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Author: Johannes de Jong, KONE

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PUBLICATION

UNDERSTANDING THE NATURAL BEHAVIOUR OF ELEVATOR SAFETY GEARS AND THEIR TRIGGERING

Johannes de Jong
E-mail: johannes.de.jong@kone.com

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2004
Johannes de Jong

ABSTRACT

A logically operating safety gear can all of a sudden function completely erratic. This article explains the behaviour of friction, the effect of friction tolerances, why erratic behaviour occurs and what can be done to prevent erratic behaviour. This paper also explains the behaviour of triggering devices such as overspeed governors, and how their operation can effect safety gear operation. The natural behaviour of safety gears and overspeed governors is often not properly understood resulting in wrong safety gear/overspeed governor combinations.

This paper also gives proposals for possible improvements to future elevator safety codes to improve the reliability of presently used safety gears.

Keywords: Safety gears, overspeed governors, elevators

1 INTRODUCTION

Safety gears were first introduction in the early 1850s and have since been an integral part of any roped elevator system. There are three types of safety gears described in modern elevator safety codes.

Instantaneous safety gears, the simplest type, where the force increases as function of the distance travelled after its application. The rated speed of elevators using this type of safety is limited to 0.63 m/s. This type is quite common for low speed, low travel applications

Instantaneous safety gears with buffered effect, similar in operation as the instantaneous safety gear, the shock being reduced by the use of oil-filled buffers. This type of safety gear may be used up to rated speeds of 1.0 m/s. Due to the costs involved this type of safety gear is not often used.

Progressive safety gears, this type has to be used for speeds in excess of 1.0 m/s and is often also used at all rated speed exceeding 0.63 m/s. The increase in force is limited by stops, build into the safety gear, to give constant friction force until the car comes to a complete stop. This to prevent dangerously high retardation levels over longer periods of time, which could cause physical harm to passengers in the elevator car being retarded.

The first two mentioned types of safety gears are usually not adjustable, while progressive type safety gears are practically always adjustable. Erratic behaviour of safety gears is most common with progressive type safety gears. Erratic behaviour is not caused by the adjustment but by the natural behaviour of friction, often resulting in confusion of the person executing the adjustment. I cannot count the numerous times when I have adjusted safety gears for a slightly harder stop, resulting in exactly the opposite I tried to reach. Often causing doubt whether the adjustment was made into the correct direction. Anyone adjusting safety gears has had similar experiences. These are not mistakes made in the adjustment, but are a natural part of the behaviour of safety gears. This article will explain what is actually the cause for this behaviour.

2 THE EFFECT OF FRICTION ON THE ADJUSTMENT

2.1 The allowed mass with constant friction

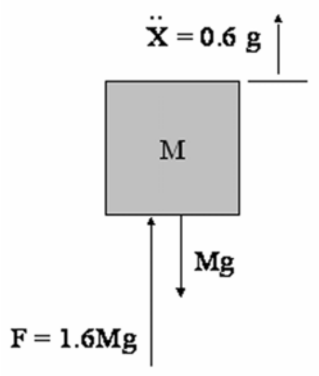

Figure 1. Mass M retarded by a force of 1.6Mg

In order to stop a mass M in free fall we need to exert a force on the mass greater than the gravity force M.g. The force should be applied opposite to gravity.

EN81clearly states, that a car in free fall (with total failure of the suspension means) shall be stopped, with an average retardation not lower than 0.2g and not greater than 1.0g. In the Annex explaining the type testing for progressive type safety gears, EN81 explicitly aims at an adjustment resulting in an average retardation of 0.6g. To reach this with a mass M we will need to exert a force of 1.6Mg on the mass (see figure 1).

If we now maintain this force and change the mass we get the retardation curve as shown in figure 2.

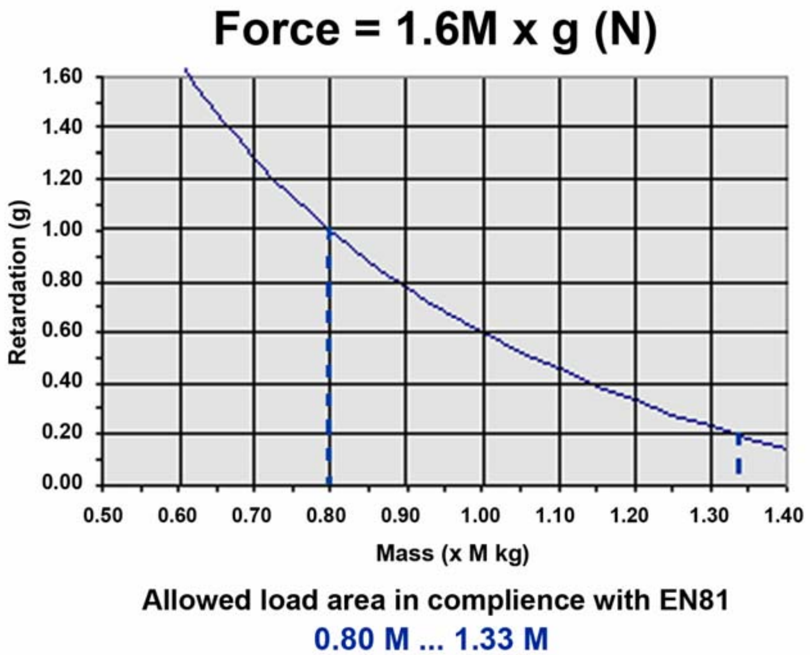

Figure 2. The retardation with constant force 1.6Mg and changing mass

As we can see from figure 2, we do not exceed the maximum deceleration of 1.0g set by EN81 if the actual mass remains above 0.80 M, and we will not go below the minimum required deceleration of 0.2g, if the mass does not exceed 1.33 M. In other words, if we adjust the friction force of the safety gear to 1.6Mg, we will still be able to stop 20% lighter cars and up to 33% heavier cars within the requirements set by EN81. This statement however is only true if the friction force would remain exactly on 1.6Mg. As we all know constant friction does not exist in reality. We always have tolerances.

2.2 The effect of friction tolerances on the allowed mass

In figure 3 we can see what happens with the allowed load if we have a tolerance of ±10% respectively ±20% on the friction force 1.6Mg.

With a tolerance of ±10% on the friction force 1.6Mg the mass must remain between 0.88M and 1.20M to comply with the retardation requirements of EN81.

With a tolerance of ±20% on the friction force 1.6Mg the mass must remain between 0.96M and 1.07M to comply.

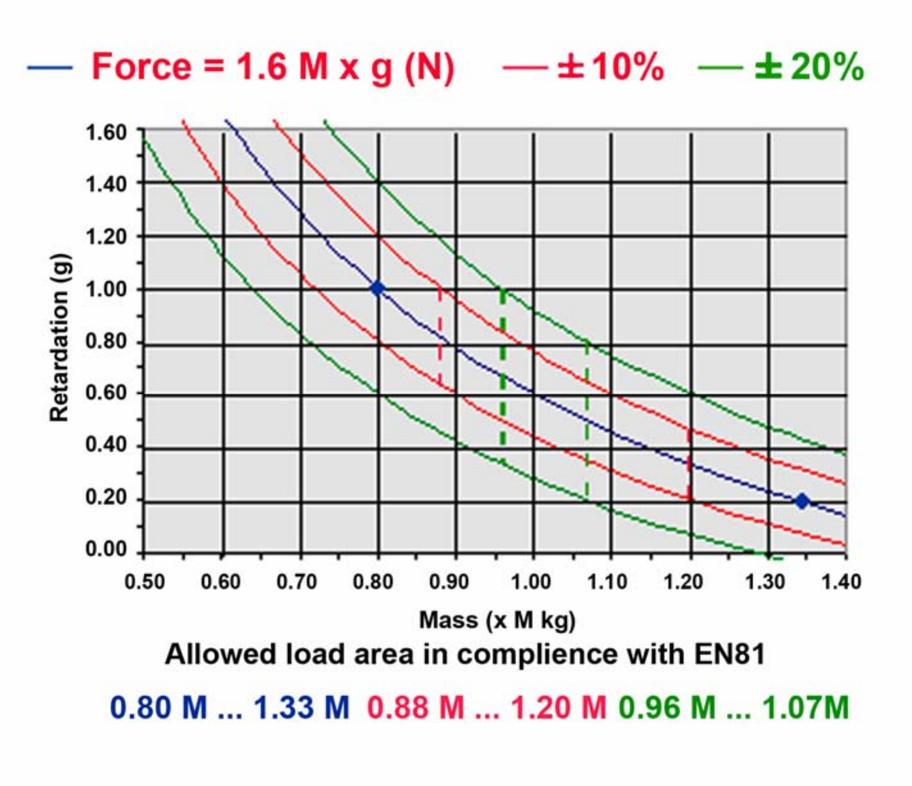

Figure 3. The effect of tolerance on the allowed mass

The range of the allowed mass decreases when the tolerance of friction force increases. At ±25% friction tolerance the lower mass border and the upper mass border join and the mass needs to be exactly 1.00M to always comply with EN81.

2.3 The effect of speed on the friction tolerances

Most materials will have a reasonably constant friction factor over a certain Force x Speed range also known as the PV range. Unfortunately this range is far exceeded in safety gear applications due to the limited space for the safety gear wedges. As a result practically all materials used in safety gear wedges are speed dependant. The bigger the speed, the bigger the tolerance range and the smaller the usable loads range.

Dr. Ing. Klaus Feyrer already documented the speed dependance of the friction factor in "Technische Uberwachung" Bd 8 (1967) Nr. 12 Pages 415 - 422. Klaus Feyrer is nowadays working as professor at then University of Stuttgart, specialised in Hoisting technology.

Figure 4 shows a large series of safety gear tests conducted at different speeds for two different safety gear settings.

We can see that the safety gear force clearly decreases with increased speed, or clearly increases with reduced speed. We can also see that there are considerable tolerances in friction force at any speed.

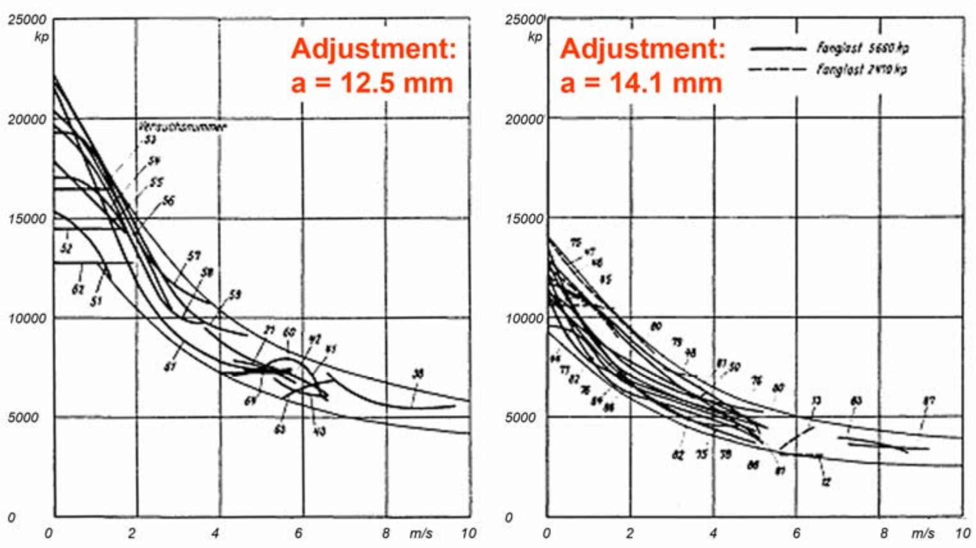

Figure 4. Friction force measurements as published by Professor Dr. Ing. Klaus Feyrer

Figure 5 shows a typical free fall speed curve of a safety gear with speed dependant characteristics.

The speed increases linearly to a speed of 5.06 m/s when tripping of the safety gear takes place. As the speed decreases after tripping, we can see the curve dipping steeper indicating increased deceleration rates and increased friction forces.

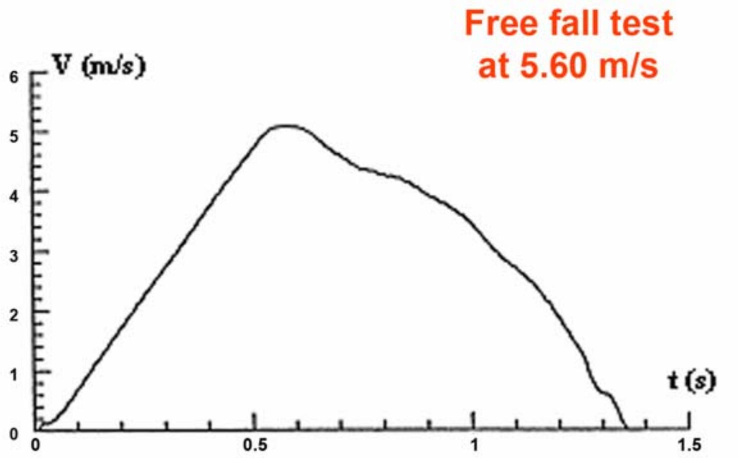

Figure 5. A Typical free fall speed curve of a speed dependant safety gear

A similar speed dependant curve can be found in "Elevator technology 12, proceedings of Elevcon 2002" in the article "The world fastest (1010 m/min) elevator", page 223.

2.4 The chance of safety gear failure

The area where every safety gear test complies with EN81 is shown in figure 6 marked as the "Safe Area". Outside this area it is still possible to complete safety gear tests complying with EN81. There is however also a chance of failure.

Figure 6 shows the relation between the chance of failure and the chance of success with a mass of 0.75M, if the friction force is 1.6Mg ±20%. At 0.64M the chance of failure becomes 100%, the safety gear retardation will always exceed 1.0g.

At the lower retardation end of the curve, outside the safe area one can pass tests complying with EN81 at low retardation, but one can also encounter retardations below 0g's, in other words fall through. The fact that the friction force is lower at higher speeds than at lower speeds makes fall through even more probable, as the average retardation is higher than the retardation at the start of gripping.

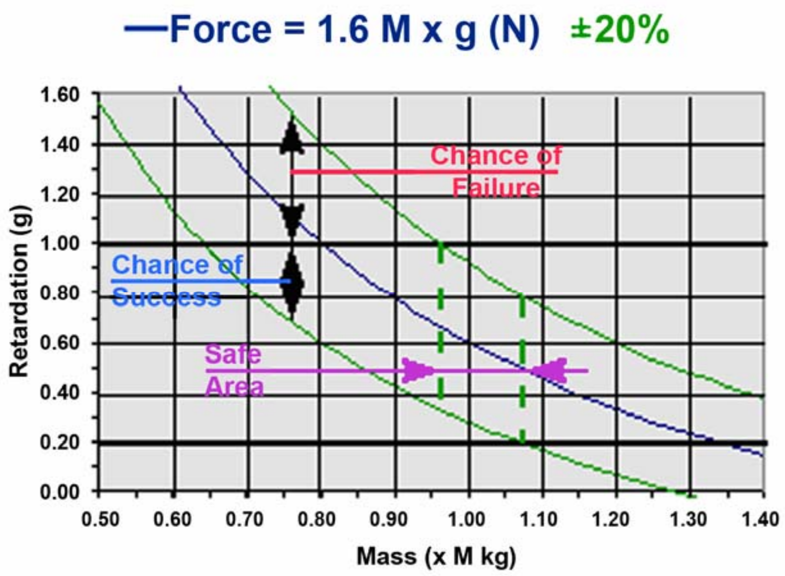

Figure 6. The safe area, chance of success and chance of failure

As friction may change dramatically between consecutive tests there is a very good chance that one can tighten the adjustment to shorten the slide, and one might still get a longer slide with the next test. The opposite may also happen.

Erratic behaviour of safety gears is a logical consequence of friction tolerances. As EN81 allows a ±7.5% tolerance on the mass to be tripped, the friction tolerances should remain below ±15% to remain in the safe area under all conditions with perfectly adjusted safety gears. To allow for small imprecision in adjustment it would be advisable to keep the friction tolerance between ±10% to prevent readjustment of safety gears on site. One should also make a large number of tests to determine the safe area and the tolerance of the safety gear. Most safety gears will have larger friction tolerances than ±10%, requiring more than occasional readjustments.

2.5 How to improve safety gear behaviour

The easiest way to improve safety gear behaviour would be to change the elevator code. The old DIN code used in Germany allowed maximum retardations of 1.4g in free fall instead of the maximum retardation of 1.0g used by EN81, this without causing harm to passengers. The lower retardation limit in free fall for both codes was set at 0.2g. The consequence of the higher upper limit is a dramatic increase of the safe area, while the target retardation only increases to 0.7g from the value of 0.6g used by EN81. As a result the friction tolerance can be increased to ±20%, preventing readjustment on site. Most safety gears would operate with little or no need for readjustment.

Another way to improve safety gear behaviour would be the use of electronically controlled safety gears. Present safety codes prevent the use of such safety gears, but the use of risk analysis may allow the use of electronically controlled safety gears in the near future. The costs involved in these servo systems may however limit the use to high cost elevators only.

KONE has improved the tolerance on safety gears dramatically by implementing its SGB06 and SGB07 safety gears. These patented safety gears are completely mechanical and apply mechanical servo principles. Due to their build, these safety gears will automatically decrease the normal force on the wedges when the friction factor increases. As a result the friction force remains practically linear at the adjusted value, with only minor tolerances.

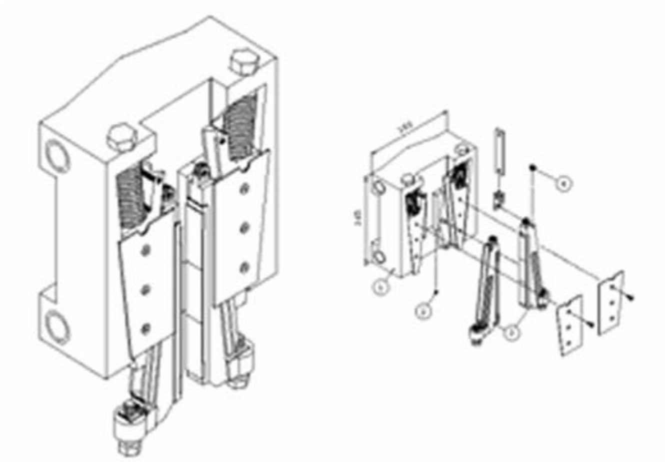

Figure 7. The KONE SGB06/07 safety gears with mechanical servo principles

As a result of the mechanical servo principle the KONE SGB06 and SGB07 safety gear are not speed dependant. Figure 8 shows a free fall speed curve of an SGB06 safety gear gripping a load of 10000 kg at a speed of nearly 10 m/s.

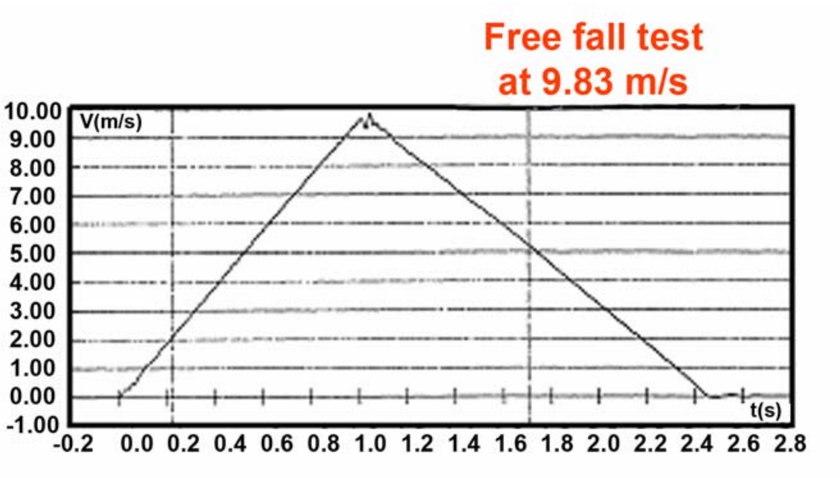

Figure 8. A typical free fall speed curve of a KONE SGB06 safety gear with mechanical servo

The retardation curve is remarkably straight compared to curves normally found for other high-speed safety gears.

3 THE EFFECT OF OVERSPEED GOVERNORS

EN81 requires that all speed governors are to be type tested. The type test however is done at a very slow rate of acceleration. This is also near to the acceleration we will see in elevators in run away situations (overspeed with ropes attached). In free fall situations (total failure of the suspension means) the acceleration rate will be practically the same as gravity (9.81 m/s2), only slowed down slightly by friction.

A governor is in principle always a flyweight device, where centrifugal force tries to fight against the force of a spring. In other words we have a spring mass system. In any spring mass system force and speed are out of phase. At slow acceleration = slow centrifugal force increase, there is a long time available for the speed to adapt, in other words position of the weight has a good correlation with the centrifugal force and therefore the speed. At increased acceleration the time available to move out the weight is shorter, and due to the phase shift between force and speed the correlation between speed and position of the weight is lower at increased acceleration.

If the position of the weight would be used as a speedometer, we would be seeing the correct speed at low acceleration, but far too little speed at high acceleration as the weight moves out too slow. In overspeed governors, we tend to use the position of the weight as speedometer readout.

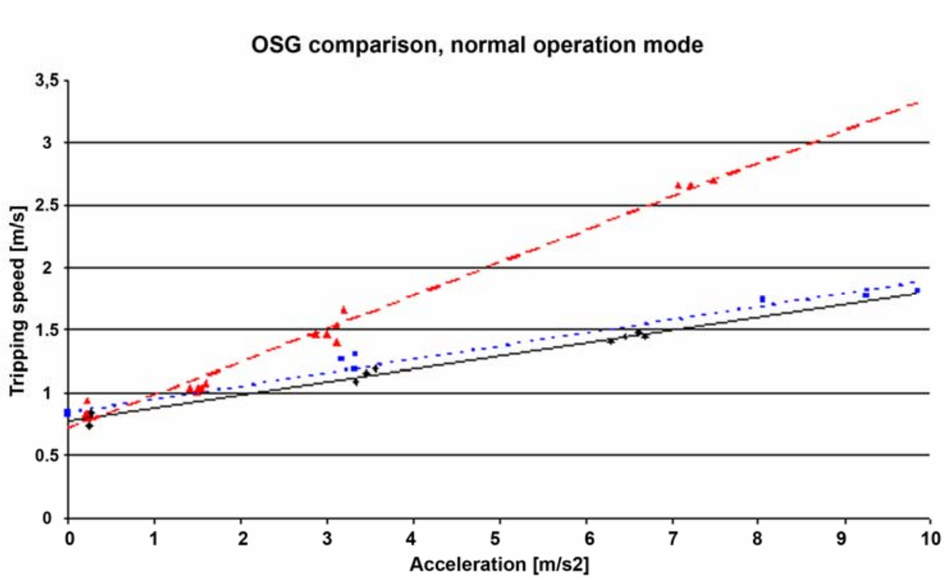

Figure 9. Tripping speed of overspeed governors as a function of the acceleration

Figure 9 shows three different low speed overspeed governors, all with original tripping speeds set at 0.8 m/s. The two lines with less increase are two identical KONE OL35 governors. The third is a very common commercial rocker arm type governor.

The KONE OL35 overspeed governors have specifically been designed to minimise the increase in speed as a result of higher acceleration. These governors show by far the lowest increase of any governor tested by us. Still the increase in speed is slightly over double at gravity.

With the shown rocker type governor, the speed increased more than four fold at gravity. Still the rocker type shown here is not one of the worse measured. Fortunately the increase in speed for any type of governor is less at higher tripping speed settings.

The energy, which safety gears need to absorb, will increase with the second power of the tripping speed. In real free fall conditions it would therefore not be strange to see complete rupture of instantaneous safety gears or fall through with progressive safety gears.

Safety gears and governors should be paired in such a way that increase in speed caused by high accelerations during free fall will not cause total failure of safety gears. This total failure can be caused by too much energy dissipation in instantaneous safety gears, or by decreased friction factors due to speed dependability or loss of safe area of progressive safety gears.

4 CONCLUSION

This article studied the effect on friction tolerances on the operation of safety gears. This article also studied the effect triggering devices, such as overspeed governors, may have on the operation of safety gears.

We can make the following conclusions:

In order to prevent readjustment of progressive safety gears, it would be advisable to reintroduce the old German DIN code allowing a maximum retardation of 1.4g and a target retardation of 0.7g in free fall. This will allow far larger friction tolerances for safety gears. The present EN81 requires too small tolerances for most safety gears in use.

If we continue using the present EN81 code, more emphasis should be focused on reducing the friction tolerance of progressive safety gears.

Not checking the increase in tripping speed of overspeed governors in free fall may lead to potentially dangerous safety gear / overspeed governor combinations, which may result in total failure in free fall.

FORTUNATELY THE OCCURRENCE OF FREE FALL IS VERY RARE.

REFERENCES

Dr. Ing. Klaus Feyrer (1967). Technische Uberwachung, Bd 8 Nr. 12, pp 415 - 422.

T. Munakata, H. Kohara, K. Takai, Y. Sekimoto, R. Ootsubo, S. Nakagaki (2002), Elevator technology 12, proceedings of Elevcon 2002, “The world fastest (1010 m/min) elevator”, page 223.

BIOGRAPHICAL DETAILS

Johannes de Jong is presently assigned as Director – Products for the Major Project Unit of the KONE Corporation. In his function he is responsible for the elevator Technology used in Major Projects globally delivered by KONE.

Johannes de Jong is a graduate of the Polytechnical University of Delft in the Netherlands where he received his M.Sc. in Engineering. He has a strong 10 years R&D background from where he was promoted to High Rise Manager for KONE’s Global High Rise Department. His field has since increased from the High Rise sector to all types of Major Projects from Low Rise infrastructure projects to Ultra-High Rise Towers.

Johannes de Jong has participated as an expert in several of the EN81

Elevator Code Workgroups and is at present also a member of the Executive Committee of the Council on Tall Buildings and Urban Habitat (CTBUH).