Brake Failures on Lifts

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Abstract. Brake failures affect many types of equipment and whilst many efforts have been made in standards to improve the outcome of a brake failure they still occur. The consequences of a failure can range from a near-miss to one or more fatalities. Many service technicians take the view that with the introduction of variable frequency drives into the lift and escalator industry that the brake no longer needs maintaining. This paper will demonstrate that this opinion is incorrect. The paper will look at what happens when a brake fails, the causes of brake failure, examples of brake failures and how recent standards have developed to reduce the risk of brake failure.

1 THE FUNCTION OF THE BRAKE

The function of a lift brake has changed over recent years with developments in drive systems.

Older systems such as single speed and two speed designs relied on the brake itself to bring the lift to a stop during an ordinary journey and the levelling accuracy would be dependent upon the condition of the brake pads, the load in the lift car relative to balance and the position of the lift in its shaft. With these drive systems the brake was also used to bring the lift to a safe stop in the event of a power supply fault or a control system situation (such as a high speed lock tip). The regular maintenance of the brake in this situation is vital.

Older but more sophisticated drive systems such as the DC Ward Leonard system or the DC static converter drive were designed such that the motor would bring the lift to a stop at a landing and then the brake would apply to hold the lift car for loading and unloading. Similarly these drive systems were required to bring the lift to a safe stop in the event of a power supply fault or control circuit situation previously described.

Modern drive systems such as the AC VV and the variable frequency drives are similar to these however maintenance is still required as situations such as high speed lock tips can still occur and cause premature wear of brake pads.

2 WHAT HAPPENS WHEN A BRAKE FAILS?

A lift can be compared to a set of scales with the heaviest side of the balance equation between the car and counterweight being the side that descends when left to gravity.

In many cases when a brake fails the lift car will run upwards due to the counterweight being heavier than a lightly loaded lift car.

As the counterweight descends, where no compensation exists, the lift car ascent increases in speed as the suspension ropes pay out onto the counterweight side.

Modern lifts are fitted with uncontrolled movement devices that will detect and arrest a runaway condition such as previously described but many lifts were installed prior to this recommendation in the standards and do not have such a facility. It should be remembered that uncontrolled movement may be caused by other situations other than a brake failure.

In addition, many older lifts using single speed or two speed drive systems rely on the brake for stopping and the accuracy of the car to landing threshold is reliant on the condition of the brake, position of the lift in the shaft and the load in the car.

3 EXAMPLES OF BRAKE FAILURES

There are many ways that a brake can fail and these include electrically and mechanically.

Examples include:

1. Brake solenoid going open circuit (single solenoid)
2. Brake solenoid going open circuit (twin polarised type)
3. Physical wear of brake pad
4. Rivets coming loose on brake pad
5. Lubricant on brake pad
6. Stuck in open position – release mechanism failure
7. Stuck in open position – other mechanical failure (such as a single line component e.g. a split pin)
8. Held in open position – residual magnetism
9. System overloaded
10. Poor adjustment
11. Overheating

The failures at 1 & 2 can allow the lift to drive through the brake and if not detected early enough can lead to physical wear and ineffectiveness of the brake as at 3.

In some cases one or more of these situations can come together to create an uncontrolled movement scenario.

For instance lubricant on a brake pad plus physical wear may lead to the uncontrolled movement scenario occurring earlier than it would have done had the pad been in good order. It is, in this situation, an external influence i.e. the lubricant probably leaking from a gearbox shaft causing the failure.

Physical wear on brake pads on modern variable frequency drive lifts should not be a problem in theory but in reality uncontrolled movement has been seen when a variable frequency drive is able to drive through brake pads which is particularly prevalent when a lightly loaded lift car is in the upper reaches of the lift shaft and the suspended masses are heavier on the counterweight side.

It is difficult to cite specific cases where brake failures have occurred especially where they were the subject of legal investigations and even more so where fatal injury was sustained however there are some reports in the public domain that can be referenced [1].

There are still a number of brake release mechanisms around that can leave the brake in the open position thus allowing the lift car to move uncontrollably.

Photograph 1 Example of a brake release that can permanently jam open

4 MECHANICAL FAILURES

An early failure of a lift brake was recorded following the Markham Colliery failure on 30th July 1973 where a single line component failed. This was a significant case in that it highlighted issues around single line components and yet many years later EN81-80 (2019) 8.1 [2] acknowledges that inadequate braking systems are an issue. Interestingly the EN81-80 (2003) [3] edition did not acknowledge this.

CONCLUSIONS

70. I conclude that:

(i) the disaster was caused by the complete failure of the mechanical brake of the winding engine because the spring nest centre rod which was a 'single line' component, broke. The design of the trunnion did not take account of the high pressures due to the spring nest, and the main lever could not rotate freely about the trunnion axle which had no practicable means of lubrication. Consequently, operation of the brake produced bending forces and induced fluctuating stresses in the rod which it could not sustain. Cracks developed in the rod and one of them extended until failure occurred;

Source 1 Markham Colliery Report [1]

The requirement to eliminate single line components has been part of the philosophy of ongoing standards for many years which is looked at later in this paper.

'Single line' components

54. The centre rod in the spring nest is an example of a 'single line' component as the safety of the men in the cage was completely dependent upon it. Such components should either be eliminated or so designed as to prevent danger, for example, failure of any 'single line' component in a braking system should cause the winding system to be brought safely to rest. Overspeed and overwind protection should not rely on single components, but where this is not possible they should be reliable and monitored to give warning of failure, or, alternatively, they should fail safe. All winding engines which are dependent upon only one brake path should be modified as should those where automatic application of the brakes is dependent on a single solenoid. Furthermore, there should be indication of any electrical fault in a safety circuit which could render it ineffective or, alternatively, the winding engine should be automatically brought to rest if a fault occurs in a safety circuit which would give rise to danger.

Source 2 Markham Colliery Report [1]

An example of a single line component failure could be experienced on a typical lift brake as below and components including the plate at G being retained by a split pin, or the rod at H failing.

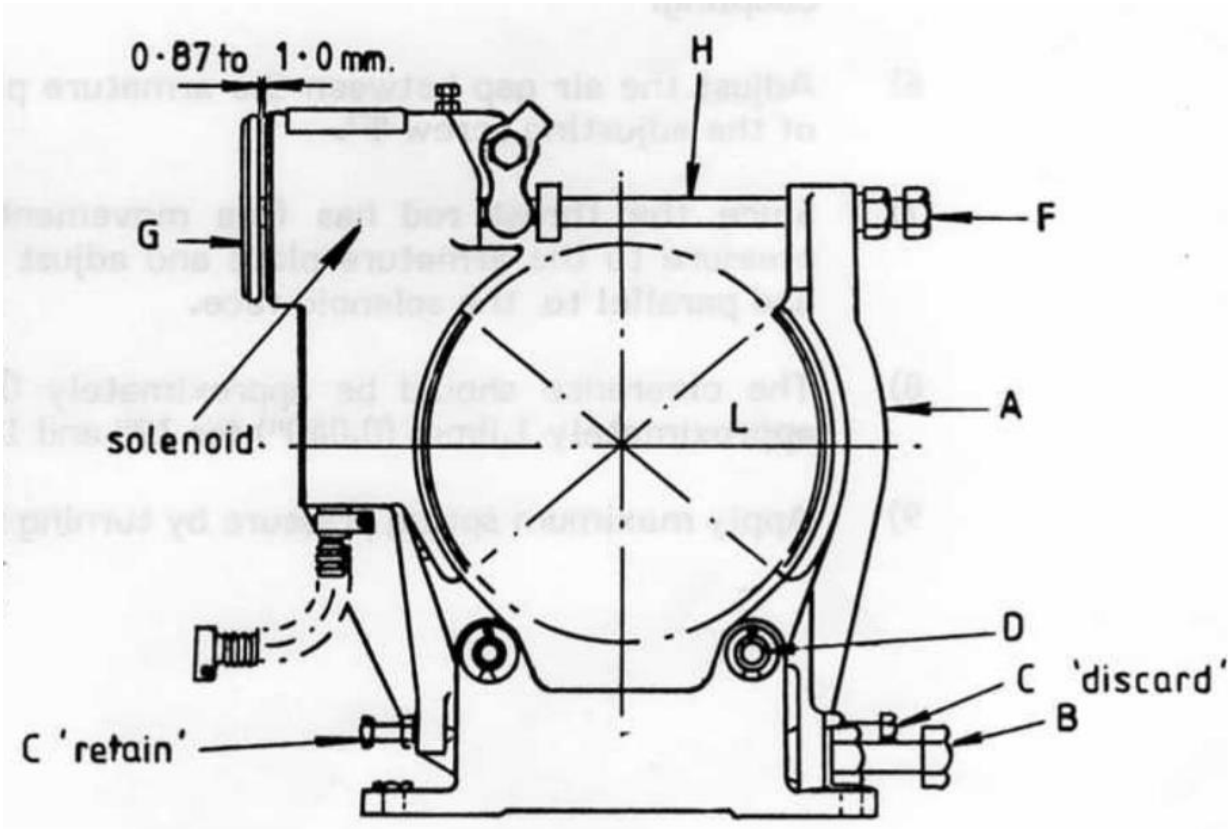
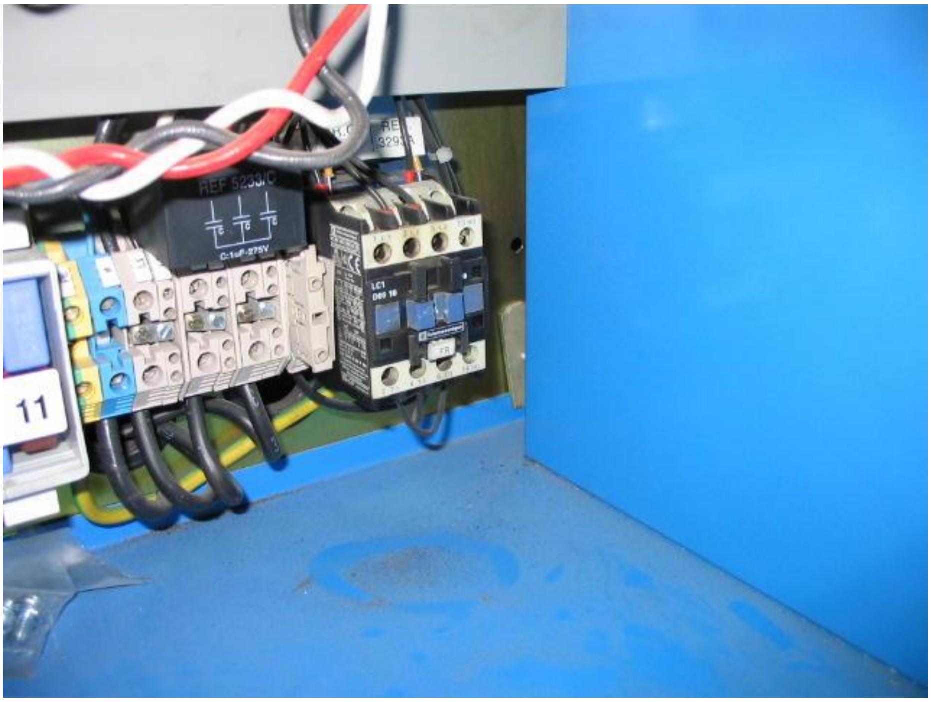


Figure 1 Typical Old Style Lift Brake [4]

5 ELECTRICAL FAILURES

Electrical failures, including the single solenoid going open circuit in the diagram above could result in a brake failure but other contributory factors could be present including high resistance on brake contactors meaning that the brake only lifts partially making it easy for a variable drive system to drive through the brake thus accelerating wear until eventual failure and lift car uncontrolled movement (runaway) occurs.

The photograph below shows a brake contactor that was involved in an uncontrolled movement incident as a result of the brake contactor not having been replaced in a timely fashion. The lift industry more often than not waits for something to fail as the impulse to initiating component replacement [5].



Photograph 2 Build up of carbon dust under the brake contactor indicating oncoming problems.

In another industry technical information notice [6] thermal fuses were fitted to lifts where the brake shoe temperature became excessive.

4. Field Solution:

To fit thermal fuses to the brake shoes that will trip when the brake shoe temperature exceeds 71 C. This will render the lift out of service when it reaches its destination. The lift will be unable to go back into service until the thermal fuse is replaced before which the cause of the overheating should be investigated and rectified

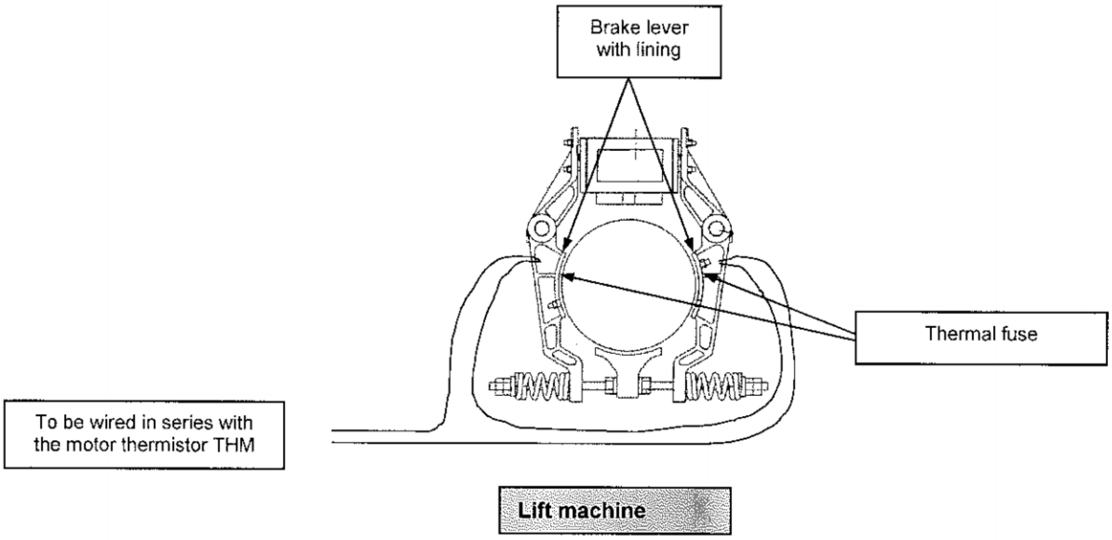


Figure 2 Industry manufacturers technical information sheet [6]

6 DEVELOPMENT OF STANDARDS

Over the years there have been many improvements in braking systems for lifts including the introduction of the A3 amendment for uncontrolled movement however this dealt with the symptom of brake failure rather than the cause.

The current edition of EN81-20 [7] includes uncontrolled movement detection and also the requirement for brake components to be in two sets this offering redundancy and monitoring of the brake itself for correct operation.

5.6.7.2 The means shall detect unintended movement of the car, shall cause the car to stop, and keep it stopped.

5.6.7.3 The means shall be capable of performing as required without assistance from any lift component that, during normal operation, controls the speed or retardation, stops the car or keeps it stopped, unless there is built-in redundancy and correct operation is self-monitored.

5.9.2.2.2.1 This brake on its own shall be capable of stopping the machine when the car is travelling downward at rated speed and with the rated load plus 25 %. In these conditions the average retardation of the car shall not exceed that resulting from operation of the safety gear or stopping on the buffer.

All the mechanical components of the brake which take part in the application of the braking action on the braking surface shall be installed at least in two sets. If one of the brake sets is not working due to failure of a component a sufficient braking effort to decelerate, stop and hold the car, travelling downwards at rated speed and with rated load in the car and upward with empty car shall continue to be exercised.

As has already been mentioned the EN81-80 (2003) [3] standard didn't mention inadequate braking systems however the 2019 version [2] has been expanded to include this situation.

7 CONCLUSIONS

The author is of the opinion that:

- Older lifts with single line components in the braking system need to be assessed.
- All brakes should be fitted with lift detection switches.
- Where modernisation takes place and an old style brake is retained and a variable frequency drive is fitted to replace an older system such as single speed, two speed etc there is a real risk that the lift can drive through a closed brake.
- Prevention is better than cure and methods of detecting the depletion of braking efficiency should be developed so as to detect rather than respond to a failure situation. The potential for uncontrolled movement should be detected before it actually happens.
- Checking of brake condition and adjustment is still an essential part of the maintenance regime as extraneous situations such as high speed lock tipping can affect braking performance.

REFERENCES

[1] Varley, G. Department for Trade & Industry, Markham Colliery Report (1974)

[2] BS EN81-80:2019 *Safety rules for the construction and installation of lifts. Existing lifts. Rules for the improvement of safety of existing passenger and goods passenger lifts (London, BSI*

[3] BS EN81-80:2003 *Safety rules for the construction and installation of lifts. Existing lifts. Rules for the improvement of safety of existing passenger and goods passenger lifts (London, BSI)*

[4] BEI, Technical information sheet (DNK)

[5] Cooper, D. How many failures are enough? LES

[6] OTIS, Technical information sheet (DNK)

[7] BS EN81-20 :2020 *Safety rules for the construction and installation of lifts. Lifts for the transport of persons & goods. Passenger and goods passenger lifts. (London, BSI)*

BIOGRAPHICAL DETAILS

David Cooper is the Managing Director of UK based lift consultants LECS (UK) Ltd. He has been in the lift & escalator industry since 1980 and is a well-known author and speaker. He holds a Master of Philosophy Degree following a 5-year research project into accidents on escalators, a Master of Science Degree in Lift Engineering as well as a Bachelor of Science Honours degree, Higher National Certificate and a Continuing Education Certificate in lift and escalator engineering. He is a co-author of "*The Elevator & Escalator Micropedia*" (1997) and "*Elevator & Escalator Accident Investigation & Litigation"*. (2002 & 2005) as well as being a contributor to a number of other books including CIBSE Guide D. He is a regular columnist in trade journals worldwide including Elevation, Elevator World and Elevatori. He has presented at a number of industry seminars worldwide including 2008 Elevcon (Thessaloniki), 2008 NAVTP (San Francisco),1999 LESA (Melbourne), 1999 CIBSE (Hong Kong), 1999 IAEE (London), 1998 (Zurich), 1997 CIBSE (Hong Kong), 1996 (Barcelona) and 1993 (Vienna) as well as numerous presentations within the UK. He is also a Founding Trustee of the UK's Lift Industry Charity which assists industry members and/or their families after an accident at work. In 2012 David was awarded the silver medal by CIBSE for services to the Institution. David Chairs the Charitable Trust that runs the Lift Symposium and is an Honorary Visiting Professor in Lift Engineering at The University of Northampton.