EVOLUTION OF SAFETY GEAR

By; John Inglis

ABSTRACT.

Safety gear on lifts has developed over the years into a variety of forms. For the record this paper will trace the evolution of safety gear and the changes brought about due to the increase in speed. The first demonstration of safety gear to prevent free fall was by Elisha Otis at the Crystal Palace Exhibition in New York 1854. The major changes in design have come about due to the dramatic increase in the heights of modern buildings, and now the evolution cycle has started to introduce a new dimension to control lifts moving out of control in the up direction.

This paper will not deal with the methods of actuating safety gear due to the limited space. The actuating methods will be dealt with in a future paper.

FEATHER BAG IN PIT

The earliest story known about safety of persons while travelling in the lift dates back to a sultan who required a means of lifting people to the upper floor of his castle, but was concerned about their safety if the rope was to break. According to stories he had a large bag of feathers placed in the pit under the platform and directed one of his servants to ride in the car while the rope was cut. The servant survived the fall with only a broken leg, so the sultan said that he was now happy that no one would be killed when riding in his people mover See Fig 1

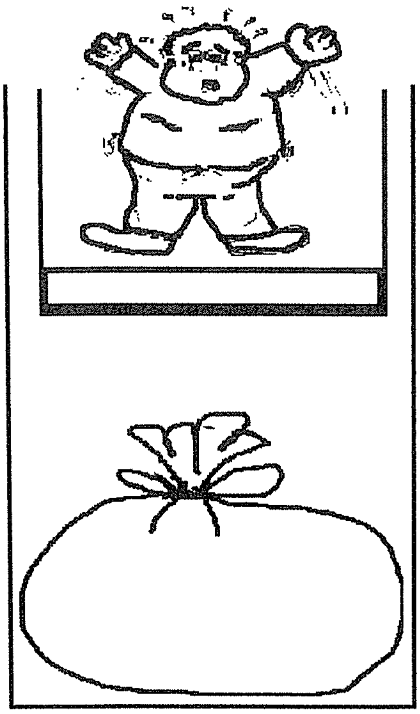


Fig.1

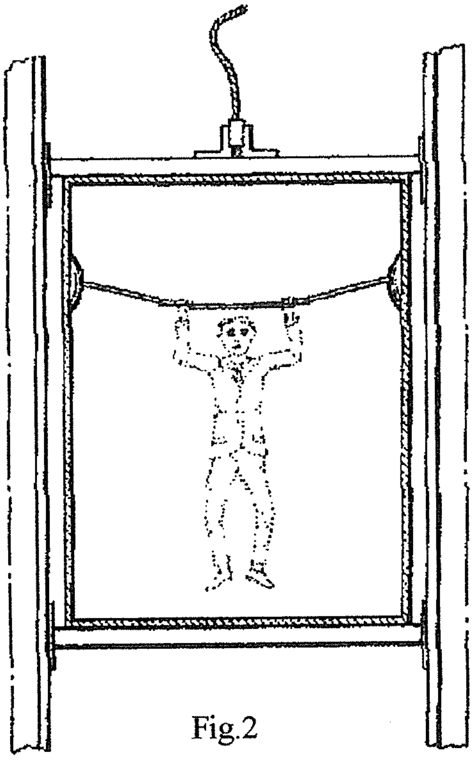


Fig.2

ITALIAN SAFETY PATENT

Many years after the feather bag safety test an Italian invented a method of preventing injury to passengers in lifts in event of free fall or over speed in the down direction. The invention consisted of a rod across the car from side to side above the passengers head, the ends of the rod terminated in large rubber diaphragms as can be seen in the illustration Fig, 2 During the fast downward movement of the car the passenger, lifts himself off the floor. When the lift comes to a stop at the pit the rod and diaphragm reduces the effect of a sudden stop. There is nothing in the invention to answer the question of how many persons can use the device at one time.

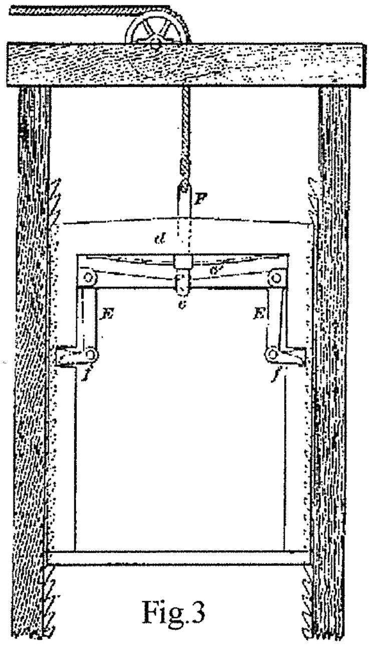


Fig.3

ELISHA OTIS

This was the first safety gear reported and was the start of a revolution for Lifts in high rise buildings. It can be seen from the illustration that the breaking of the suspension rope allowed the spring in the crosshead to extend sideways and engage the recesses in the vertical members either side of the lift car. Lifts in these early days only operated at slow speed and no cushioning was provided. This method was an acceptable way of arresting a free falling car.
As the rise became higher and particularly in the case of lifts fitted with machines located at the bottom floor the weight of suspension rope became excessive particularly when the car was at the upper section of the shaft. This meant the spring in the car crosshead had to be able to operate against the weight of rope if the break was at the machine end. See Fig, 3

METHODS OF APPLYING SAFETY GEAR FORCES

Leaf spring Fig.4.
The first recorded use of a long flat leaf spring as part of safety gear I believe was on Elisha Otis's demonstration lift in 1854. This method of safety gear was only applied to slow lifts, as there was no method of controlling the retardation.

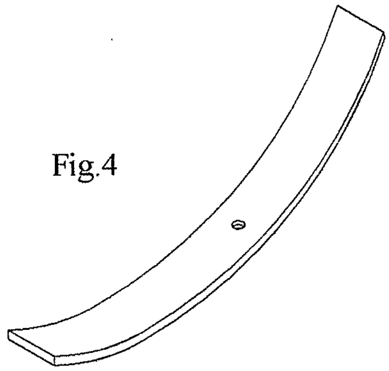


Fig.4

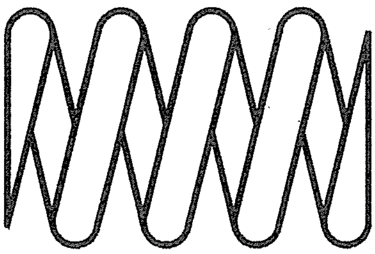


Fig.5

Compression coil spring Fig .5.
Coil springs were used in many ways in relation to safety gear, smaller springs were often used to move the safety gear to engage the guide rail, larger springs were used to provide the required breaking force in the case of sliding type equipment.

Horseshoe spring "C" spring Fig.6
The horseshoe spring had several advantages, it was compact and provided a non adjustable spring to minimise incorrect application.

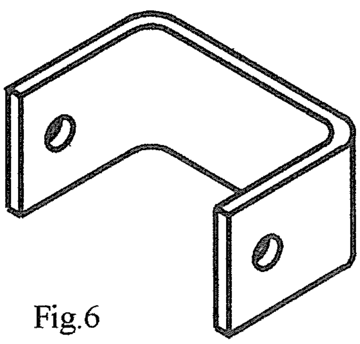


Fig.6

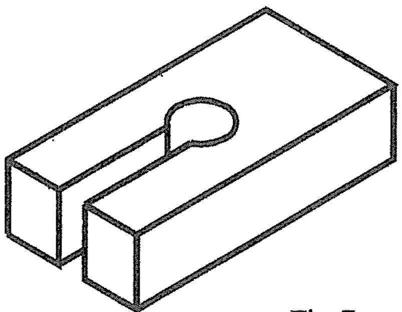


Fig.7

Block spring. Fig.7
Block springs had similar features to the "C" spring, but was used mainly on small lifts up to about 2.0 m/s.

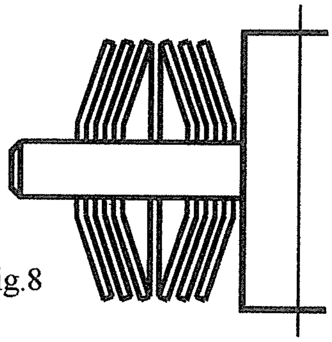


Fig.8

Conical (Disc) spring washers Fig. 8.
Many manufacturers have adopted this form of spring for their safety gear due to its availability. It also involves less design and quality control in the lift manufacturers factory as standard tables of disc arrangements can be applied.

Laminated spring. Fig.9
This spring arrangement has been used mainly in conjunction with roll type safety gear. The introduction of this flexible element behind the roller has permitted roll types to be used at higher speeds.

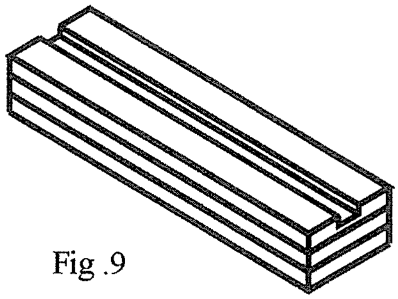
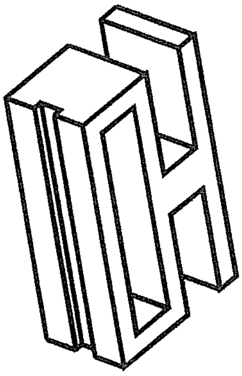


Fig .9



Elastic element Fig.10
This is an example where computer technology was used to design an elastic element to develop the required force for the engaging roller. This development further allowed instantaneous safety gear to be configured for progressive application. (by Dynatech), see also assembly Figs 36 & 37.

Fig 10

Mechanical Clamping Device Fig.11
(Increasing pressure untill governor pulls through) This form of safety gear was called wedge clamp because of the wedge action from the rope drum pushing the wedges out between the rollers on each side of the car, this then creating the clamping action.

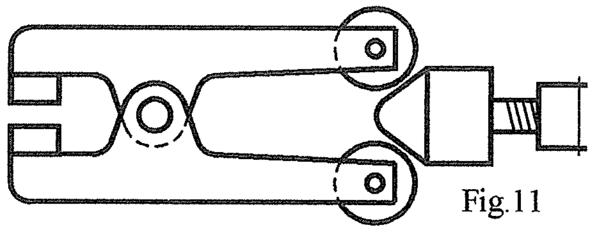


Fig.11

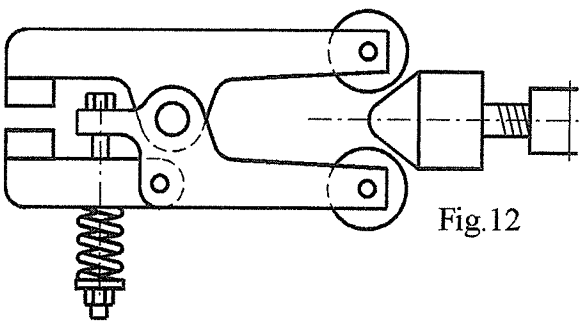


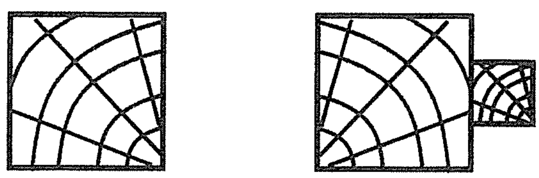
Fig.12

Mechanical Clamping Device Fig.12
(Constant pre-set pressure after governor pulls through) The safety gear in this figure is similar to that in Fig. 11 but has a spring added to allow a constant clamping force to be applied. The spring arrangement can be on the short arm or the long arm, the latter requiring a smaller spring due to mechanical advantage.

CAMS ON WOOD

In the early days lifts were guided by timber, in some cases only one timber member on each side of the car. Over time this was changed to a large timber member as a means of support for a smaller timber section such as tallow wood as the actual running guide. See Fig.13

Fig 13



The introduction of safety gear of a twin serrated cam arrangement (See Fig.14.) allowed the car to run on the small guide and the safety gear to engage on the backing timber. These cams were provided with long tails on the casting to prevent any possibility of the cam rotating a complete circle. The second reason for the long tails was for the operation of the " yoke bolts" used to actuate the cams.

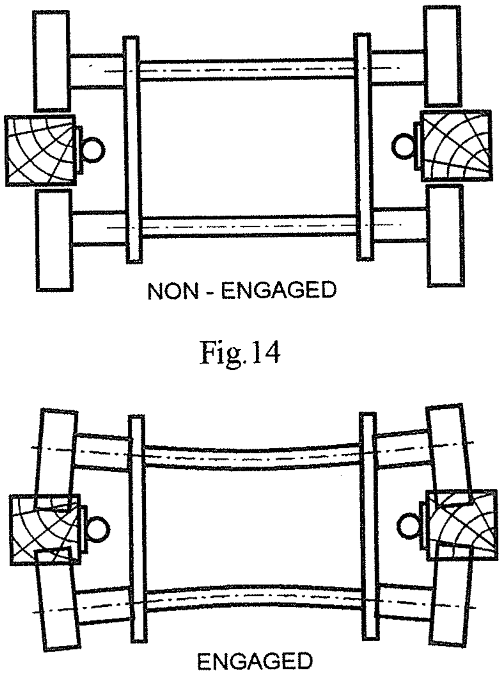


Fig.14

This type of safety gear was usually allowed to be used on lifts up to 200 fpm or 1.0 m/s as the action of the cams engaging the timber caused a decelerating effect due to the compression of the timber.

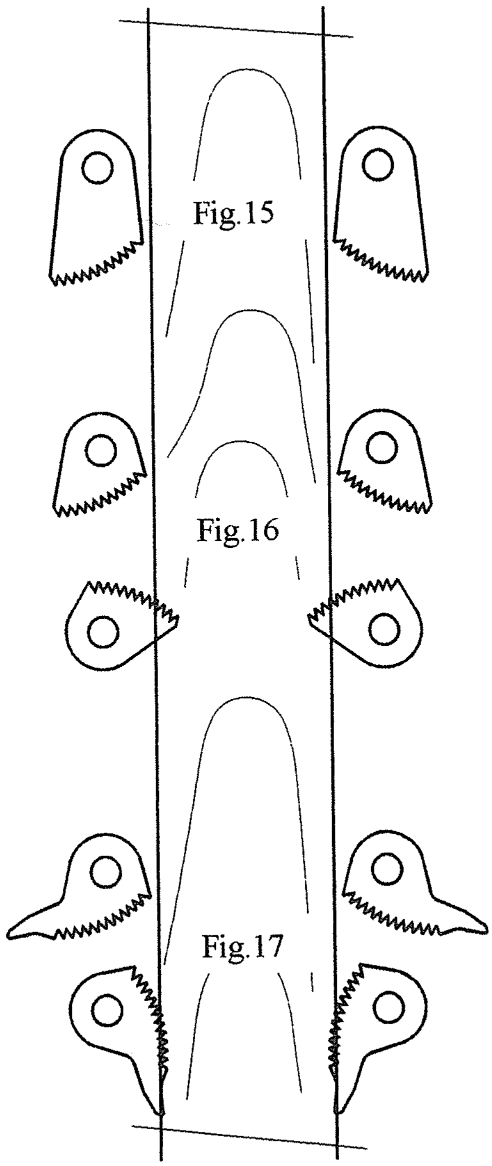
The design of the teeth on the cams was very critical, the shape and the angle of tooth engagement had to ensure the cams became self-energising after the initial contact with the timber backings.

The timber had to be good quality straight grain free from knots and of equal hardness to ensure that when stopping on the safety gear the platform remained level.

The cam may slide down the face of timber backing with out engaging for several reasons (See Fig.15), firstly the shape of the cam and how it first contacted the timber, secondly the hardness of the timber, and thirdly where people had painted the timber causing a slide rather than gripping.

Crushing the guides affected by wood rot or termite infestation caused many failures when testing the safety gear. See Fig. 16

Cams fitted with a tail to prevent excessive rotation. Cams as shown in Fig. 17. initially did not have an extended tail, but faults in timber backing due to water rot and termites allowed the cams to sink into the timber too far and in some cases do a complete revolution.



YOKE BOLT ATTACHMENT AND ACTUATION

This method of safety gear application was very popular when the safety gear was operated by breaking or slackening of any lifting rope, it did not require governor operation although this was applied to latter versions to protect against over speed conditions with the ropes in tact. Fig.18

KNIFE on WOOD

Very early designs of safety gear that operated on timber guides or backings used the single or double knife or chisel system. The example in Fig19 shows how the knife was built into the shoe assembly.

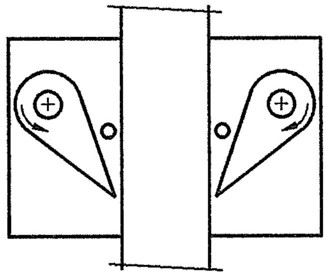


Fig.19

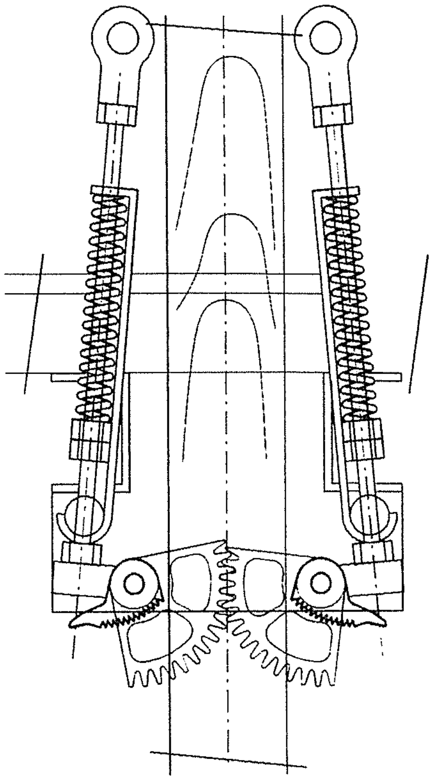
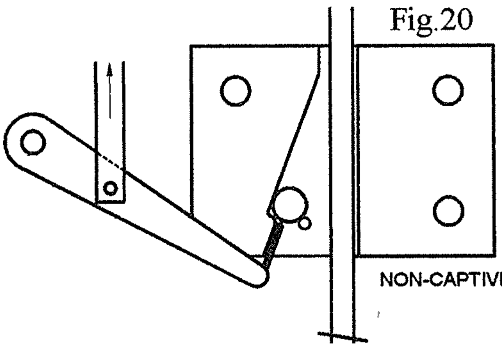


Fig.18

CAMS on ROUND STEEL GUIDES

For many years either timber or timber backed round steel guides were used, as lifts became faster the move was to safety gear operating on round steel guides.

Fig.20

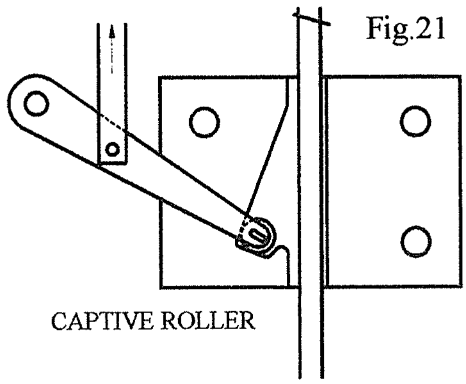


ROLLERS on FLAT STEEL GUIDES or TEE STEEL

This form is called instantaneous safety gear, as the stopping distance is very short with no appreciable slide. See Fig 20

In the early designs the rollers were not captive and this caused many false engagements due to either bouncing of the car or too much clearance in the guide shoe allowing the roller to contact the guide rail.

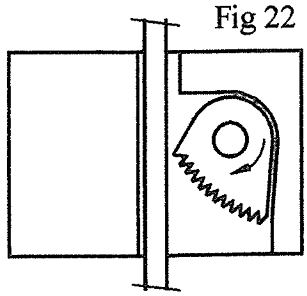
Fig.21



CAPTIVE ROLLER on FLAT STEEL GUIDES

The use of captive rollers (See Fig 21) was made to avoid accidental engaging of rollers and in particular the engagement of a roller on one side of the car only due to a bounce or inertia effect of the rollers or the actuating means. The linkage between rollers ensured that both rollers engaged at the same time.

Fig 22



CAMS on TEE STEEL GUIDES

Many early designs of cam type safety gear only relied on the rod connecting the cams, this in turn caused bending of the rods beyond their yield point. The results were that the safety gear would not perform correctly next time. Future designs employed cams that were designed to be supported by the housing, so taking load off the connecting rods. See Fig 22

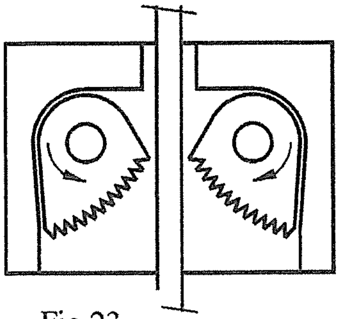


Fig.23

TWIN CAMS on TEE STEEL GUIDES

For large goods lifts the twin cam arrangement was popular as it was capable of larger loads and also it was found easier to release when driving the car in the up direction. Again the use of cams designed to be supported by their housing allowed lighter connecting rods. See Fig 23

RESILIENT BUFFER TYPE

There have been several applications where resilient buffers have been fitted between the car floor and the safety gear channels. This method has allowed instantaneous safety gear to be used to a higher speed without causing injury to passengers or equipment. See Fig 24

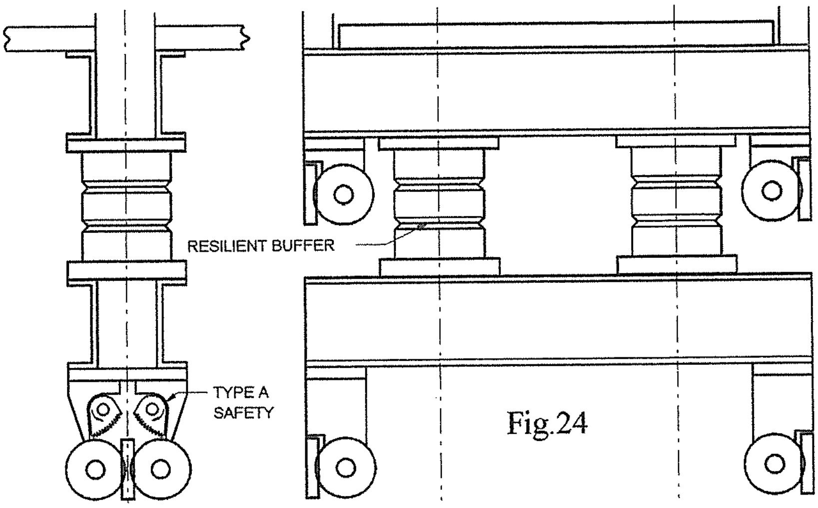


Fig.24

OIL BUFFER TYPE

This form of safety gear was designed to use instantaneous safety gear on a lightweight assembly suspended under the car and connected to the car via a single or double buffer of the hydraulic type Fig.25

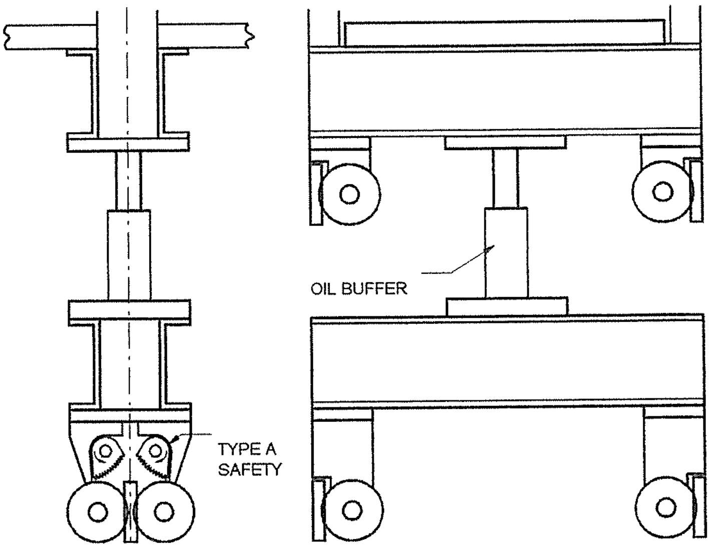
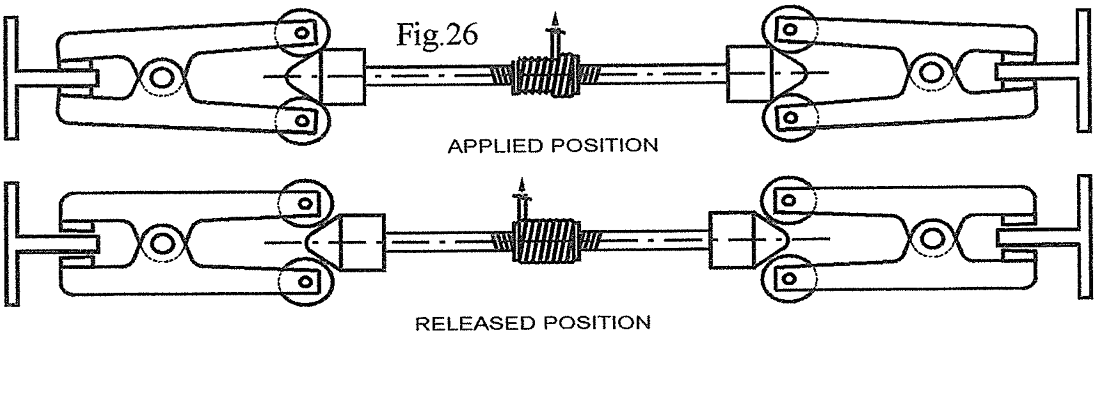


Fig .25

WEDGE CLAMP on TEE STEEL GUIDES

Wedge clamp is one of the early safety gears designed to decelerate the car when actuated by the governor. Access to wedge clamp unwinding handle (release) in car floor was a major problem when either the car was full of passengers or goods that covered the release access hole inside the lift on the floor See Fig 26

Fig.26



FLEXIBLE GUIDE CLAMP (FGS) on TEE STEEL GUIDES

This is the name given to the Otis elevator safety system developed during the 1940's. It relies on its initial actuation from the governor and then becomes self energising. In some cases it uses some force from the governor rope pulling through the governor jaws as the safeties slide down the rails. One of the main advantages of this safety gear over the wedge clamp equipment is its ability to become disengaged or reset by driving the car in the up direction. Fig's 27 & 28

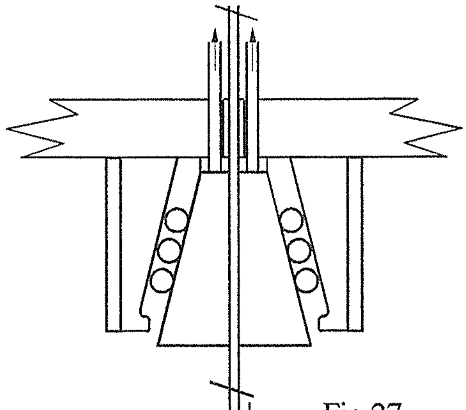


Fig.27

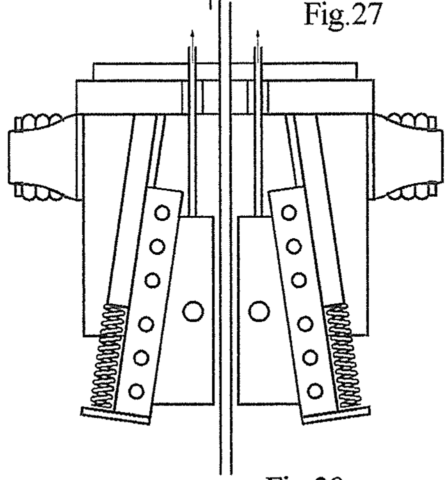


Fig 28

PROGRESSIVE SAFETY GEAR "WEDGEMATIC"

This safety gear was designed in Australia and uses a different spring/pressure arrangement to create jaw force on the rails. When the governor operates it locks the safety gear jaws onto the rails and as the car descends further the force developed by the taper spindle and spring brings the force up to full pre-set value. This force remains constant until the car comes to rest and then driven in the up direction to release the jaws. See Fig's 29, 30, 31

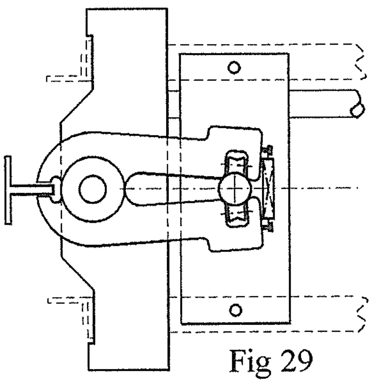


Fig 29

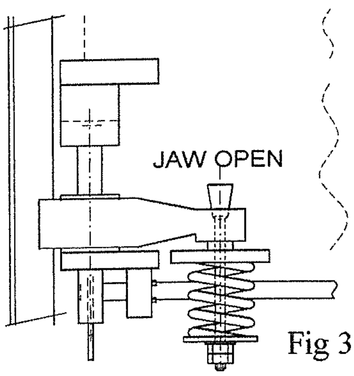


Fig 30

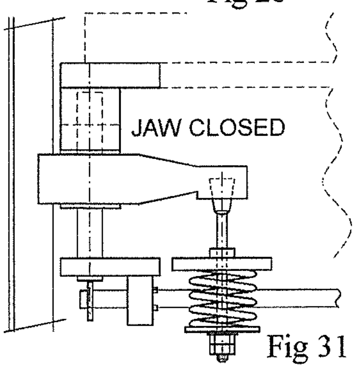


Fig 31

PROGRESSIVE SAFETY GEAR DEVELOPMENTS IN RECENT TIMES

Most of these units are only suitable for low to medium speeds up to about 2.5m/s.

The Fig. 32 Shows how the designer combined the eccentric action on the right hand side to engage the rail and compress the disk springs on the left hand side, these disk springs are pre-set to suit the load and rail thickness. (By Schlosser)

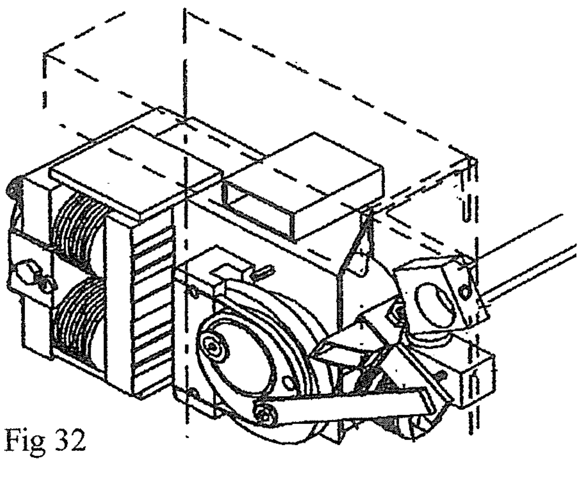


Fig 32

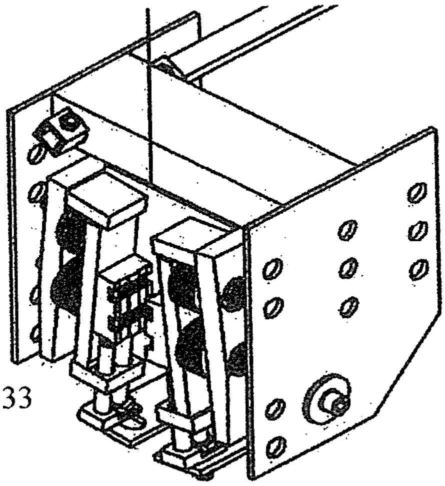


Fig 33

In Fig 33 The design is suitable for larger loads and combines the twin tapered faces and wedges to engage the rail and compress the dual disk spring system up to its pre-set value which again has been set to suit the load and rail thickness. One other advantage of the twin-tapered faces and wedges is that it easier to release when lifting the car to reset the safety gear.

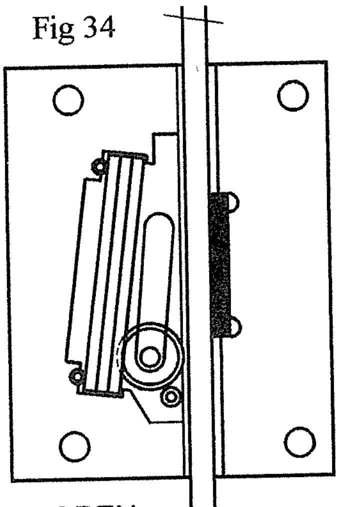
The unit shown in Fig's. 34 & 35 uses the instantaneous roll type in conjunction with a dynamic element in the form of a laminated spring, this allows the assembly to be classed as a progressive safety gear.

The leaf spring stack is selected by thickness to suit the required forces. When the roller reaches the top of its travel it has been designed to rotate at which point the force remains constant.

With the aid of computer design a safety gear as shown in Fig's 36. & 37 was developed, this unit has an elastic element that is machined to the required profile to suit the load and rail thickness.
After analysis of the deflection in the element and critical stress points have been corrected to provide long life and high degree of repeatable performance.

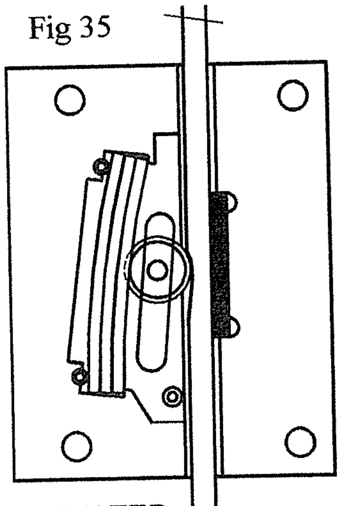
This unit also allows for the roller to rotate at the top of its travel.

Fig 34



OPEN

Fig 35



ACTIVATED

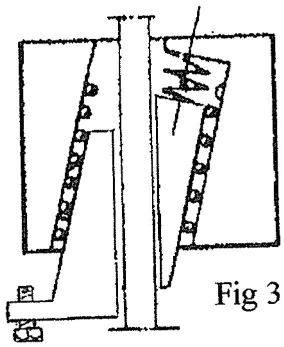


Fig 38

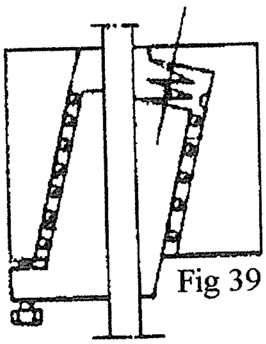
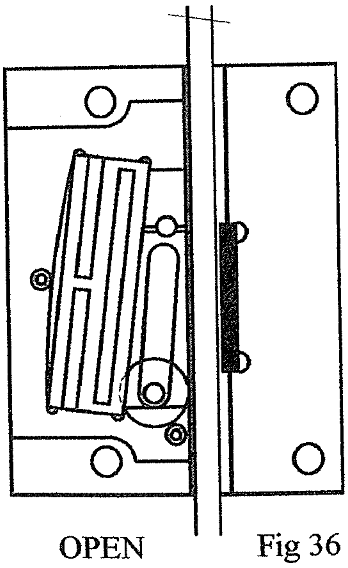
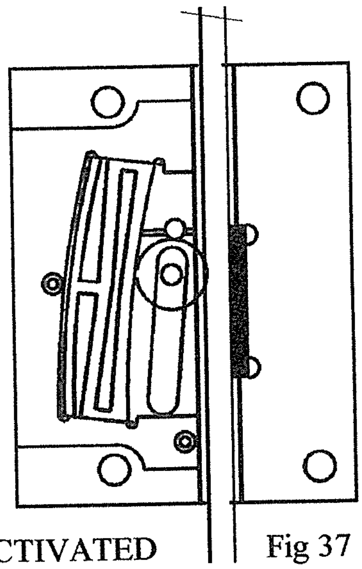


Fig 39



OPEN Fig 36



ACTIVATED Fig 37

A new concept for what first off looks like a form of Flexible Guide Clamp safety gear. A closer look reveals an unusual reverse wedge arrangement. The inventor points out that this arrangement requires a much smaller spring due to the combined wedge and spring function. The components in Fig 38 & 39. are mounted in a solid block of metal that forms the housing.

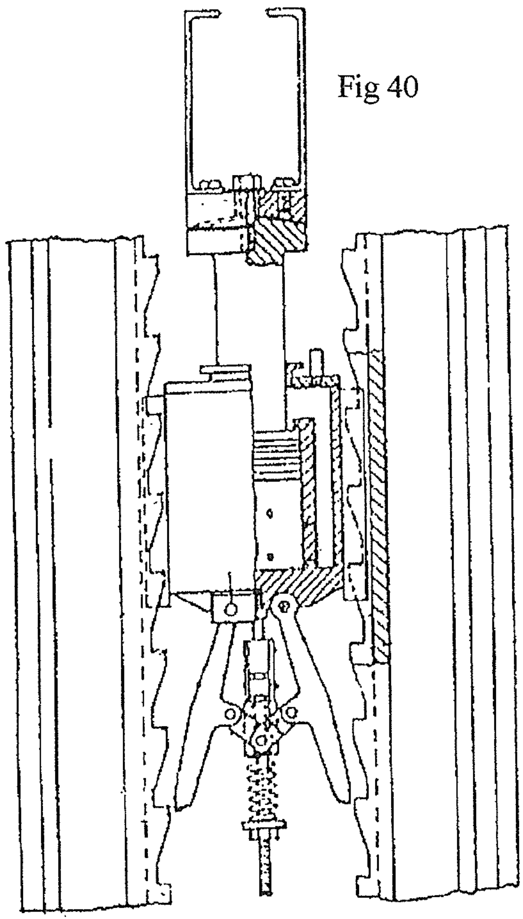


Fig 40

OIL CUSHION SAFETY GEAR

One of the main problems with the original Elisha Otis "rack" system was the very hard stop, a patent was taken out sometime after which included an oil buffer damping system, one of these units was placed on each side of the lift car and operated in conjunction with the twin racks which also acted as guides. Fig 40

SAFETY GEAR SELECTION CRITERIA

There are some very important points to consider when designing or selecting safety gear:

Load rating
Check that the safety gear selected is at least equal or higher than the car weight plus duty load (including any "C" class loading if applicable)

Speed
Instantaneous safety gear is limited to 0.65 m/s in most countries.

Clearance to guide rail
The clearance to guide rail face varies from about 1.5 mm to 5 mm and must be considered when selecting the guide shoe type and car loading.

Guide shoe type.
For slow speed lifts the type of guide shoe is usually either cast iron or plastic and these when in good order have a small clearance, thus avoiding inadvertent operation of the safety gear. On the other hand roller shoes allow the car to float due to compression of roller or deflection in the springs incorporated in roller mountings.

Guide rail finish.
Some safety gears have been tested and approved for specific guide rail finish and blade thickness. Ensure that the safety gear has been specified correctly.

Accessibility for service
Many manufacturers install assembled lift cars complete so it is important that the safety gear is accessible for inspection and repair without major dismantling of other parts.

Environmental conditions.
Environmental conditions such as water or dust can cause damage to both the guide rail surface and safety gear equipment. Regular inspection is needed to ensure correct operation.

Codes or Regulations
Codes and Regulations are changing all the time, ensure that you are complying with the latest version and the performance requirements stated.

NOMINAL MAXIMUM SPEEDS PERMITTED FOR DIFFERENT TYPES OF SAFETY GEAR

GUIDE MATERIAL	SAFETY GEAR TYPE	SPEED LIMIT M/S	REFER FIG.No.
Metal rack	Leaf spring/dog	0.5 ?	3 & 4
Metal rack	Dog/oil cushion	1.0 ?	40
Timber	Knife/chisel	1.0	19
Timber	Cam type	1.0	15,16,17 & 18
Steel	Roll type with resilient cushion	1.0	24
Steel	Roll type	0.65	20 & 21
Steel	Cam type	0.65	22 & 23
Steel	Oil Cushion	2.5	25
Steel	Wedge clamp	5.0 (some applications were higher)	26
Steel	Flexible guide clamp	12.5 (special gib were required over 7.0 m/s)	27 & 28
Steel	Wedgematic	About 6.0	29, 30 & 31
Steel	Eccentric/disk springs	2.5	32
Steel	Tapered wedges/disk springs	2.0	33
Steel	Roll/leaf spring	2.0	34 & 35
Steel	Roll/elastic element	2.0	36 & 37

For exact loading check with manufacturer.

Biographical notes;

John Inglis OAM has been in the lift industry for fifty-six years and a member of technical committee's for thirty-two years. John chairs many lift code committee's and represents Australia on the ISO TC178 committee. His other activities include being a member of IAEE since 1986 and a member of the IAEE executive board in recent years.