Ascending car overspeed protection

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ABSTRACT

Ever since counterweighted traction lifts have been built, uncontrolled movements of the car in the upward direction have occurred owing to electrical or mechanical faults.

This paper discusses the physical constraints and critically reviews the possible and available safety devices to deal with this problem. The review considers the requirements of the relevant safety standards and codes.

1. HAZARDS OF UNCONTROLLED UPWARD MOVEMENTS OF THE CAR

The first traction sheave elevators with a counterweight were built around the year 1900. The counterweight balances out the entire weight of the car as well as a part of the rated load – generally approx. 50%. This achieves sufficient traction on the sheave in both directions whether the car is full or empty. In addition, the torque that has to be transmitted is reduced, and consequently a smaller drive system can be employed.

Since this time, however, it has been possible for a car containing less than 50% of its rated load to be pulled upwards by what is then the heavier counterweight. The normal elevator safety gear, which only comes into effect if the car is travelling downwards, offers no protection for this eventuality!

The following hazards arise in the event of uncontrolled upward movement of the car:

A. If the car starts moving with the door open, any of the occupants trying to save themselves by leaving the car may become trapped between the front edge of the car floor and the lintel of the hoistway door. Alternatively, they may lose their balance when jumping from the car and fall into the elevator hoistway.

As protection against this second hazard the apron underneath the car floor has been extended to 75 cm (in Germany this occurred with the introduction of EN 81 [2] and with the amendment of the TRA 200 [3] regulations in the same year, 1986).

B. If the car moves upward, it vacates the opening of the hoistway door. There is then a danger that someone approaching the elevator hoistway may fall in. For this reason EN 81 [2] has demanded a device (spring or weight) which ensures that the hoistway door closes automatically whenever the car moves more than 25 cm upwards. This is another regulation that has been adopted from TRA 200 [3] – in 1992 in this case.

C. If persons are in the car during uncontrolled upward movement, they will be accelerated upwards with the car. The car does not reach a standstill until the counterweight lands on its buffers or runs up against the hoistway ceiling. The level of danger to which the occupants of the car are exposed varies according to the speed that can be achieved.

The speed achieved varies in proportion to the initial speed (whether the acceleration is from rest or from the rated speed), the magnitude of the acceleration (the greater the difference in weight between the car and counterweight, and the smaller the masses that have to be accelerated, the greater this acceleration will be), and the height of the hoistway; it also varies in inverse proportion to the frictional losses.

One spectacular accident on a building site in Toronto, Canada in August 1987 involved the car of the site elevator accelerating upwards over 42 storeys due to a break in the traction sheave shaft. When the car hit the hoistway ceiling, two of the five occupants were killed while the remaining three survived with severe injuries [6]. As a result of this accident, the Canadian regulations were changed in June 1990. Since then safety devices to counter unwanted upward movement of the car have been demanded.

Evaluation of the 171 incidents of unwanted upward movement of elevator cars reported in Germany's accident statistics from 1972 to 1992 [7] reveals no such necessity. Only one of the reported accidents has had fatal consequences; the victim was trying to leave the car at the time. One of the main reasons may lie in the fact that buildings in Germany are considerably lower.

2. POSSIBLE SAFETY MEASURES AGAINST UNWANTED UPWARD MOVEMENT OF THE CAR

Unwanted upward movement of the car may occur regardless of the type of elevator drive system. It is of no consequence whether the drive system uses ropes and traction sheave, chains or belts, hydraulic systems, frictional wheels, or a linear induction motor on the car or counterweight. Wherever a counterweight is used, unwanted upward movement of the car may occur.

It is therefore justifiable that the European Lift Directive [1] in its essential health and safety requirements (Annex I) should contain a general stipulation to prevent uncontrolled upward movements of the car. The Canadian safety regulations for elevators [5] also require safeguarding measures "on every counterbalanced elevator, where the counterbalance exceeds the mass of the empty car".

EN 81-1 [2] only contains design standards for electrically driven passenger and freight elevators with traction, drum or chain drives. As counterweights are only permitted for traction sheave drives, the regulations concerning unwanted elevator movements in EN 81-1 therefore only refer to traction sheave elevators. As this is the most common type of drive for elevators, the remainder of this study will primarily be concerned with the safety problems of traction sheave elevators.

2.1 Prevention of uncontrolled upward movements by appropriate design of the counterweight

As already mentioned in the Canadian regulations, it is possible to design the counterweight so that it is not heavier than the car. This is the safest method of preventing unwanted upward movements but does require greater traction from the sheave and a doubling in size of the drive system. For this reason it is only used for small rated loads and speeds.

As the frictional losses of the lift system also counteract the upward movement, the counterweight can be increased by a corresponding amount (approx. 10 to 20 % of the rated load). However, then only the losses in the hoistway may be considered because if the drive shaft breaks, for example, the losses in the drive system will not have any effect!

2.2 Direct measures for preventing unwanted upward movements

As the benefits of better traction and reduced energy consumption make it advisable to design the counterweight with approx. 50% of the rated load, another possibility is to reduce the counterweight to the car weight when an unwanted upward movement occurs. This eliminates the driving force for a further upward movement and the frictional losses bring the car and counterweight to a standstill.

There are several options here: a part of the counterweight can be separated by a trigger mechanism, which is then retarded during the fall. Alternatively, the counterweight can be partially filled with sand or water, and in an emergency the filling flows out into the hoistway.

The counterweight must then be rendered operative by the installation engineer before the elevator can be put back into service.

2.3 Indirect measures for preventing unwanted upward movements

There is also the option of employing additional measures to alter the weight ratio between the cabin and counterweight. A range of such measures has been proposed and patented – for the purpose of saving energy. One example of this is US Patent No. 3,845,842 [8], which proposes moving a chain or quantity of liquid stored on the counterweight to the car via a device in the machine room: the counterweight becomes lighter, the car becomes correspondingly heavier and the driving force for the upward movement is eliminated. The same device can then be used to make the elevator ready for operation again.

A similar effect can in fact be achieved by coupling a mass to the counterweight so as to reduce its load; hydraulic means or an electric motor can also be used to bring about this load reduction.

2.4 Safeguarding measures during the occurrence of unwanted upward movements

EN 81-1 [2] assumes that the car is first accelerated upwards without the cause being remedied, and only when overspeed has been reached are additional safety devices intended to counteract the hazard.

2.4.1 Additional safety devices

As long ago as 1993, G. Schiffner published a detailed survey [9]:

- safety gear on the counterweight (which has already been prescribed for accessible spaces below the counterweight)
- additional safety gear in the upward direction
- additional brake either on or in close proximity to the traction sheave (if the service brake is on the motor)
- rope brake (acting directly on the suspension rope or the compensating rope)

Inspection authorities working in the former German Democratic Republic after the opening of the border discovered a brake safety gear that functioned in both directions. However, the mechanism for the upward direction was taken out of service and sealed because a safety gear that worked in the upwards direction was not permissible at that time. In the meantime a range of safety devices are available which again make use of this system.

In accordance with Annex F.7 of EN 81-1, all of these safety devices have to undergo a type-examination.

2.4.2 Positioning of the service brake on the traction sheave

Gearless drives are becoming more and more firmly established in elevator construction, and in these drives the service brake – a dual circuit brake compliant with the requirements of EN 81-1 – is located directly on the traction sheave.

In future the use of this solution will become more and more widespread since EN 81-1 permits a brake on the traction sheave as a protective device against overspeed for the ascending car, provided that this additional function is subjected to a type-examination. This is also supported by the fact that 168 of the 171 unwanted car movements in the German accident statistics [7], which were referred to above, would not have occurred at all if the service brake had been fitted on the traction sheave (see also my lecture entitled: Braking systems for rope elevators [10]).

An interesting point in this context is the proof by K. Fichtner that even when the service brake is used as a safeguard against unwanted upward movements, the maximum retardation values are less than 9.81 m/s^2 – as demanded [11].

3 CONCLUDING CRITICAL REMARKS

The introduction of a protective device against overspeed for the ascending car leaves many questions unanswered in the application of this regulation and particularly so in connection with the handling of the type-examination in Annex F.7 of EN81-1 [12].

However, the aim of this paper is to examine the purpose of this regulation in terms of increased safety for the elevator users. It attempts to point out contradictions and provide suggestions for improvements:

3.1 Scope of the new regulation

Some doubt has been expressed as to whether an accident in Canada in a 44-storey building can be transferred to the European situation, where, in general, the height of buildings is considerably lower. This doubt is supported by the evaluation of the German accident statistics [7].

It is therefore difficult to comprehend why an elevator with a short travel (2 or 3 stops and travelling at low speed) should have to be equipped with a safeguarding device to protect it against overspeed in the upward direction.

3.2 Proposals for improving safety

EN 81-1 does not require safety devices unless overspeed occurs in the upward direction. The elevator users' safety can, however, be improved considerably if all the available methods are exploited to prevent the hazardous situation occurring in the first place.

Preventive methods directed at the causes of unwanted car movement, as listed under items 2.1 – 2.3, are not considered at all in the standard.

In many cases the cause of unwanted car movements is an interruption in the connection between the service brake on the motor and the traction sheave, as shown by the evaluation of accident statistics [7]. A break of the traction sheave shaft has often been the cause for this. As a result, the requirement of TRA 200 in January 1996 (draft in September 1993) [3] for the mounting position of the traction sheave shaft bearings to be statically defined has brought about a considerable improvement in safety. It has led to many manufacturers of elevator drive systems changing their designs so that the number of elevators being constructed with drive systems where the shaft is mounted on three sets of bearings is continuously decreasing. In my opinion, it would have been useful if this provision had been incorporated into the new EN 81-1.

The requirement in EN 81-1 for the brake to be positioned directly on the traction sheave or in its immediate vicinity does not guarantee adequate safety. This presupposes that the brake on or near the traction sheave will remain effective in the event of the shaft, axle or bearings of the brake disc breaking.

The brake or auxiliary brake on the traction sheave, as an item of safety equipment to protect against overspeed in the upward direction, which is only needed in very rare cases if at all, is subject to a type-examination whereas the service brake itself, which may often be responsible for the safety of the elevator 1000 times per day, requires no such type-examination. I would propose that the service brake should also be subject to a type-examination, especially when it is mounted on the traction sheave.

It is difficult to understand why the protective equipment should only be required for overspeed in the upward direction. The danger faced by the elevator user diminishes as the speed of an uncontrolled movement decreases. As there are means to detect uncontrolled movements in both directions instantly, greater safety could be achieved if the safety devices came into effect at all speeds.

The safety regulations in the United States [4] are currently being revised. There, too, the intention is to include protective devices against uncontrolled movements of the car.

REFERENCES

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Annex I: Fundamental safety and health requirements for the design and construction of elevators and safety-related components

[2] European Standard DIN EN81 : Part 1 : 1986 and 1999 - Lifts and Service Lifts
Safety rules for the construction and installation of electric lifts

[3] Technische Regeln für Aufzüge TRA 200
Personenaufzüge, Lastenaufzüge, Güteraufzüge

[4] ASME/ANSI A17.1 - 1993 and A17.1a - 1994
Safety Code for Elevators and Escalators

[5] CAN/CSA-B44-M90 - June 1990 - Safety Code for Elevators

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[6] Inquest renders report on Scotia Plaza tragedy
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[7] K. Feyrer/F. Dudde: Schutzmaßnahmen gegen unkontrolliertes Fahren von Treibscheibenaufzügen - Dortmund 1995

[8] United States Patent 3,845,842 – filed June 13, 1973 – Inventor: Wallace H. Johnson

[9] G. Schiffner: Safety concepts and safety equipment preventing the uncontrolled movement of traction-sheave lifts - Elevator World March 1993, page 53

[10] R. Stawinoga: Braking systems for rope elevator
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[11] K. Fichtner: „Absturz nach oben" baumuster-gebremst?
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[12] W. Kurz:: Annex F7/1 – Safety device to prevent overspeeding when the car is traveling upward – Lift-Report 1/2000, page 32

BIOGRAPHICAL DETAILS

Dipl.-Ing. Roland Stawinoga has been involved in the design of elevators (and escalators) for more than 45 years. He is a member of the IAEE and well-known for his technically authoritative lectures (ELEVCON'93 in Vienna, LifTech'94 in Brussels, ELEVCON'95 in Hong Kong, London Lift Seminar '95, ELEVCON'96 in Barcelona, ELEVCON'97 in Shanghai, ELEVCON'98 in Zurich, II and III Jornadas de Transporte Vertical in Zaragoza 1997 and 1999), which have also been published in the most important elevator trade journals (Elevator World, Lift-Report, Elevatori, Ascensores y Montacargas, Vertical Report, China Elevator), as well as for his other contributions to elevator engineering in Lift-Report.

In 1973 he took charge of the Technical Department in the firm of G. A. Koch in Hamburg, where he first became acquainted with V-belt drive systems and played a decisive role in their further development. 1990 saw the founding of his own engineering office, where fully equipped with the latest CAD technology, he employs his extensive and expert knowledge in assisting elevator companies to construct high-quality installations. His special interest continues to focus on the design and development of elevator drive systems in general and on the V-belt drive in particular.