the event of any possible rope breakage; they act on the lift car guide rails although nowadays no lift rope can be destroyed by rodents any more.
If lifts exhibit "a good design", as J.A. Nederbragt put it in his interesting paper at INTERLIFT 1991 in Munich, the safety gear can be dispensed with.

Here in this country, the Netherlands, a different approach was adopted with great success.

The rope brake was invented here which has been successfully installed on more than 500 lifts.
I would like to mention the following as an example:

In our high-rise building with eight passenger lifts all the lift car guide rails had to be renewed.

Owing to the many and often unnecessary catching tests the guide rails had become deformed, i.e. bent. Several attempts to re-align these catching guide rails failed as the rails had lost their stability.

The cost of the new rails together with the necessary dismantling and re-installation work amounted to about half a million marks. Was this conversion work necessary?
Is it not possible to save these costs and considerable assembly time with "good and better designs"?

I believe that we are all required to courageously adopt new approaches and to work out an improved safety system with "good designs".

For the TÜV acceptance test every lift is subjected to a catching test. A goods lift with a load capacity of 5000 kg and through-loaded with two car doors 2500 mm wide and 2500 mm high caught on one side during this catching test.
Both car doors were damaged.
This damage was caused by a non-uniform response of the safety gear.
The catching wedges were drawn in by the speed limiter, rope, catching lever and catching shaft.
It is almost a miracle if both catching wedges of the brake safety gear on a large lift car with a high load capacity are activated uniformly.
I think that in this case hydraulic activation of the catching wedges could provide assistance. The benefits would be:
"Uniform activation guarantees reliable engagement of the catching wedges".
In Germany we have about 40 million cars with hydraulic brake activation.

In 1955 I passed my driving test in a Volkswagen Beetle with cable brakes. Braking with the mechanical cable brake always caused problems. Nowadays, an accurate brake system has been developed, ABS or anti-blocking system, which has an optimum braking performance owing to its oil-hydraulic activation.
I wish that lift safety gears were also further developed in order to obtain uniform and precise engagement of the brake wedges and thus a safe brake path.

The blocking catching gears should be discounted owing to the high forces which act on the rails, causing subsequent deformation. After every catching test the rails have to be repaired and reworked. It is really a paradox because development of the safety gears came to a halt 140 years ago but with the electric lift controls incorporating microprocessors we are already in the 21st century whereas with the safety gears we are still in the 19th century. Do serious accidents have to horrify the lift world before a long overdue change or modification is introduced?

For the sake of completeness I would like to mention that it is considerably more expensive to dismantle a paternoster lift than a normal passenger lift.

The front shaft wall side, the access side, is completely open from the bottom to the top after dismantling and has to be subsequently lined. This also results in substantial additional expense.

The new passenger lift car has been provided with vandal-proof steel enamel sheeting on the walls. Now, after one and a half years it can be said that the new lift was well-received by the house occupants.

Finally, I would like to add that the floor load also had to be checked in view of the new and higher load capacity of the lift.

The bottom floor in the machine room did not need to be reinforced as a bearing floor.

The loads acting on the shaft pit also had to be checked.

6. Conclusions

Finally, I would like to draw your attention to a very rare paternoster accident which occurred between last Christmas and the New Year.

We know paternoster accidents which can occur during the transport of ladders. A young women is said to have entered a paternoster lift with a pram. The pram turned over, the child fell out, and both mother and child were not injured but three cabins were damaged.

But back to our curious accident. A young man was given a new and expensive racing bicycle as a Christmas present. He had to go to work but he was afraid to leave his new bicycle in front of the house. So he decided to take his racing bicycle into the office on the 4th floor using the paternoster lift.
By the 2nd floor the bicycle was already totally ruined and four cabins were completely demolished.
What had happened?
On entering the cabin on the ground floor the man was unable to keep the bicycle still while up-ended. The bicycle scraped against the wall, became jammed and the young man saved himself by jumping out of the moving cabin - lucky he did so. The bicycle and four cabins were completely destroyed. The young man merely suffered from shock.
The accident sounds unbelievable but it really did happen.

You can understand how paternoster lifts can cause serious accidents when they are used and loaded incorrectly.