Uncontrolled Overspeed
J P Andrew[1]

Abstract. A major part of the design and specification of equipment for the arrest or prevention of overspeed, particularly the safety gear/overspeed governor combination, concerns itself with the performance when carrying rated load, or, in the event of upward overspeed, zero load in the car. In particular, specification is concerned with performance of safety equipment in the face of suspension failure, however unlikely that might be. This paper sets out to investigate the performance of overspeed protection when there is a partial load in the car, whether with a failed suspension or not, and to discuss the opportunities in this respect provided by the introduction of the so-called rope brake.

Keywords: Overspeed, Car, Safety gear, Ooverspeed governor, Rope brake

1 INTRODUCTION

Perhaps the most fundamental safety criterion for any lift system is the safe arrest of an uncontrolled overspeed, whether in the up or down direction. Of course, "uncontrolled overspeed" is at the least a redundant phrase, if not a tautology, since, by definition, any overspeed condition is almost certainly "uncontrolled" and must imply an important failure in the lift system. In common parlance, however, the overall phrase "uncontrolled overspeed" gives slightly more emphasis to the urgency of such a situation than does the simple "overspeed".

For the purpose of this discussion, we will define overspeed as a condition where the lift car and counterweight exceed the rated speed of the lift by any more than the amount permitted in standards.

A malfunction condition which we will not consider will be unintended movement with the entrance open. Clearly, whilst movement with the entrance open is permitted for purpose of re-levelling during loading and unloading, this is a special circumstance and must be constrained in terms of both location within a predefined distance from floor level and the creep speed at which such movement is permitted. Should either the permitted distance from floor level or the permitted levelling/re-levelling speed be exceeded whilst the entrance is open, immediate arrest of movement is mandatory. If, during re-levelling at floor level, the system should exceed the permitted re-levelling speed, it is logical to classify this as an 'overspeed'. Nevertheless, the common perception of the term overspeed is an event where the car exceeds the rated speed.

Perhaps the term 'uncontrolled movement' gives the most generalized definition of the class of hazards associated with the possibility that a lift will move in a manner outside the envelope permitted by the performance specification of the control system.

In this discussion we shall confine ourselves to the issues which arise should a traction lift exceed its rated speed, whilst acknowledging that many of the considerations apply in parallel both to hoists and to direct and indirect acting hydraulic lifts. Al Sharif [1] has given a comprehensive discussion of the protection to be afforded, and the advantages of the rope brake as against a safety gear acting on the guide rails.

After any overspeed event, the subsequent and immediate issue is to expedite the safe release of any trapped passengers.

---
[1] Corresponding e-mail address: jpandrew@tiscali.co.uk

A whole range of architectural possibilities in terms of building height and complexity was rendered possible after the introduction, by Elisha Otis, of the 'Safety Elevator', which is credited with being the first lift system with reliable protection in the event of suspension failure. It is also worth making the point that Otis's safety elevator primarily detected, and reacted to the fundamental failure, i.e. failure of the suspension, without, necessarily, delaying arrest until the lift achieved an overspeed.

It is universally acknowledged that, in particular, for the purpose of arresting an overspeed in the down direction, a device must be provided on the lift car which, even in the event of suspension failure, will reliably engage with the guiderails and bring the lift car safely to rest. Historically, all national and international safety standards have made such a stipulation. Furthermore, safety standards specify how such a device shall be rated in terms of both load-bearing capability and, of course, maximum imposed retardation in free fall with rated load in the lift car.

The main objective of this discussion is to examine the differences between free fall after suspension failure, overspeed in the down direction with the suspension intact, overspeed in the up direction, and the implications for the severity of the arrest where the lift car is less than fully loaded.

2 SUSPENSION FAILURE

Despite the fact that suspension failure, is almost (if not quite) unknown, it is this eventuality which, alongside entrapment, is perhaps the most common source of apprehension in the mind of the day-to-day user. Indeed, one recalls that the Elisha Otis Safety Elevator specifically addressed this problem in that failure of the suspension would release a spring-loaded mechanism to engage with the guide rails and arrest the downward motion. Note that the safety mechanism was entirely autonomous at the car, and required no additional equipment, e.g. an overspeed governor located in the machine room or well.

However, it is clear from the Otis Patent of 15th January,1861 (an important and well-remembered date) that the mechanism was very much an instantaneous safety device which, when triggered by suspension failure, would engage spring loaded dogs on the car with suitable (substantial) serrations on the face of the guide rail.

Nevertheless, the issue to which attention is to be brought here is that the device was entirely autonomous on the lift car, requiring no external overspeed governor. The safety gear was held off by the tension in the suspension ropes directly compressing the safety gear engagement springs.

Indeed, in the context of an indirect acting hydraulic lift such a tripping mechanism is still envisaged today [2] (EN81-20:2020 Clause 5.6.2.2.2), which also specifies that where springs are used for the tripping of the safety gear, they shall be of the guided compression type (EN81-20:2020 Clause 5.6.2.2.2(b)). For the sake of completeness, we note that, of course, where suspension failure or a safety rope is employed to engage the safety gear, there must also be a rupture valve to detect an excessive flow of hydraulic fluid and arrest any consequent overspeed with intact suspension.

3 OVERSPEED IN THE DOWN DIRECTION WITH SUSPENSION INTACT

The Safety Elevator represented a major step forward in lift technology, and could be claimed, justifiably, to be fundamental to the modern lift industry and the development of the high-rise building. Roping systems, more complex that our modern, common 2:1 indirect acting hydraulic arrangement, were used to provide a higher lift speed in a hydraulic lift, albeit over somewhat shorter travel than can be achieved by a rope driven system with a traction motor

(note that Queen Anne's "flying chair" in the 18th Century was actually a hoist rather than a lift).

With the subsequent development of longer travel/higher speed traction lifts, it was, of course, essential to provide a reliable system to bring the lift safely to rest in the event of an overspeed with intact suspension, as would be very likely if the brake were to fail.

Having been incorporated to arrest a 'free fall', the concept of the safety gear is extended to arrest any downward overspeed by expanding the detection of failure beyond basic suspension failure, to the detection of any excessive downward speed, whether or not the suspension has failed. This detection is now achieved by means of an overspeed governor incorporated as a separate and independent speed measuring device. The requirement is universally envisaged in standards as the combination of an overspeed governor matched to a safety gear.

Of course, given the higher speeds involved with traction lifts, the safety gear itself has developed to arrest the downward travelling car by engaging with the flat surfaces of the guide rails. There is a further distinction now between the 'instantaneous' type, which engages with the guide rail in a largely uncontrolled manner, and the 'progressive' type, applied at higher speeds and arranged to exert a controlled stopping force, thereby limiting the deceleration to which the car and its passengers may be subjected.

4 OVERSPEED IN THE UP DIRECTION

Over the past number of decades there has been a number of incidents where a lift car with a load less than balanced load, has ascended the well at an uncontrolled speed until the counterweight hits the buffers in the pit. Given the normal performance requirements for buffers, this is most likely to subject the counterweight to a deceleration of g_n, or even, momentarily, in excess of g_n.

The car then continues to ascend under its own inertia and has, in some cases, been travelling at a speed which resulted in a collision with the underside of the slab at the head of the well, resulting in serious injury, if not death, to passengers in the car. Even if the passengers are uninjured, it is only slightly less serious that any overshoot of the car after the counterweight hits the buffers, means that the ropes become slack, and the car drops back under temporary free fall, potentially engaging the car safety gear before tension has been restored in the suspension. As a consequence, the car may be arrested in the headroom above the top landing. A car arrested in the headroom, with ropes slack and higher in the well than the uppermost entrance is clearly a complex (and critical) situation in terms of releasing any trapped passengers.

A common solution to this issue is the incorporation of a safety gear and governor associated with the counterweight. The counterweight safety gear is, of course, a long-standing requirement where there are accessible spaces beneath the counterweight buffers, and it is clearly logical to extend this principle, in conjunction with a counterweight overspeed governor, to arrest overspeed of the car in the up direction. However, in the event of an upward overspeed of the car, an instantaneous safety gear installed to arrest a free-falling counterweight might well impose a deceleration in excess of g_n. Consequently, as with a buffering counterweight, a potential drawback to the application of the counterweight governor/safety gear combination lies in the possibility of setting the safety gear on both counterweight and car. This has occurred in some cases, and, as with a buffered counterweight is due to the upward over-speeding car continuing to travel in the up direction, after the counterweight safety has been set, until it comes to rest under gravity, with the consequence that the suspension will, to a greater or lesser extent, become slack. As with a buffered counterweight, the car will then 'free fall' until the suspension regains tension. It is possible that during the free fall, and before tension has been restored in the suspension, the car will achieve an

overspeed, setting its own safety gear. We now have the embarrassing situation that we have both car and counterweight with safety gears set, and a more or less slack suspension. Although in these circumstances the car is not necessarily trapped in the headroom above the uppermost entrance, this is still a difficult situation to resolve, requiring some expertise and ingenuity to release, safely, any trapped and probably very apprehensive passengers.

An alternative means to arrest an upward overspeed of the car nowadays is, of course the application of an emergency brake acting directly on the ropes rather than the traction sheave. The emergency rope brake renders the emergency stop independent of traction between sheave and ropes.

5 SAFETY GEAR OPERATION WITH FAILED SUSPENSION

Let: P = Car mass (kg)
Q = Rated load (kg)
F_{sg} = Decelerating force exerted by the safety gear (N)
g_n = Acceleration due to gravity (9.81m/s^2)
a_{FC} = Car emergency deceleration with rated load (m/s^2)
a_{EC} = Car emergency deceleration with empty car (m/s^2)

In the majority of car designs, the car mass will lie in the range $Q \leq P \leq 1.4Q$. This range allows for a variety of configurations, from a simpler car design to a design with heavy décor (e.g. marble panelling or a fully mirrored interior with, perhaps, a marble floor).

However, we wish to consider potential 'worst case' situations. In particular, in the event of a failed suspension, the failure is not necessarily at the car top. To allow for a "free fall" event where the suspension failure occurs at some distance from the car, e.g. at the counterweight end with the car at a lower floor, we will increase our nominal upper car mass (1.4Q), thereby including the potential mass of the ropes within the value of P, i.e. a range of car mass relative to rated load

$$Q \leq P \leq 1.6Q$$

Our intention is, notionally, to cover suspension failure with a heavy car at a lower floor together with a failure at or near the counterweight rope anchorage, ranging to a failure with a light car with the suspension failure at the car anchorage.

The "standard" mass of a single passenger is taken to be 75kg, i.e. in converting the rating of a lift car from kg to 'persons' the mass per passenger is taken, normally, as 75kg. However, throughout this discussion, when we consider a lightly loaded car, e.g. with a single passenger, we shall consider the possibility of a frail, possibly elderly person, or even, perhaps, a child, where the mass of that passenger might be significantly less than 75kg. Indeed, your author himself, although elderly, is not frail, but has a body mass (fully dressed) of only some 68kg! Consequently, when considering a lightly loaded car, we shall, in fact, consider a car which is actually empty, this being a 'limiting case' for any calculation.

Clearly, whatever the relative magnitudes of car mass and rated load (and whether or not the value of P includes an allowance for the rope mass) it is unacceptable to have any loading situation where the safety gear will not arrest a free-falling car! In the context of EN81, the range of permitted deceleration is $0.2g_n \leq a \leq 1.0g_n$, i.e. a minimum of $0.2g_n$. Of course, normal, good engineering practice will. aim to set the safety gear to the mid-range, i.e. a deceleration rate around $0.6g_n$ Nevertheless, as noted above, we wish to consider 'limiting case' situations. This means considering not only minimum and maximum loads, but situations where, for whatever reason, with rated load in the car, the safety gear operates at its maximum or minimum permitted deceleration rate.

Let us consider first a system where, whatever its setting during commissioning may have been, the safety gear operates at g_n the maximum permitted by EN81 with rated load in the car. In this case, the force exerted by the safety gear must be such as to support the load, $(P+Q)g_n$, together with a further force $(P+Q)a_{FL}$ in order to impose the emergency deceleration. With the safety gear operating with a_{FL} equal to g_n, this will require a retarding force F_{sg} given by:

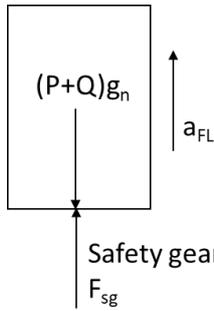$$F_{sg} = (P+Q)g_n + (P+Q)a_{FL} \tag{1}$$

$$F_{sg} = 2(P+Q)g_n \tag{2}$$

In the event that the suspension failure occurs at the car end and with an unloaded car, then the same safety gear force F_{sg} may be applied, and the empty car deceleration a_{EC} will be determined by the expression

$$F_{sg} = Pg_n + Pa_{EC} = P(g_n + a_{EC}) \tag{3}$$

Combining expressions (2) and (3)

$$P(g_n + a_{EC}) = 2(P+Q)g_n$$

i.e.

$$a_{EC} = \frac{P+2Q}{P}g_n \tag{4}$$

Figure 1

Taking our range of car mass relative to rated load ($Q \le P \le 1.6Q$), this implies an empty car deceleration in the range

$$\frac{P+2P}{P}g_n \le a_{EC} \le \frac{P+3.2P}{P}g_n$$

i.e.

$$3g_n \le a_{EC} \le 4.2g_n$$

With a single passenger, or a small number of passengers, in the car this must constitute a potential for injury, particularly for a frail or elderly passenger.

Starting from this viewpoint we can also investigate the potential 'empty car' performance at the other end of the permitted operating range, i.e. safety gear deceleration at rated load $a_{FL} = 0.2g_n$. Equation (1) becomes

$$F_{sg} = (P+Q)g_n + (P+Q)a_{FL}$$
$$= 1.2(P+Q)g_n$$

Whence we can now calculate the empty car deceleration as

$$Pg_n + Pa_{EC} = 1.2(P+Q)g_n$$

$$a_{EC} = \left(0.2 + \frac{Q}{P}\right)g_n$$

Using the same range of relative values for P and Q, i.e. $Q \le P \le 1.6Q$ the deceleration a_{EC} with an empty car will lie in the range

$$0.825g_n\big|_{P=1.6Q} \le a_{EC} \le 1.2g_n\big|_{P=Q}$$

Finally, let us look at the 'empty car' performance with a mid-range value of safety gear deceleration with rated load $a_{FL} = 0.6g_n$

$$F_{sg} = (P+Q)g_n + (P+Q)a_{FL}$$
$$= 1.6(P+Q)g_n$$

Whence we can now calculate the empty car deceleration as

$$Pg_n + Pa_{EC} = 1.6(P+Q)g_n$$

$$a_{EC} = \left(0.6 + \frac{Q}{P}\right)g_n$$

Using the same range of relative values for P and Q, i.e. $Q \leq P \leq 1.6Q$ the deceleration a_{EC} with an empty car will lie in the range

$$1.2g_n\big|_{P=1.6Q} < a_{EC} \leq 1.6g_n\big|_{P=Q}$$

The foregoing demonstrates that for a single passenger, if the emergency arrest is within the requirements of the code, deceleration cannot be limited to $0.6g_n$ or even $1.0g_n$ in most circumstances Whilst this may be unavoidable, nevertheless in the event of suspension failure it is clearly essential to arrest the downward motion, whatever the potential consequences for a lightly loaded car.

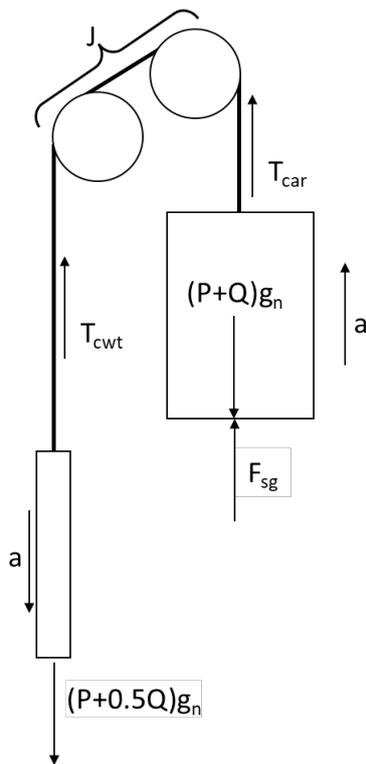## 6 SAFETY GEAR OPERATION WITH INTACT SUSPENSION

Figure 2

So far, the discussion has followed through the straightforward mechanics of protection, by means of a safety gear system, in the event of suspension failure. This is a normal and straightforward aspect of lift system design. However, we wish to consider the consequences of the arrest, by the safety gear, of an overspeed with an intact suspension. In such a case all the well masses are still connected, and will affect the deceleration rate.

In considering the arrest of a car where the suspension has failed, we have been constrained only by the consideration of operation under the minimum and maximum loads which might be present on the car side.

We will now try to investigate the potential behaviour of the car in the event that there is a catastrophic failure in the machine room such that the system runs away in an uncontrolled manner without application of the normal brake. At this stage, we are not considering the intervention of any emergency braking mechanism other than that afforded by the operation of the safety gear (we will consider the intervention of an emergency rope brake later).

For the sake of completeness, we will note that unless the load is greater than balanced load, the car will run away in the up direction, and will continue to accelerate until the counterweight hits its buffers, or the counterweight safety gear (if fitted) operates.

Let us consider the arrest of an uncontrolled overspeed in the down direction with rated load in the car. We will assume that the system is balanced at 50% and that during the overspeed and the subsequent emergency stop at least some tension in the ropes is maintained on both car and counterweight side, i.e. we note that should the emergency deceleration rate approach g_n, then since the upward travelling counterweight cannot decelerate under gravity at a rate in

excess of g_n, the suspension will tend to become slack and the car side dynamics will tend towards the behaviour during arrest in a 'free fall' situation.

In addition to the parameters P, Q and F_{sg} defined earlier, we will also define:-

$$T_{car} = \text{Rope tension on the car side (N)}$$

$$T_{cwt} = \text{Rope tension on the counterweight side (N)}$$

We can now define the motion of the lift system during emergency braking :-

$$F_{sg} + T_{car} = (P+Q)(g_n + a) \tag{6}$$

$$T_{cwt} = (P+0.5Q)(g_n - a) \tag{7}$$

Based on the masses and inertias of the rotating elements relative to the well masses, it seems reasonable, at least for our purposes here, to ignore the machine room inertia (see appendix), in which case $T_{cwt} \approx T_{car}$ Combining equations (6) and (7)

$$(P+0.5Q)(g_n - a) \approx (P+Q)(g_n + a) - F_{sg}$$

Whence

$$a \approx \frac{F_{sg} - 0.5Qg_n}{2P+1.5Q} \tag{8}$$

In the context of the Directive, in free fall an appropriate value of safety gear deceleration 'a' with rated load in the car in compliance with relevant standards would be $0.3g_n$. Applying this value in Equation (1) :

$$F_{sg} = (P+Q)g_n + (P+Q)a_{FL}$$
$$= 1.3(P+Q)g_n$$

This gives a range of values for F_{sg} between $2.6Qg_n$ and $3.38Qg_n$, depending on the relative masses of car and rated load. In the case of free fall, since there is no rope tension, a fraction of the safety gear force between $2Qg_n$ and $2.6Qg_n$ is required simply to support the load, leaving a value between $0.6Qg_n$ and $0.78Qg_n$ available to impose the necessary emergency deceleration.

Clearly, with ropes attached, this is not the case. The greater value of deceleration with ropes attached will occur with the larger value of F_{sg}, corresponding to a car mass equal to 1.6 times the rated load. Taking the upper value, we have

$$a = \frac{3.38Qg_n - 0.5Qg_n}{4.7Q} = 0.61g_n$$

Whilst, taking the lower value for F_{sg}, corresponding to a light car, we will obtain

$$a = \frac{2.6Qg_n - 0.5Qg_n}{3.5Q} = 0.6g_n$$

i.e. discounting the influence of the rotating elements, the deceleration would lie in the range $0.6g_n$ to $0.61g_n$, depending on the ratio of car mass to rated load. As suggested above we can assume, with a fair degree of certainty, that the effect on the deceleration rate due to the machine inertia is not large.

We can repeat the analysis for an empty car "falling upwards", and the accelerations to be expected when (if fitted) a counterweight safety gear operates.

In this case, taking the counterweight safety gear force as F_{cwt}

$$F_{cwt} + T_{cwt} = (P + 0.5Q)(g_n + a)$$

$$T_{car} = P(g_n - a)$$

$$a = \frac{F_{cwt} - 0.5Qg_n}{2P + 0.5Q}$$

However, we must bear in mind that in these expressions, we are looking at the deceleration rate imposed on the system by a counterweight safety gear, not the car safety. If the counterweight safety is set to provide a deceleration in free fall of, say g_n, then taking the system as balanced at 50%, we can calculate the counterweight safety gear force – F_{cwt} – as

$$F_{cwt} = 2(P + 0.5Q)g_n$$

Whence, independent of the car mass

$$a = \frac{F_{cwt} - 0.5Qg_n}{2P + 0.5Q} = \frac{(\cancel{2P + 0.5Q})}{(\cancel{2P + 0.5Q})}g_n = g_n$$

In either case, given that the effect of the system rotational inertias will be relatively small, we could expect a passenger to be subjected to an *upward* deceleration in the order of g_n – sufficient to throw an elderly person seriously off balance. Indeed, and as noted earlier, if the rated speed of the system is such that the counterweight is fitted with an instantaneous safety gear, the overshoot of the car after the counterweight safety has set may allow the car sufficient 'free fall' to set its own safety gear.

From the foregoing discussion, we can draw the conclusion that a safety gear combined with an overspeed governor, installed with the primary purpose of arresting a car in free fall following suspension failure, is not, necessarily, and ideal way to arrest an overspeeding car where the suspension has remained intact.

7 ROPE BRAKE

It is interesting to apply the analysis of a car with intact suspension in the context of arrest by means of a rope brake. It is elementary to conclude that a rope brake is clearly not a suitable means of arresting a car with failed suspension. It might be possible to argue that a rope brake could, possibly, arrest the car in the event of suspension failure at the counterweight end, but a moment's consideration would rule this out as an unreliable and speculative technical solution.

Returning to the arrest of a system with intact suspension, if we define F_{RB} as the braking force to be applied by the rope brake, then by replacing F_{sg} with F_{RB} we can redefine expression (6), in the context of the operation of a rope brake :

$$F_{RB} + T_{car} = (P + Q)(g_n + a) \tag{9}$$

and then re-apply expression (7) with expression (9)

$$T_{cwt} = (P + 0.5Q)(g_n - a) \tag{7}$$

to identify the braking force required to bring the car safely to rest in the event of uncontrolled overspeed with intact suspension. In this context expression (8), defining the deceleration rate with rated load in the car becomes

$$a = \frac{F_{RB} - 0.5Qg_n}{2P + 1.5Q}$$

We can re-arrange this expression to define the required braking force in terms of the well masses and the required acceleration a :-

$$F_{RB} = (2P + 1.5Q)a + 0.5Qg_n$$

If we apply the same limits to the braking deceleration a, i.e. $0.2g_n \leq a \leq 0.6g_n$, then if the brake were set to give a deceleration of, say, $0.25g_n$, the expression becomes

$$F_{RB} = (2P + 1.5Q)0.25g_n + 0.5Qg_n = (0.5P + 0.875Q)g_n \qquad (10)$$

Having calculated a value for F_{RB}, the force to be applied by the rope brake to arrest a fully loaded car, we can then investigate the deceleration rate imposed on an empty car "falling upwards"

$$F_{RB} + T_{cwt} = (P + 0.5Q)(g_n + a)$$
$$T_{car} = P(g_n - a)$$

Whence, applying our calculated value for the "rated load down" braking force required to achieve a deceleration of $0.25g_n$ (expression (10) above), the "empty car up" emergency deceleration is given by

$$a = \frac{0.5P + 0.875Q}{2P + 0.5Q}g_n$$

As before, taking the range of car mass from P = Q to P = 1.6Q, this gives a range of "empty car up" emergency braking deceleration

$$0.45g_n\big|_{P=1.6Q} \leq a \leq 0.55g_n\big|_{P=Q}$$

Which means that, having specified a brake setting to give an emergency deceleration of $0.25g_n$ for rated load down, then across the whole range of car mass the emergency deceleration rate falls within the range $(0.2g_n \leq a \leq 0.6g_n)$ falling well within the maximum of 1.0gn permitted under the standard.

Consequently, when the suspension is intact, and in contrast to the application of an over-speed governor in conjunction with a safety gear acting on the guides, a rope brake can be set up to provide a compliant deceleration rate across the whole range from empty car up to rated load.

8 CONCLUSIONS

Clearly, it is both fundamental and essential to the safe design of any lift system that the car be fitted with a safety gear in order that in the event of any failure of the suspension the car may be brought to rest. Further, if there are accessible spaces beneath the counterweight, e.g. the machine room for a 'bottom drive' lift, then similar considerations apply to the counterweight. For the safety of people who may be below the pit, the counterweight must also be fitted with a safety gear.

Based on our foregoing discussion, it could be suggested that notwithstanding its absolutely essential function, nevertheless, from the point of view of the safety and comfort of passengers, particularly the frail or elderly, a safety gear, whether instantaneous or progressive, is not, necessarily, an excellent way to bring the car to rest from excessive speed. As we have seen, even if the 'full load' deceleration afforded by the safety gear is at the minimum permitted level $(0.2g_n)$, then depending on the ratio of car mass to rated load, the deceleration imposed on an empty, or lightly loaded car is likely to exceed the maximum permitted by the Standard for arrest at rated load. The inescapable conclusion must be that although it seems to be the only feasible means to arrest a car in the event of suspension failure, nevertheless, a safety gear is not a desirable way to arrest the downward motion of a car carrying passengers.

With the advent of devices such as the emergency rope brake, it could be considered that, given sufficient research and development for standards to begin to allow for the possibility, such a

device may, in the event of overspeed with intact suspension, provide the opportunity to improve the method of stopping the car, thereby reducing the risk of frightening, if not injuring passengers in the event of a catastrophic system failure short of suspension failure.

Indeed, within current standards, it seems quite feasible to engage a rope brake before the safety gear would be brought into play. EN81 requires that the safety gear should not be engaged before the downward speed exceeds 115% of rated speed, and not more than 125% rated speed (for speeds in excess of 1.0 m/s).

Given that the foregoing discussion regarding arrest by means of a safety gear with or without an intact suspension simply re-iterates a well know standard problem, the majority of systems are designed to disengage the drive and engage the 'normal' braking system at, say, 10% overspeed. In the vast majority of cases, this avoids engagement of the safety gear. However, it does not avoid the issue if the overspeed is the consequence of a catastrophic system failure where, for whatever reason, the normal system brake fails to engage. It seems logical therefore, to consider using a rope brake as a further emergency stopping mechanism between the normal brake and safety gear engagement, e.g. suppose we set the 'normal' emergency stop by the system brake at, say 8% overspeed, but then engage an independent rope brake at, say 12% overspeed, on the assumption that the system brake has failed, then engagement of the safety gear for any failure other than suspension failure could be avoided, with consequent improved safety of passengers in a car with less than rated load (whether the overspeed occurred in the up or the down direction). Of course, it remains for the design to determine whether, with a system accelerating under the out of balance load, there would be sufficient interval between 8% overspeed and prior to 12% overspeed for the 'normal' brake to engage and thence prevent engagement of the rope brake.

However, if rope brake systems were to be subjected to type examination and test, in the same context as safety gears are examined, might we then consider a further, and significantly more controversial provision against the possibility of suspension failure.

Current requirements are that in the event of overspeed in the down direction (normally car down) then the overspeed is detected and the safety gear engaged in order to bring the car safely to rest. As we have noted already, from our calculations above, it is not necessarily feasible to arrange a safety gear to arrest the car with 'absolute' safety for any passengers at all states of load, either in the face of suspension failure or, more likely, in the event of an uncontrolled overspeed with intact suspension. Let us consider then, a system fitted with an appropriately type examined and tested rope brake system which could be relied upon to arrest any overspeed where the suspension remained intact. In these circumstances we could confine the safety gear to the issue of protecting the system and its passengers from the fundamental failure – the failure of the suspension, not the consequent overspeed.

Does this not set us at liberty to adopt the principle, already permitted in the context of an indirect acting hydraulic lift, of simply engaging the safety gear immediately upon detection of a suspension failure, e.g. by means of an 'idle rope'? In an indirect acting hydraulic lift up to rated speed 1m/s, on the basis that the pipe rupture valve will arrest any overspeed where the suspension remains intact, it is permitted to rely upon an idle rope to protect against suspension failure. Given a type approved and tested rope brake system, could the same principle be applied to a traction lift and, perhaps, over a higher range of rated speed?

Even more controversial, as part of such an investigation, could we consider simply making the safety gear system totally autonomous on the car, e.g. rather than activation by an overspeed governor, by spring activation of the safety gear (by compression springs, of course) immediately upon detection of a loss of tension in one or more of the suspension ropes. Although an overspeed might not be prevented in all circumstances, e.g. if the suspension failed

whilst travelling down at rated speed and rated load, this would mean that the car was arrested immediately, without waiting for the overspeed to occur. Furthermore, in many circumstances this might increase the safety of the emergency arrest. For example, in the event of suspension failure at less than rated speed, e.g. if a (poorly maintained) system with a weakened suspension initiated an emergency stop for any reason, the safety gear would engage immediately upon a suspension failure triggered by the emergency stop.

Of course, an autonomous, on-car, self-actuating system responding simply to loss of rope tension, rather than to overspeed, would introduce a design problem in that it is essential, as stipulated in the standard, that testing of the safety gear shall be possible without the need to enter the well during the test. Although it is straightforward to understand that with a car mounted overspeed governor system or an idle rope operated safety gear, a test is fairly straightforward, if it was desired to introduce a system which would engage the safety gear immediately upon simple failure of one or more of the suspension ropes, a compliant test might prove more of a problem.

It is clear that whilst such an innovation seems attractive, an enormous amount of detailed analysis and testing must be undertaken before any such proposal is brought forward for consideration and possible approval.

Less critical from the point of view of safety would be the elimination from the well of equipment relating to the governor, since overspeed detection could be confined to the machine room without the need for a mechanical connection to the lift car, with consequent elimination of pit mounted equipment e.g. the governor tension pulley. This would have advantages from the viewpoint of layout design, since the governor rope running the length of the well and associated governor tension pulley would not be required. Being confined to detecting overspeed with intact suspension and with causing actuation of the rope brake rather than the car/counterweight mounted safety gear, the overspeed governor could perhaps, simply be driven from the main sheave or diverter/secondary pulley.

With the advent of more and more adventurous and complex architectural designs, where some buildings are no longer 'simple' vertical structures, such an innovation might make it more straightforward to incorporate lifts into these sophisticated configurations.

Note that this type of problem is not new to the lift designer. As an example, the lift to the observation deck in the Peace Tower at Parliament Buildings Ottawa (4) with a travel of approximately 61 metres has a horizontal traverse of 3.7 metres over the first 30 metres of its travel. A fairly complex problem for the lift layout design!

REFERENCES

[1] L Al-Sharif: *The Lift Directive and the Rope Brake.* Research Gate (May 1996)

[2] British Standards Institution, *Safety rules for the construction and installation of lifts — Lifts for the transport of persons and goods Part 20: Passenger and goods passenger lifts.* BS EN 81-20:2020

[3] Directive 95/16/EC amended by Directive 2006/42/EC

[4] https://www.tpsgc-pwgsc.gc.ca/citeparlementaire-parliamentaryprecinct/decouvrez-discover/paix-peace-eng.html)

APPENDIX A   THE SIGNIFICANCE OF THE ROTATING ELEMENTS

Let us define the parameters of the equivalent rotating inertia in the system as

J = Equivalent inertia of the rotating parts (kgm^2)

R = Equivalent radius of the rotating parts (m)

$\ddot{\Theta}$ = Angular deceleration of the equivalent inertia of the rotating parts (rad/sec^2)

The angular deceleration is given as

$$\ddot{\theta} = a/R \tag{A.1}$$

where a is the linear acceleration of the system. We can note also that the equivalent inertia may be represented by

$$J = mr^2 \tag{A.2}$$

where m is the 'equivalent mass' of the rotating parts and r is its radius of gyration. We note that the equivalent radius R relates to the rope speed of the system, i.e. the notional physical dimensions and is different from the radius of gyration for the equivalent inertia, and that in

general $r \le R$ (we may recall from our A-level physics that for a plain disc, $r = R/\sqrt{2}$)

In order to simplify the discussion, we are considering only 1:1 roping, making the assumption that a multiple reeved system can be resolved into an acceptably close approximation by an equivalent single roped arrangement with suitable adjustment of the equivalent inertia etc. allocated to the rotating parts.

We have defined the motion of the lift system during emergency braking :-

$$F_{sg} + T_{car} = (P + Q)(g_n + a) \tag{A.3}$$

$$T_{cwt} = (P + 0.5Q)(g_n - a) \tag{A.4}$$

The tensions on the car and counterweight sides will differ by the amount required to decelerate the system rotating masses in the machine room (machine, gear where relevant, traction pulley, diverter pulley etc), i.e.

$$T_{cwt} - T_{car} = J\ddot{\theta}/R = Ja/R^2 \tag{A.5}$$

Now consider the right-hand side of equation (A.5). If we substitute our expression for the notional equivalent mass and radius of gyration for the rotating elements, we obtain

$$\frac{J}{R^2} = m\left(\frac{r}{R}\right)^2 \tag{A.6}$$

As noted above, based on elementary mechanics, we can stipulate with certainty that $r \le R$. Furthermore, in normal circumstances, m, the equivalent mass of the rotating elements in the machine room will be (relatively) small in comparison with the well masses.

The combined mass of car, rated load and counterweight, balanced at 50%, is P+Q on the car side, and P+0.5Q on the counterweight side, giving a combined well mass 2P+1.5Q. Even with an empty car, the combined well mass will be 2P+0.5Q.

It seems not unreasonable to postulate that even with the minimum value of well mass (i.e. empty car)

$$m\left(\frac{r}{R}\right)^2 \ll 2P + 0.5Q \tag{A.7}$$

and that consequently, $T_{car} \approx T_{cwt}$.