Is load testing during initial acceptance inspection still the contemporary method?

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ABSTRACT

§ Do **traditional load tests** still fit in the 3rd millennium?
§ What are the precise objectives of load tests in elevator codes?
§ What exactly are the conclusions?
§ Is there a better alternative?

For decades the elevator industry has been relying on **load tests** as a proper proof, that the installation of new elevators meets the specification. However, in the last decade elevator technologies were rapidly changing, high tech and sophisticated transducers are playing an ever increasingly significant role. Nevertheless, traditional load testing was retained unchanged. The German TUV has developed methods to replace all load tests by modern measurements of safety relevant physical parameters. This method exactly quantifies the available safety features and provides excellent documentation of test results. No-load acceptance tests with the TUV method are considered the better solution, practiced not only in Europe but also abroad.

1. INTRODUCTION

All over the world elevators have to pass an initial acceptance inspection before they are put into service and thus can be used by the public. With such a commissioning test the installer has to provide proper evidence that all specified safety aspects and code requirements are met. For many decades the elevator industry has been relying on traditional load tests as a substantial proof, that the newly installed elevator meets the specification.

In the last decade, common elevator technologies have been rapidly changing. Now, high tech and sophisticated transducers are playing an ever increasingly significant role. Nevertheless, traditional load testing procedures have been retained unchanged, being a part of the code-of-practice almost all over the world. Why have modern technologies so far not had an effect on testing procedures hitherto existing? Are commissioning tests not considered essential enough to request here the adaptation to the state-of-the-art as well?

In many fields of industry, it is a well-established method to verify the safety of a component or its fitness for use by testing it at an extent which is significantly above the rated load condition. According to this principle, the elevator industry had defined load tests to cover particularly the two crucial safety aspects “traction” and “safety gear application” many decades ago. The passing of both the traction and the safety gear tests are most important for the overall safety of the elevator. Traditionally, these aspects have to be verified by means of load tests, before the elevator is put into service and can be used by the public.

This paper concentrates on discussing the previous methods and new existing alternatives for conducting these tests. The applicable code requirements for the testing procedures are based on the European Lifts Directive 95/16 /EG and the standard EN 81 part 1.

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2. DEBATE ON PRINCIPLES OF THE PREVIOUS TEST METHODS

This paper concentrates on discussing the two most important applications of load testing.

2.1 Traction test

Traction is the capability of a traction drive elevator that its ropes are driven by friction in the grooves of the driving sheave. The safety codes specify for a safe elevator operation both a minimum and a maximum value.

The determination of the traction factor is depending on the effective ratio of the rope forces on either side of the traction sheave (rope forces of car's side to rope forces of counterweight side). Sufficient traction prevents a slippage of the ropes on the traction sheave. In principal, the friction must be high enough to prevent the ropes slipping on the traction sheave if the elevator car is loaded with rated load. Usually, the determination of the traction is based on a calculation as specified in the code. However, in practice the effective available traction is influenced by various aspects, which are not covered by calculation, such as rope construction, type and amount of lubrication, material of sheaves and ropes, manufacturing tolerances, balancing of car weight and counterweight, etc.

Consequently, the adherence to the fundamental traction requirement had traditionally been proved during the commissioning of the elevator by means of a load test. The percentage of the required overload in the car is stipulated in the applicable elevator safety code or standard. The elevator standard EN 81, part 1, Annex M specifies a minimum traction requirement of 125 %, which means the elevator car loaded with a total of 125 % of the rated load must securely come to a stop when travelling down. The former German TRA elevator safety code had a more stringent requirement and stipulated to conduct the traction test with 150 %. It is unquestionable that this test had proved a higher level of safety, and as a result the number of incidents due to low traction had been significantly lower.

To determine the traction, an approach can be also made for the ratio of the rope forces of the counterweight side to the rope forces of the empty car side. Due to different masses on either side, a travel of an empty car upwards results in a traction ratio of more than 100 % on the counterweight side. For elevator cars with constant rated load, the traction is getting higher if the elevator cars are lighter in weight. For cars with a balancing of 50 %, the applicable formula concludes a traction factor of even more than 125 % (see Figure 1).

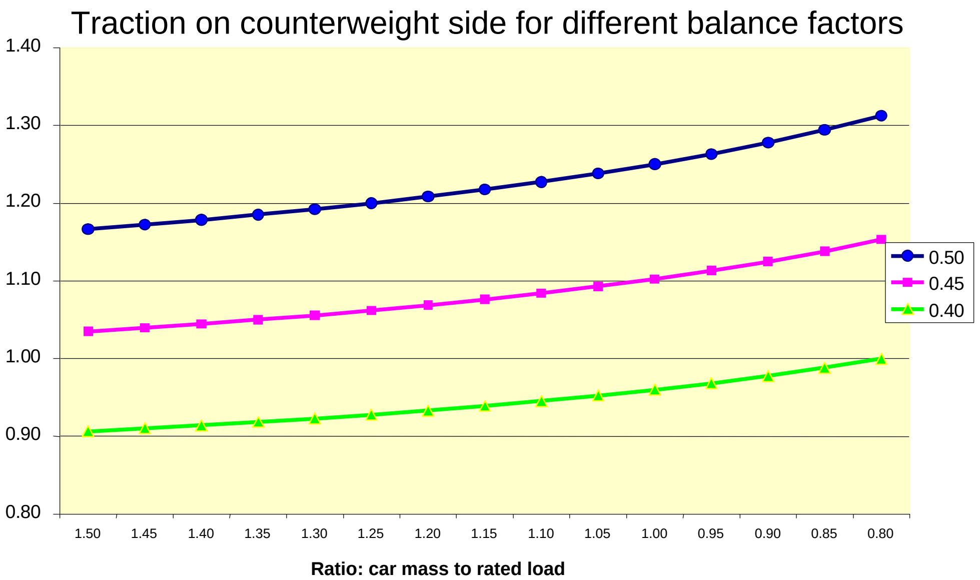

Figure 1: Traction factors for an empty car travelling upwards against mass ratio

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Therefore, the travel of the counterweight in downward direction without any slippage of the ropes can be considered equivalent to the traction test as per Annex D of EN 81 with a descending car loaded with 125 % rated load. Consequently, such a load test cannot prove any additional safety compared to an ascending empty car.

For proving that traction is not too high, no load is required anyhow. For this purpose, the empty car must not be raised when the counterweight rests on the compressed buffers.

As a matter of fact, 25 % overload for a traction test usually is very easy to meet for new elevators. Otherwise, the initial traction value of a new elevator will decrease over the time due to wear and tear. So, it would be desirable to verify that a new elevator has got a significant higher traction, and thus increasing the confidence level.

2.2 Safety gear test

The safety gear is the ultimate safety device of an elevator. In compliance with the EN 81 the aim of the load test before being placed on the market and putting into service is to check the correct mounting, correct setting and the soundness of the complete assembly, comprising car, safety gear, guide rails and their fixing to the building. The test shall be made while the car is descending, loaded with 125 % of rated load and travels with rated speed.

Furthermore, the code specifies that for progressive safety gear the average deceleration in case of a free fall of the car, loaded with rated load, shall lie between 0.2 and 1.0 g. These two limits had been defined in order to make sure that on the one hand a minimum braking force is bringing the fully loaded elevator car to a full stop within a reasonable stopping distance, and that on the other hand a maximum deceleration prevents passengers in the car from falling and getting hurt.

There is neither any code requirement for the deceleration of an empty car nor for a load of 125 % rated load in the car. Moreover, the code does not exactly define how to verify for the commissioning test if the prescribed permissible range of deceleration between 0.2 and 1.0 g is met. And it is hardly possible to conclude from a test with 125 % rated load to the free fall condition.

From the legal point of view, safety gears have to pass a compulsory type test before they are allowed to be used as a safety component of an elevator. However, the correct function of the safety gear on site is not only depending on the manufacturer's appropriate adjustment of the spring forces, but reflects also various parameters on site, such as machining of the guide rails, lubrication, etc. Hence, in spite of a type approval procedure that both covers safety and reliability issues, a verification of the correct settings during the initial acceptance testing is essential.

In case of a load test the effective average deceleration of the car is usually less than 1 g. As the counterweight is decelerated by gravity (1 g) it is thus coming to a faster stop than the elevator car. Therefore, rope forces of the counterweight are constantly contributing to stop the loaded car. Thus, the load test condition cannot cover the prescribed free fall criteria of the EN 81. The safety gear test is terminated in a fraction of a second; just witnessing the test can hardly provide any exact and useful information. All modern quality assurance methods stipulate, however, that a proper documentation all test results must be provided and objective evidence can be given that specified criteria are met.

As a matter of fact, the safety gear test with 125 % rated load does not permit any statement if the prescribed range of deceleration for the worst case scenario (100 % rated load in a free fall) is met. Measurement of an impression of the safety gear slide on the guide rails can only allow limited conclusions. That means, a safety gear test with (over -) load in the car is absolutely inappropriate to verify the evidence of conformity with the safety code.

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3. HOW TO MEET CODE REQUIREMENT WITH ALTERNATIVE METHODS

For more than 10 years the German TUV has been using the PC-driven ADIASYSTEM method to replace any periodic statutory load tests on elevators. Meanwhile there is a track record of more than a million of periodic elevator tests. Due to that vast practical experience gained with no-load testing method, the TUV Industry Service · TUV South Group is offering the ADIASYSTEM testing and evaluation procedure for the commissioning tests of new elevators. There are several articles available in the public domain, describing the fundamental issues of this method, how to apply this method for periodic inspections. So it is not necessary to repeat those details here, but to concentrate on describing the application of the method for commissioning tests. Again, this method is making up to date measurements of safety relevant physical parameters, is exactly quantifying accessible safety features and provides an excellent documentation of test results.

Due to the soundness of many convincing arguments, the no-load commissioning tests using this method generate more and more interest, not only in Germany but also abroad.

3.1 Traction test

The concept of the ADIASYSTEM traction test is to measure an additional rope force, equivalent to a load in the elevator car, and to check if this force is causing a slippage on the traction sheave. The test is conducted on just that one rope, which has the lowest tension on the counterweight side and so presumably has the lowest traction. Therefore, this testing procedure does absolutely have no risk of overstressing any of the elevator component parts. In practice, it is very easy to increase the rope force, and going beyond the 125 % load criteria, until a sufficient high traction is achieved. Typically, TUV's inspectors always check that a traction factor of at least 200 % is achieved. This significantly increased acceptance requirement does not only compensate for a simplified testing procedure on just one rope and missing dynamic issues, but is resulting in having a noticeable higher level of confidence than specified in the safety code.

Of course, rope forces can be easily further increased until the fixed rope starts slipping on the traction sheave, which means measuring the maximum friction or quantify the obtainable traction. Measurements on real elevators show that often the available traction exceeds even 400 %, which means the effective load in the car could be 4 times the rated load, and the friction is still high enough to prevent slippage of the overloaded car. This kind of information enhances the competence of the inspector, as the test result allows for an accurate conclusion of system immanent parameters. So far, the traditional load test does not provide any concrete quantifiable measuring results, but only permits a pure Yes-or-No decision and can never identify any existing safety reserves.

In cases the ADIASYSTEM traction test does not exceed the 200 %, TUV asks its own inspector to repeat the traction test on all ropes, and calculate the overall average value, to decide if the 125 % acceptance criteria is met or not met. As mentioned before, almost all elevators are passing the 200 % test. As a consequence, the very small percentage of the new elevators installed, which do not meet this requirement, need additional attention, and it is important to make use of a method that can easily identify those having insufficient safety features.

For all types of traction elevators including machine-room-less elevators, all sizes and products from all manufacturers the ADIASYSTEM traction test can be conducted. In case the mounting of the rope force measuring device is not possible on the car side, the test can be also conducted on the counterweight side. Then, the initial traction value for the empty car, before increasing the rope force on the counterweight side is already 100 % or more, as displayed above in Figure 1. The method is also applicable to elevators using belts as a means of suspension, as specific fixing devices are available, too.

The ADIASYSTEM does not just verify if only a 125 % load criteria is met, but can easily quantify the excessive traction reserves, regardless of the rope construction, the type and amount of lubrication, the material of sheave and rope or manufacturing tolerances. Findings of the actual measurements are suitable for a proper documentation.

3.2 Safety gear test

For the further discussion, it is important to comprehend the design of a progressive safety gear. This device is generating a constant braking force to the guide rails, regardless of the load in the elevator car and regardless of the speed. More mass loaded into the elevator car or a higher speed cause a longer stopping distance and a longer stopping time. The constant braking force however causes a constant average deceleration over the stopping time. To a large extend, this theory is also verified by empiric measurements, showing a slight increase of the average deceleration over the overall stopping time, subject to thermal and speed influences on the friction factor. The correct determination of the average deceleration of the empty car is prerequisite for the next conclusions.

Usually, when a safety gear stops an empty elevator car, the deceleration is more than 1 g. In this case, the counterweight is just decelerated by gravity (1 g). The different stopping speeds of elevator car and counterweight cause slack ropes between these components for a short period of time, until the elevator car comes to a stop. In this short period of time, the only forces affecting the elevator car are the braking forces of the safety gear. Therefore, an empty elevator car usually stops as in a free fall. To meet that assumption it is essential that all devices that contribute to a fast stop (machine brake, rope brake, etc.) have to be deactivated for the safety gear test.

The deceleration measurement of that quasi free fall records all different factors having an influence on the friction to the guide rails, such as lubrication, temperature, speed, etc. The assessment is based on the effective average deceleration, from the time when the safety gears are fully engaged until the car comes to a full stop. Also the requirement of the permissible deceleration in the EN 81 is a mean value over the overall stopping distance.

A data logger is used to record the deceleration of the empty car. This information is downloaded to a PC, converted into a diagram and analysed by the ADIASYSTEM software, calculating the average value of the actually measured deceleration. In addition the program predicts the deceleration for the rated load condition, assuming the same braking forces of the safety gear have to stop the mass of the elevator car plus the rated load. So the forecast of the deceleration for the rated load condition is based on common physical terms. Both values, the measured empty car as well as the rated load deceleration, are displayed by the program (see Figure 2). In addition the following information is unchangeably saved together with the measuring values: date and time of measurement, serial number of used device, measuring rate, measuring range of sensor and elevator mass parameters. This data is like a fingerprint of the measurement and is a substantial part of the documentation.

A free fall of a car with rated load marks the worst case. As the consequence the EN 81 code specifies compulsory deceleration requirements for this very condition, and the verification of the correct setting of the safety gear during the commissioning test is considered of prime importance. ADIASYSTEM is the only available method to conclude if the above code requirements are met.

As demons trated in empiric tests, the braking forces of the safety gear are largely independent of the speed. The ADIASYSTEM algorithms make allowance for that aspect and predict equivalently if a safety gear test is conducted at a lower speed than the rated speed. In practice, safety gear tests using this method are usually performed by tripping the empty car at rated speed. However, a reduction of the test speed is recommended for a rated speed > 2 m/s, in order to prevent a vigorously bouncing counterweight.

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Whenever a safety gear test shows that the acceleration of the empty car is less than 1 g, the theory of slack ropes effective on the car when coming to a stop is no longer met as imprecise rope forces from the counterweight might contribute to stop the car. Empiric tests for the approval of the method conducted in Germany in the early 1990s proved that due to the short duration of the test, the high rotating masses and particularly when a high traction value of more than 200% is available, no influence from the counterweight had been detected. Thus, the same algorithm is also applicable. For typical new elevators with a relation of rated load compared to the car mass, the empty car deceleration however must be always more than 1 g.

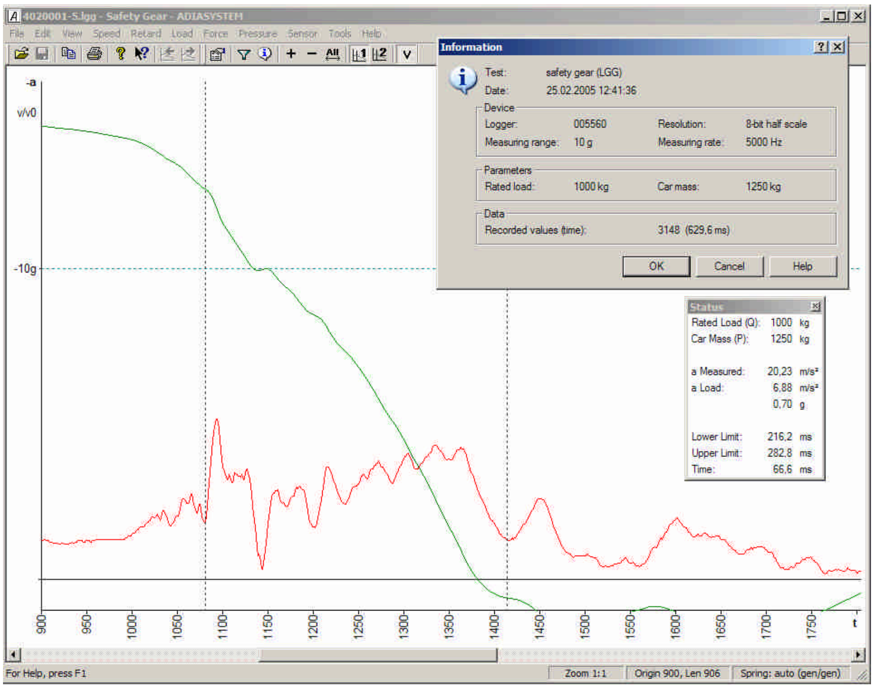

Figure 2: Findings of a safety gear test

For the calculation of the rated load deceleration the knowledge of the elevator car mass is required. Often this particular information is not available. The ADIASYSTEM tool kit includes specific devices to measure the exact weight of the car and counterweight, up to 4,000 kg. That means all correct elevator system parameters can be measured, in order to provide evidence that code requirements are met or not met.

Apart from the correct setting of the safety gear the EN 81 stipulates the load test also to check the correct mounting, and the soundness of the complete assembly. Again, the progressive safety gear always generates a constant braking force, which means also the forces to the guide rails and brackets remains the same, regardless if the car is loaded with 125 % of rated load or is empty. If the car is loaded, much more kinetic energy is to be absorbed, causing more wear and tear, the stopping distance and duration are longer, but the effective forces remain almost constant. The strain to the car itself is even higher for the empty condition, as the empty car comes to a full stop at a higher deceleration. So, to cover these issues a 125 % load test does not make sense.

It is undisputable that load tests may cover further aspects not discussed above, which cannot be replaced by the ADIASYSTEM method. The most frequently heard argument is that the mechanical strength of the elevator car, particularly the stiffness of the floor, is not tested. That is right. However, it has never been the intention to require a load test as a proof of the mechanical stability of the floor. Furthermore, nowadays elevators cars are repetition parts that need no verification of the basic design all the time. Also the elevator installers' claim, that they do not need a load test for making their adjustments, such as correct levelling with rated load. That means if the alternative methods of the ADIASYSTEM are applied during the commissioning test, there is virtually no reason left to require a load test.

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4. LEGAL ISSUES

As mentioned before, the application of load tests during the initial acceptance testing is prescribed in both the European Lifts Directive as well as in the harmonised standard EN 81. In general, the Directive only defines general essential health and safety requirements. In spite of the fact that it is desirable to have standards harmonized at European level, it is explicitly stated that such standards retain their non-binding status. That means, whenever a load test is required in the Lifts Directive its application is compulsory. However, in case the EN 81 specifies conducting a load test, alternatives methods can also be applied.

The Lifts Directive is in principal offering different so-called modules for declaring conformity. TUV as a notified body is referring to Annex X (Unit Verification), as this annex is not mentioning load tests at all: "The notified body must carry out the appropriate tests as set out in the relevant standard(s) referred to in Article 5 of the Directive, or equivalent tests, to ensure its conformity with the relevant requirements of this Directive". That means a notified body has the option to conduct alternative tests in order to ensure conformity of the elevator with the relevant requirements of the Directive, provided the testing method has been approved to be at least equivalent in quality, effectiveness and safety to the rules intended by the code. TUV is using the ADIASYSTEM as an equivalent method to the load tests accordingly. Furthermore, reference to alternatively conduct equivalent tests is made in Annex IV, Final Inspection, and in Annex XII, Product Quality Assurance for Lifts as well.

5. CONCLUSIONS

Measurements of safety relevant physical parameters using a sophisticated PC-driven method can provide significantly more authentic results than traditional load tests. The result of the measurement reflects all actual effects of the particular elevator having an influence on the finding. In contrary, load tests just permit simple Yes-or-No decisions that can never generate quantitative findings. The presented method particularly generates accurate results in figures or a diagram, which can be easily used to verify if the code requirements are met or to quantify safety reserves in the system. All findings are generated electronically and thus are excellently suitable for documentation purpose . Especially the documentation of the commissioning test is quite important for reliability and warranty issues.

The ADIASYSTEM safety gear test is the only method to conclude at all if both the free fall condition and the specified permissible deceleration limits are met. As the test comes to conclusions with an empty car and/or a reduced speed the kinetic energy to be absorbed is significantly less compared to a full load test, and thus it is less destructive.

In all industries traditional methods are changing if new, better and more advanced methods are becoming available. Load tests do no longer represent the state-of-the-art for an initial acceptance test of an elevator.

REFERENCES

(1) European Council and Parliament Directive 95/16/EC of 29 June 1995 (Lifts Directive)
(2) EN81-1 Safety rules for the construction and installation of lifts. Part 1: Electric lifts

BIOGRAPHICAL DETAILS

Alfons Petry graduated with a Dipl.-Ing. degree in mechanical engineering at the Technical University Aachen, Germany. He is an expert engineer authorized by the Bavarian State Ministry of Labour, Munich. For more than 27 years he is accomplishing various assignments within the TUV South Group, being today Director Innovative Systems of the TUV Industry Service.