# PROGRESSIVE SAFETY GEAR

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## ABSTRACT

The necessity for the application of safety gears with elevators is discussed. A summary of the requirements for progressive safety gears, of advantages and disadvantages. New design of Czechoslovak progressive safety gear, respecting the requirement of minimizing the deterioration of guide rails. The results of tests are introduced.

## 1 INTRODUCTION

The safety gear has been the most discussed elevator safety device in the last years. We may ask a question: Is the application of such a safety device necessary or not. Most experts would apparently say: Yes, as it is the final safety device in the event of the breakage of elevator ropes and a consequent free fall of the car. The Dutch professionals seem to be most advanced in this field as several thousands of elevators without any safety gear have been in operation in the Netherlands. Anyway, even here considerable restrictions have been in validity, allowing only passenger elevators of small rated loads up to 300 kg, with maximum rated speed of 0.5 $ms^{-1}$ and maximum rise of 15 m not to be equipped with a mechanical safety gear. Furthermore the car must be suspended to at least 4 elevator ropes and the mechanical gearing of the machine must be of irreversible type. The safety gear has been replaced by a special brake with these elevators, pneumatically operated, acting readily upon the suspension ropes. The free fall of the car after the breakage of suspension ropes is not taken into consideration. The device mentioned here is set in operation regardless of the direction of car travel, which seems to be a great advantage.

The safety gears must be perfectly reliable though with most elevators it is actually in operation during the test and revision only. Should it be set in operation irrespective of what the reason for the increase of car speed in a downward direction may be its operation should not result in any harm to the passengers. The safety of passengers in a decending car is secured in this way, but no safety code requirements have been formed concerning the case of the increase of car speed when running in an upward direction.

It is difficult to satisfy the specified requirements in laboratory conditions, let alone with actual elevators. As generally known, the coefficient of friction on guide rails varies id dependence on several factors, the contact is effected by the tolerances of guide rail dimensions etc. Furthermore, the function of the safety gear is verified during the tests, while the gear is inactive for a considerably long time between two successive revisions.

## 2 SAFETY CODE REQUIREMENTS

In this chapter specifications included in the European standard EN 81.1 will be discussed.

The progressive safety gear, which is set in operation by an overspeed governor, must be used for rated speeds in excess of 1.0 $ms^{-1}$. It must stop the car in the event of its speed attaining a predetermined value in a downward direction of travel whatever the reason for the increase of speed may be. The predetermined value equals the tripping speed of the governor.

During the safety gear operation following a free fall of the car with rated load the average value of the car retardation should lie between 0.2 $g_n$ and 1.0 $g_n$. This value should guarantee a safe operation preventing the passengers from injuries, but also should secure an additional reserve of braking force for unexpected circumstances.

In compliance with EN 81.1 the tripping speed should be at least 115 % of the rated speed and less than the value calculated from a formula contained in the code. The response time of the governor must be short to avoid the danger of an excessive increase of car speed.

The standard specifies the car deceleration during the safety gear operation in the case of free fall. The same safety gear must stop the car regardless of its load travelling downwards at a speed attaining the governor tripping speed, i.e. the effect of the counterweight is still exerted. In contrast to free fall the rate of deceleration will be greater in this case. When a definite type of safety gear has been employed, the rate of deceleration cannot be influenced in dependence on the outer conditions as a definite braking force has been adjusted. In order to minimize the deceleration and prevent the counterweight suspension ropes from being released (as a consequence of the effect of the cwt inertial force) the braking force should be small, but still sufficient enough to stop the car in the case of free fall. Another solution may be the application of two safety gears, one in the case of free fall and another one for stopping the car attaining the governor tripping speed with the counterweight still in effect. Since this solution can hardly be taken into consideration, it seems to be much desirable to consider the conditions on which the danger of free fall could be avoided.

The European standard EN 81.1 in Chpt. F 3 regarding the adjustment of the braking force specifies the average deceleration as 0.6 $g_n$, apparently to secure a certain reserve of braking force in the case of unexpected factors to appear, e. g. the effect of the tolerance of the width of guide rail web, the variability of the coefficient of friction etc. However, the braking force so adjusted will result in the car deceleration in excess of 1.0 $g_n$ in the event of stopping the car at the tripping speed, particularly when the load will be small (e. g. 1 person). The release of the cwt suspension ropes and the "jumping" of the counterweight will be very probable in this case.

## 3 CONSTRUCTION OF PROGRESSIVE SAFETY GEAR

A safety gear of the gradual wedge-clamp type was a typical representative of progressive safety gears several tens of years ago.The braking force exerted by jaws on guide rails was controlled by an equalizing spring on one rocker arm. The jaws of bronze or cast iron did not damage the surface of guide rails. The braking forces of both jaws were the same irrespective of the width of the guide rail web. On the other hand there were several disadvantages typical for this type of safety gear. The response time was long as the operating mechanism was complicated and the mass of its individual components was relatively great. Special tools and technique were required to release the safety gear and make it ready for another operation after it had stopped the car on guide rails. In compliance with EN 81.1 this type of safety gear cannot be used nowadays as the release of the safety gear must be carried out by the motion of the car in an upward direction.

A large group of progressive safety gears is represented by flexible guide clamp types. The braking force is exerted by a helical equalizing spring or a set of Belleville springs and sometimes by an equalizing U-spring for light duty elevators. In this safety gear wedge-shaped gibs are incorporated moving on hardened steel chromium-plated rollers to minimize friction between the jibs and the safety clamps. This is a necessary condition for the wedging action to take place. In spite of the angle of the jibs being rather small ($3^{\circ}$ to $5^{\circ}$) the coefficient of friction on the rail-gripping side is often increased by notching the jibs. Notched gibs cause damage to guide rail surface.

To avoid the damage of guide rails the coefficient of friction between the gib and the rail should be high at the beginning of the action and should be decreased to a reasonable value after the safe contact between the jib and guide rail has been achieved.

With safety gears of definite braking force adjusted the variable width of guide rail web (large tolerance) effects the magnitude of the braking force to a large extent. Let us assume the force of equalizing springs of 500 kN at the compression of 5 mm: with the coefficient of friction 0.1 the braking force will be 50 kN. In the case of the guide rail web being thinner by 0.1 mm than the specified dimension, the braking force will be less by 1250 N, in the case of the same plus tolerance the force will increase by the same value. If the tolerance will be plus at one point and minus at another one the difference in braking force will be doubled.The variability of the coefficient of friction is of a similar effect. If, e. g. the coefficient is increased from 0.1 to 0.16, the force is increased from 2500 N to 4000 N and vice versa. As a consequence it is necessary to set properly safety gears on both sides of the car. The difference in force should not be in excess of 2000 N and the safety gear of smaller force should be mounted on the governor rope side to utilize its equalizing effect.

Another factor effecting the function of progressive safety gear is the wear of gibs and guide rails. Wear of guide rails usually takes place where hardened gibs are applied. With the application of bronze, brass and cast iron gibs wear is diminished. Wear certainly depends upon the unit pressure in the contact area and on the energy that must be dissipated. Furthermore it is influenced by the lubrication of guide rails. With higher rated speeds this influence is decreased as oil may be burnt on a longer braking distance and the seizure of gibs may occur.

As already mentioned the response time from the instant when the tripping speed has been attained to the commencement of the braking action should be as short as possible. Bearing in mind free fall of the car an inertial effect should be considered when the system is being designed. This can be achieved by incorporating a sufficient inertial mass of the overspeed governor in the system.

Taking account of all factors and considerations discussed here a new type of progressive safety gear was designed in Czechoslovakia recently, the principle of which is illustrated in Fig. 1. It is a compact safety gear in a cast-steel block, assembled and adjusted for a definite braking force by the manufacturer. The safety gear need not be further adjusted on the site. The clamps are provided with smooth cast-iron gibs having grooves for the removal of oil in the case of lubricated guide rails. The clamps are fitted on a pair of levers, each provided with a set of Belleville springs for exerting the braking force. The number and arrangement of springs varies in dependence on the rated load of elevators. Since the coefficient of friction is rather small because of a smooth surface of the gibs the force necessary for placing the safety clamps in a self- locking position is induced by means of a claw on the upper side of the clamp. The claw is pressed to the rail at the commencement of the safety gear operation as it projects over the clamp. As soon as it penetrates into the guide rail the system becomes independent on the governor rope, the levers start to rotate and the springs are compressed.

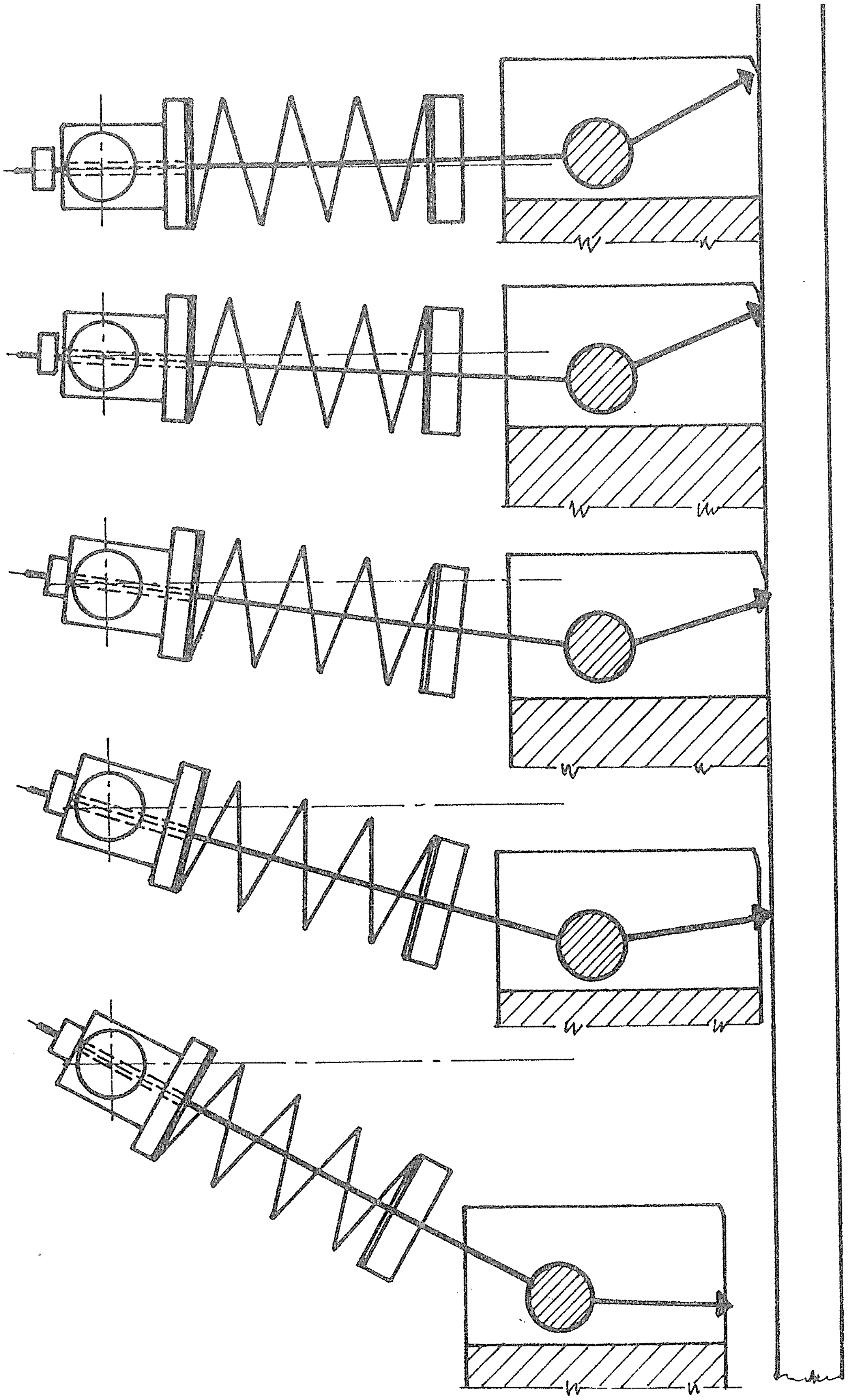

FIGURE 1.

After the smooth cast-iron gibs have been places in the final position, the engagement of the claw with the rail is interrupted and the braking action takes place. The release of the clamps is accomplished by moving the car in an upward direction. Concurrently the claw is pressed upon the rail again. The visible marks of the claw on guide rail made at the beginning and at the end of the operation may be used for an accurate determination of the braking distance. The marks are minor and can be easily removed.

The cast-iron clamp offer the following features:
a) they do not damage guide rails, the marks after the safety gear operation are negligible
b) cheap material
c) cast-iron has good resistance to high unit pressure and temperature
d) the coefficient of friction with lubricated guide rails increases with the burning of oil

## 4 RESULTS OF TESTS

The safety gears were tested in a testing tower for rated speeds of 1.0, 1.6, 2.5 and 4.0 $ms^{-1}$ and rated loads of 400, 630, 1000 and 1600 kg.

They satisfy all requirements:
a) reliable function in the first stage (placing the clamps in a self-locking position by means of a claw)
b) no damage to guide rails has been observed
c) easy adjustment of the braking force for different loads
d) the coefficient of friction of 0.1 was independent of the braking force (car load) and almost constant during the safety gear operation

The tests were taken in the case of free fall from zero speed. They proved the fact that the system "governor - safety gear" was rapid in action and the inertial effect occured at the speed of approximately 1.0 $ms^{-1}$. This speed was found dependent on the inertial mass of the system "governor - tensioning device of governor rope" only. The braking distance was determined both by mechanical marks on the guide rail (already mentioned in Chpt. 3) and by electro-optical sensing units. The speed/time dependence was taken off by a tachogenerator and registered by an oscilograph. The retardation was calculated for each braking distance.

The safety gears were so adjusted for each rated load as to stop the car theoretically with the retardation of 0.2 $g_n$. The following values of average retardation were gained, while the actual values varied in the range of 30 %:

| Rated load (kg) | Average retardation ($ms^{-2}$) |
|---|---|
| 400 - fully loaded car | 1.7 |
| empty car | 3.0 |
| 630 - fully loaded car | 2.3 |
| empty car | 7.3 |

| Rated load (kg) | | Average retardation($ms^{-2}$) |
|---|---|---|
| 1000 - | fully loaded car | 3.1 |
| | empty car | 8.0 |
| 1600 - | fully loaded car | 3.7 |
| | empty car | 10.0 |

In spite of the results being favourable it was determined to adjust the braking force so as the theoretical deceleration be of 0.3 $g_n$ for a fully loaded car. Thus a higher reserve will be achieved in the case of the occurence of unexpected factor, such as the inaccuracy of adjustment, larger tolerance of the width of guide rail web or variability of the coefficient of friction, though a higher retardation may occur during the safety gear operation especially with empty car.

The governor switch was adjusted to cut off the safety circuit when the speed of 115 % of the rated value was attained so that the elevator could be stopped before the tripping speed of the governor was attained in either direction of travel. Thus only in the case of a rapid increase of speed the safety gear is set in operation.

## 5 CONCLUSION

The results of tests confirmed the fact frequently stated in many previous papers and concerning the great range of values gained by measurements. Furthermore the tests revealed a significant fact that it was impossible to guarantee in all operation conditions the rate of deceleration less than 1.0 $g_n$ when a definite braking force of the safety gear had been adjusted, irrespective of whether the safety gear was actuated in the case of free fall or of the car speed attaining the governor tripping speed.

## 6 REFERENCES

Aberkrom, P. and Gaakeer, A.C.J. "Experiments with safety gears", International lift symposium, Amsterodam 1984
Izienicki, G.L. "Overspeed control governors and safety gear", Elevator World, November 1986
Koppensteiner, W. "Modern construction of safety systems at Otis", International conference Lift 2000, Budapest 1985
Nederbragt, J.A. "Uncontrolled speed up and down. Is it necessary to consider free fall?", International lift symposium, Amsterdam 1984

## 7 BIOGRAPHICAL NOTES

After the graduation at the Technical University of Prague in 1957, specialization "Hoisting, Building and Conveying Machines, the author was employed with TRANSPORTA in Prague, gradually taking several posts in Design Dpt and finally becoming Director of Research and Development. Later he joined VÍTKOVICE Institute for

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