Computer-aided Measuring, Testing and Recording of Safety-related Lift Data

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ABSTRACT

For several years the German inspection body TÜV has been using its "Advanced DIAgnostic System for lifts" (ADIAS), when inspecting traction-driven lifts. The method is based on the assessment of safety-related parameters of a lift by means of special gauges, a data logger and a computer. The lift-manufacturing industry,which faces the demand for product liability, is interested to give evidence of safety parameters after installation. The new, modified version of ADIAS for manufacturers can fulfil that requirement, as it can measure, test and record all relevant lift data. It is an excellent tool to investigate and document all kind of travel, speed or acceleration curves as well as the setting of the safety gear.

1 Scope of Computer-aided Applications Regarding Lifts

Only a few applications are available on the market that combine the capabilities of portable computers with suitable procedures for lift testing or organising lift data. Most software programs concentrate on providing a data bank for handling the essential lift data, for both administrative and economic purposes, or for making reporting about inspections more efficient.

A completely different approach is the **ADIAS** method. (The abbreviation ADIAS in the German language means **Aufzugs-DIAgnose-System**, in English **Advanced DIAgnostic System for lifts**.) ADIAS was developed by the German inspection body TÜV BAYERN some five years ago. In this case, a portable computer together with specific measuring instruments and the appropriate software are used for diagnostic purposes of a lift. During testing safety-related data are measured and processed in a fast calculation to obtain test results with high accuracy. The results can be easily stored and can give a proper evidence of compliance with specified acceptance criteria.

The objectives for developing ADIAS reflect the demands by the German Technical Lift Inspection Code, particularly to the prescribed **load test** at statutory periodic inspections of lifts once every two years. Test weights in the car are required to give evidence of

- the available **traction** of a traction drive lift
- the efficiency of the **car safety device**

The transportation of test weights is time-consuming, costly and troublesome. Consequently, the ADIAS was developed to replace the required load tests. Today, the ADIAS method is officially approved by the national German Lift Committee for statutory lift inspections and is practised by all TÜV lift inspectors for the periodic examination of traction drive lifts on principle.

2 Advantages of Computer-aided Tools

The scope of the ADIAS features goes far beyond the replacing of the load test. The significant advantages of the application of the ADIAS method were identified very soon by lift manufacturers as well as lift maintenance companies. In response to the strong interest, a modified version of ADIAS was created to be used by the professional staff of lift companies. This version specifically fulfils the demands by the lift industry. Its features are the subject of this paper.

The whole set of hardware and software of the modified version is named

PROFESSIONAL ADIAS TOOL KIT (in the following referred to as **PAT**).

PAT is a completely new measuring, testing and documentation method to assist lift professionals when they carry out installation works, tests or maintenance operations. The advantages of the new system include, but are not limited to the following aspects:

- Measuring current and relevant lift data with special digital gauges.
- Assessment of specified design criteria, giving clear indications of the actual values / deviations compared to specification.
- Recording and saving of test results on the PC's hard disk for documentation purposes.
- Recorded measurements can be easily compared with previous test results.
- Recorded measurements give proper evidence whether the specification's warranty requirements are fulfilled or not.
- Investigations of very specific tests, such as the measurement of component parts to verify the proto type test results.

3 Documentation of Test Results

The entirely new aspect of PAT is not only that it specifies the results in exact figures, it also provides user-friendly modern testing equipment and at the same time an excellent tool for proper documentation of the test results.

Special consideration is to be given to this last aspect. Manufacturers and maintenance companies have to respect the requirement of documentation of test results to fulfil their product liability. The documentation of all results in internal certificates is a principal demand in all quality assurance systems. The companies also need this documentation in order to give evidence that they have carried out tests and their results. The documentation is an important proof that may become necessary in case a damage occurrs. Only with the existence of the certification the company can show that it had fulfilled its duties.

4 Features of PAT

The PAT method provides hardware and software modules not only to replace the above-mentioned load tests. Moreover, it covers several additional features for the measurement, testing and recording of a great variety of

- **distances**
- **speeds**
- **loads**
- **decelerations**
- **voltages**

The hardware necessary to carry out these tests includes a compatible notebook PC, a microprocessor-based data logger for the deceleration measurement and digital gauges for the measurement of distances and forces. Everything fits in an equipment kit of only 8 kg weight.

The following points give a brief summary of the most essential testing procedures:

4.1 Distance Measurement

For distance measurements use is made of an electronic meter gauge with a revolving roller. The rubber lining of the gauge's roller is applied from a fixed point against a running rope and thus delivers the travel pulses. The resolution of the device is 0.5 mm. Three different types of measurements are available:

4.1.1 Travel

With the software module "Travel" the travel of a lift can be determined. As the triggering in this program is mainly carried out through the keyboard, all distances that the lift has covered between two key strokes can be measured.

4.1.2 Brake Distance

The program "Brake distance" determines the distance which the car moves after the brakes are locked (or at the moment the voltage at the brake magnet is switched off). This means the total braking distance, including the delay period caused by the engagement of the brakes. The measurement is initiated by a trigger signal from the clamps of the brake magnet or the ground connection at the end of the safety circuit.

4.1.3 Odometer

With the "Odometer" option the meter gauge can be used for all kinds of distance measurement. When any key is pressed, the actual distance covered starting from this point (added or subtracted) is immediately displayed on the screen.

4.2 Speed Measurement

Also for speed measurements use is made of the same meter gauge. The computer clock serves as reference time for the speed calculation. The measurements are based on stipulated short-time periods. The computer first counts the pulses of the meter gauge and then calculates the speed from these pulses. The following three alternatives are available:

4.2.1 Triggered by Keyboard

The program "Speed - triggered by keyboard" determines the speed of the car at the very moment at which a key is pressed. The average speed of the next 500 msec is determined and displayed on the screen. If the finger is kept on the key, the speed is constantly shown for subsequent intervals of 500 msec each.

4.2.2 Triggered by Switch

In the program "Speed - triggered by switch" the car's instantaneous speed at the moment of a closing or an opening of a switch is determined. Hereby the average speed of the following 50 msec is calculated. A typical field of application for this part of the program are measurements at which the triggering pulses are generated by the control, for example "levelling speed with open door".

4.2.3 Speed Diagrams

In the case of many applications it is interesting to investigate the speed-time or speed-distance behaviour of the lift car. The module "Speed diagrams" provides a tool for the analysis and documentation of all kinds of speed diagram, triggered by keys or switches. This module can for instance be used to examine a riding cycle between two landings in order to evaluate the quality of the ride, or to check the function of the overspeed governor. The triggering point can set a mark in the diagram, for example at the moment the "door open" contactor is released. So it is possible to identify particular events within the diagram.

4.3 Load Measurement

Load measurements are used to investigate the available traction of the lift. The program offers the choice of testing the traction at the car side or the counterweight side. In addition, with load measurements the balance of car weight and counterweight can be checked.

As the available traction characterises one of the fundamental safety aspects of a traction drive lift, the procedure of the traction test is outlined in the following in greater detail.

4.3.1 Traction Test at the Side of the Car

Traction sheaves are subject to tear and wear. A slightly changed groove shape can alter the friction factor and reduce the traction significantly and cause an accident. It is impossible to recognise insufficient traction by pure visual inspection of the sheave. Therefore, the findings of the traction test are essential for a serious assessment of the lift's safety.

The software module "Traction (car)" and the PAT hardware can replace a traction test with an overload in the car. The traction calculation is based on the force of one rope that is measured by means of an electronic force meter gauge.

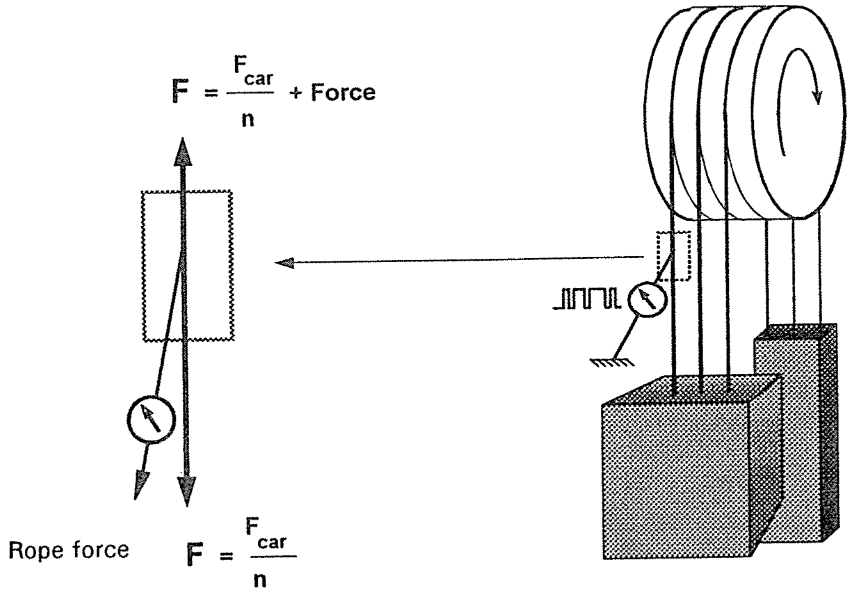

Figure: **Traction test with PAT**

For the determination of the traction with the PAT method the maximum transferable force of one rope on the side of the (empty) car is measured. This rope force is used to calculate the traction of a car loaded with rated load for the complete system with all ropes. In practice, one rope is fixed to the building. Then the force in this rope is increased by moving the car "UP" until this rope starts slipping in the groove of the traction sheave. The measured additional force in this rope is calculated for the total traction of the car.

The findings of testing with PAT verify: If the lift is loaded with "X" kg (which is "Y" times the rated load), the car will start slipping from a standing position; or including the effects of a dynamic coefficient: If the car loaded with "X" kg is moving "DOWN", it will not come to a stop position again.

The essential advantage of the traction test with the PAT method is that the result of the traction is not restricted to one specific load condition (for example the loading of the car with 1.5 times the rated load). The rope force of the fixed rope can be increased continuously until it starts slipping in the groove. This point is used to calculate the system's maximum available traction:It gives a clear indication of the total available excess safety reserves.

4.3.2Traction at the Counterweight Side

In case no measurement on the car side is possible, the traction test can also be carried out analogously at the counterweight side by the program "Traction (counterweight)". In this caseof measurements at the counterweight side the entry of car mass is, however, necessary for the conversion of the forces. Errors can occur if exact data about the car mass are not available.

4.3.3 Balance

With this software module the lift's half load balance can be determined. The testing procedure of the balance is very similar to the traction test. The force meter measures forces as in the traction test: the brakes are released and the dead centre is established by turning the hand wheel. This dead centre is reached when the turning of the hand wheel requires the same force for both directions (internal slack can be felt). The balance is calculated and shown on the screen as rated value, percentage value and as deviation from the standard.

4.4 Retardation Measurement

In both the German Lift Code TRA 102 and the European Standard EN 81 the permissible decelerations for a car loaded with rated load are specified: the range is between 0.2 and 1.4 g in case of TRA, and between 0.2 and 1.0 g in case of EN 81 respectively.

Previously, the compliance with these specifications had been only verified with extensive high-tech measurements during proto type tests of the safety gears. In periodic statutory inspections the safety gear had to be capable of stopping a car (carrying the rated load) at rated speed by gripping the guides. However, no stopping distance could be specified and no statement was possible, whether the deceleration complied with requirements. So the findings of this test were limited: In case of an engagement of the safety gears, the car loaded with rated load would not fall (example: break-down of the transmission). The findings did not cover the free fall of the car (breakage of the suspension devices).

Therefore, a reliable and efficient device for everyday deceleration measurements was needed. To master this application, a sophisticated microprocessor-controlled data logger with an integrated acceleration sensor was developed as a part of the PAT system. As it can be used for various measurements, its operation is explained in greater detail.

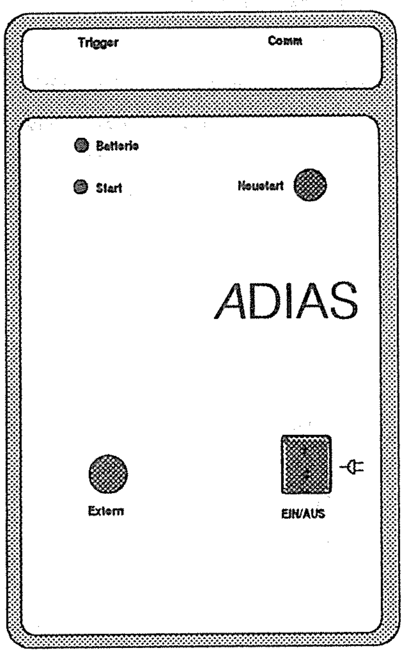

Figure: **Data logger**

4.4.1 The Data Logger ADILOG

The data logger is a sensitive high-tech measuring instrument, very accurate and uncomplicated in use. Its weight is only 0.35 kg. The acceleration sensor used (piezo-capacitive type with a good overload capacity) measures in vertical direction with only slight lateral sensitivity. The frequency response is 0 - 1,000 Hz. The sensor has a measuring range of +/- 10 g with a linearity distortion of less than 1%.

It is available with a memory capacity between 32 kB and 1 MB. The measuring frequency can be set between 0.1 and 5,000 Hz. The memory can be divided to store individual events of at least 1 kB measuring values, each one organised as a separate ring buffer memory. So in case of the 1 MB version up to 1,000 different measurements can be recorded and stored at the same time. The logger has also a port for other external sensors to make it suitable for all kinds of measurement.

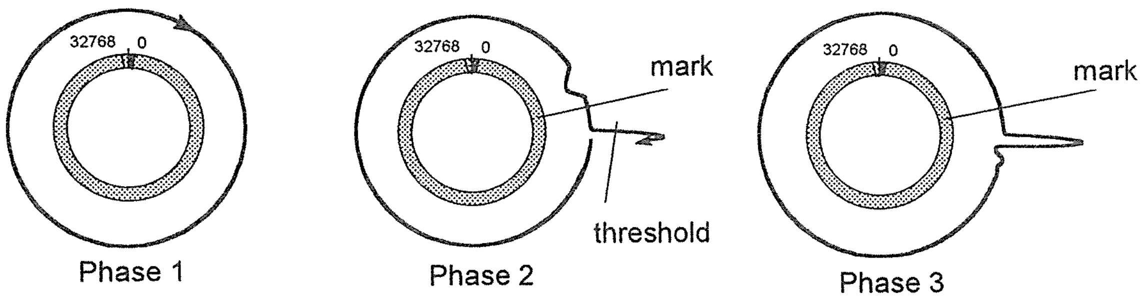

Figure: **Ring buffer memory**

The function of the ring buffer memory is as follows: After the logger is switched on it measures the acceleration and continuously writes the measuring values into the ring memory (for example with a capacity of 32,768 Bytes (phase 1)). As soon as the measured value exceeds a certain threshold value (the set value when switched on is +0.56 g, at standard position it is 1.56 g, due to gravity = 1 g) a mark is set (phase 2) and the memory is only filled up to 1,024 values before this mark (phase 3).

4.4.2 Safety Gear Test with the Data Logger

With PAT the exact course of deceleration during the safety gear test is evaluated. Special consideration is given to progressive safety gears - the only permissible type for speeds of more than 1 m/s. During the safety test the empty car is clamped at rated speed. Simultaneously, the logger is measuring and recording the car's deceleration. After the test the collected data are analysed and evaluated. The PAT software calculates the deceleration of the empty car and in addition the corresponding value for a car with the rated load.

If the safety gear is correctly adjusted, the deceleration of a safety gear test with an empty car will always be more than 1 g. As this will cause the counterweight's jumping, only the mass of the car is effective on the safety gear. This short moment "car without counterweight" is used for the analysis, as this situation is equivalent to a free fall of the car. Thus, the finding of the safety gear test can indicate whether in a free fall of the lift the car (loaded with rated load) is decelerated within the permissible limits. Then in all less severe cases (load < rated load, or no free fall) the car would certainly come to a stop.

In order to be able to analyse the actual safety gear operation, the beginning and the end of the safety gear test in the safety gear diagram have to be marked with limits. These limits can be easily set and moved to the correct position in the curve by means of the cursor keys. To facilitate the setting of the upper and the lower limits, the speed curve can be superimposed on the deceleration curve. The numeric values beside the lower and upper value indicate the time (in msec) which has passed since the recording started. The value in the origin represents the number of measuring points at this place.

As soon as both limits are set, two additional values will appear on the screen. The value a_{empty} (m/s^2) indicates the average deceleration measured in case of the empty car between both limits, The figure a_{loaded} (m/s^2) is the value calculated for the car loaded with rated load, in the case of a free fall. This value has to comply with the deceleration requirement specified in the codes. The following figure shows a typical deceleration curve, with the speed curve superimposed and both limits marking the operation of the safety gear:

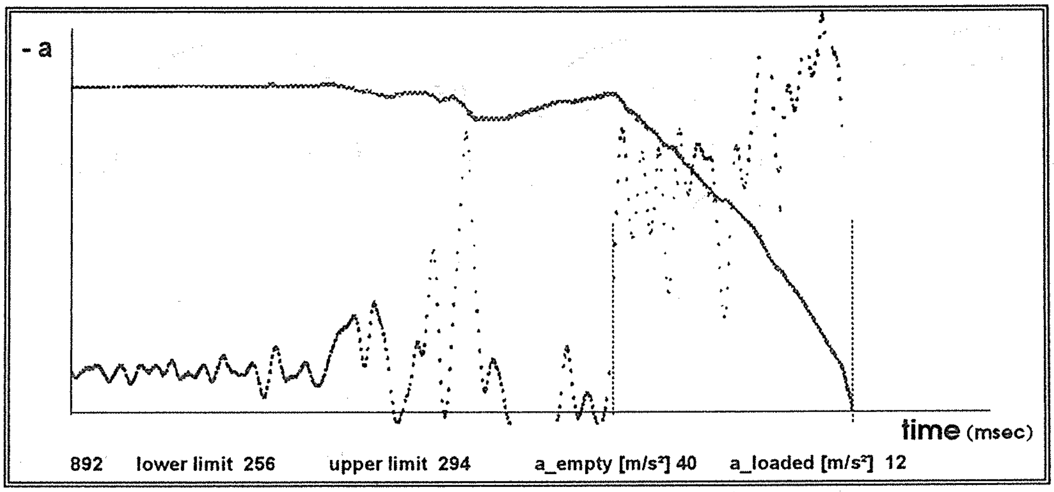

Figure: **PC screen with deceleration diagram**

The program makes it possible to store measured safety gear test data on the PC's disk as well as to load and evaluate curves which were formerly saved. All necessary instructions for the operation are given by the program.

The deceleration curves shown in the diagrams are easily understandable. The exact sequence and functioning of the engagement of the safety devices can be recognised. In spite of the simple graphic representation extensive findings are possible. Each type of safety gear can be identified by specific characteristics in the deceleration curves.

Of course, the testing technique with the data logger can be used for similar applications whenever deceleration measurements are required, for example in case of type examinations of safety gears or of buffers.

4.4.3 Acceleration Measurements along a Travel Distance

With this program the data logger is used to measure accelerations of +/- 10 g along various kinds of travel distance. By connecting up the external sensor ports with three loggers the acceleration can be measured in three dimensions. This kind of measurement can be used to evaluate the quality of the travel.

4.4.4 Vibrations

With this module the logger can be used to measure any kind of vibration within a range of +/- 10 g. The measurements are in the real-time mode.

4.5 Voltage Measurement

4.5.1 Voltage Tester

The voltage tester provides a simple but useful tool to check with the trigger lines whether there is any voltage or not, for example at the contacts of the control.

4.5.2 Oscilloscope

With a special electronic sensor attached to the external port the data logger can store voltage data like an oscilloscope. If the logger is directly connected to the PC, it can work like an oscilloscope in the real-time mode (future option).

5 What are the Benefits for the User?

With PAT lift engineers or mechanics have an efficient tool to provide exact test results that are figured out and can be easily compared for compliance with the standard. They depend no longer only on their know-how and experience as well as on the result of the visual inspection for a yes-or-no-decision.

Test results are measured and recorded, and can be saved or printed or compared with previous results. Thus, the lift company can give evidence and better fulfil its product liability in case of doubts or claims.

Proper documentation is a must for any quality assurance system. With PAT the traceability and relationship of particular test results to one specific inspection are easy to realise.

PAT applications cover a wide range of tests. It can also simplify very sophisticated tests that previously required large sums of money for measuring techniques.

The system kit contains a modern, fully compatible computer of notebook size. For the needs of PAT only a small percentage of the PC's total storage capacity is used. This means the PC can also be utilised for other software programs that can help to make lift testing more effective, more productive or better organised. Individual solutions can include programs for example for word processing and data bank applications as well as for a statistical analysis.

The PAT software and the operational environment are very user-friendly. No computer or programming knowledge is expected. Depending on individual preference, the environment offers the choice of simply pressing a single key, of working with pull-down menus or using a trackball (or mouse) for the same function. Operational guidance, necessary parameters and results are displayed on the screen. For all actions a comprehensive context-sensitive help function is available. In certain cases acoustic beep signals give additional indications.

The existing hardware and software modules provide plenty of additional applications for many aspects that are not specified in detail in the lift code. There are many cases when it is very helpful if more accurate test data can be made available, for example for type approval verifications, research & development, damage investigation, ...

Additional software modules are already available or will be available soon:

- Text string tracing program for fast searching in text files (specifications)
- Hardware test auxiliary program
- Meter gauge program
- Data bank for principal lift data
- Data bank for documentation of test results
- Design review calculation complying with EN 81 and TRA (German lift code)
- Vibration measurements
- Calibration verification

6 Future Aspects

In the near future in "intelligent" buildings all safety-related functions will be constantly monitored. This also includes data of lifts. The recording of these data will be similar to the way it is done with PAT. Lift manufacturers realise they have to put more emphasis on conformity with these modern technologies. Their obligations to product liability, their commitment to quality assurance and their need for a method to document safety-related lift data demand modern hardware and software solutions that can meet these requirements.

Biography:

*Alfons **Petry** graduated with an MSc degree in mechanical engineering (Dipl.-Ing.) at the Technical University in Aix-la-Chapelle (TH Aachen), Germany in 1977. He is an officially authorised expert engineer by the Bavarian Ministry of Labour, Munich. In 1987 he received a postgraduate certificate to be a quality assurance expert engineer. For more than 15 years he has been employed with TÜV BAYERN, Munich; during that time he has been entrusted with different responsibilities, such as shop inspections and expert opinions for the Material Testing / Quality Assurance Division, co-ordination of international activities for the TÜV BAYERN Group, marketing & sales for the Lifts & Cranes Division.*