Lift Modernisation the Lost Art of Engineering

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Abstract. This paper investigates the techniques and tools available to the lift modernisation engineer and uses case studies of lift forensic engineering, codes used for imported lifts, reliability impact testing of door systems and ride quality that is achievable. The experienced lift modernisation engineer needs to understand the limitations and design characteristics of the aging lift equipment being considered and how it can be blended in with new engineering components and systems and the original and current code requirements. Also the structural limitations of the building have to be considered for lift equipment removal, routes possibly across floor slabs and the suitability of lift shaft walls for new fixings.

1. INTRODUCTION

"The lift modernisation designer asks, "When is a lift system old?" "When does it require a transplant, brain surgery or a facelift?" in other words, "a modernisation". Lift companies, architects and consultants use various terms to describe a lift modernisation, i.e., conversion, retrofits, renovating, changeovers or upgrading…" [1]

At recent lift conferences and symposia, a high proportion of papers and poster sessions (approximately 30 %) have been devoted to the system approach to lift performance as defined by lift traffic analysis research. The next highest number of papers were devoted to mechanical and electrical design with a bias towards traffic control and green issues. Worryingly all of these papers generally focus on the 'new build' systems rather than the existing lift stock.

According to the published data as of March 2010, there were an estimated 4.5 million units installed within Europe and approximately 207,000 units in the UK [2].

Within the UK there are an estimated 114,000 lift units which were installed prior to 1986 [3]. Depending on the design of the original equipment and how it was maintained, these units may be coming to the end of their useful theoretical design life. The majority of these existing units are in small buildings where, the constraints of a lift modernisation are the existing lift shaft, the size of motor rooms and any equipment which could be re-used, refurbished or modernised.

Within Europe, an estimated 64% of the lifts currently being maintained have been installed in residential buildings and only 14% within offices. Therefore, it appears that a considerable amount of effort and time is being used to carry out lift system analysis on a small proportion of the European lift stock.

When confronted with an existing lift, the majority of lift manufacturers do not consider modernisation as an option for improvement. They prefer to install "standard" units from a catalogue rather than take up the challenge of keeping the old equipment and bringing it back to its original design standard.

In Poland, the existing lift stock is considered to be 81,683 units and it has been estimated that there are over 25,000 units which are 60 years old [4]. These units have had no modernisation and have a level of original design and craftsmanship that is difficult to achieve today. If Poland decided to replace these historic lifts with new EN81 lifts, it would be considered, and quite rightly so to be an act of historic vandalism.

This does not necessarily reflect on the skills and the expertise of the design engineers and field technicians who specialise in ‘new lift installations’ but a concern remains that the skills and the expertise of lift modernisation is not being transferred to the younger engineers and technicians employed by companies - consultants, mechanics or technical sales engineers alike.

2. LIMITATIONS

Lift modernisation demands the skills of an engineer with the subtleness of an artist. It could also be described as a technical cookbook where all of the ingredients can be found but unless they are blended correctly in the right proportions the results of the finished lift modernisation could end up being worse than the condition of the system before the works were carried out.

Nowadays, the ‘new lift installation’ sale transaction is dictated in the form of the standard company product range which has no room for change or compromise because of the way the manufacture and type testing procedures are set up and carried out.

The skilled lift modernisation engineers are not constrained by limitations which come with a new lift installation. They have much more of a “blank canvas” approach towards components or materials which can be used and blended into the scheme design. A good modernisation project has an important advantage; the lift does not lose its character but retains or improves on, important technical and safety aspects from when it was originally installed.

A savvy modernisation engineer can restore a lift to its original specification and still provide a safe and reliable installation which could outlast a modern lift product from a standard generic range. The older lift equipment has a proven design and manufacturing process, highly reliable and robust components and a high probability of survival. The new lift installations tend to be much more complicated and consist of complex components and sub systems designed to ensure competiveness rather than longevity.

3. MISSION CRITICAL

Just because a lift is “old” it does not mean it has to be unsafe or unreliable. Instead, what has to be considered is whether this lift can fully fulfil its function to transport passengers and goods safely and reliably. Therefore, we have to consider mission critical systems which may require modernisation. These systems include components and sub-systems in the lift motor room, lift shaft, information systems as well as primary safety systems. The mission critical components include, but are not limited to, gearless machines, worm gear drives, controllers, selectors, pulleys, door drives, over speed governors and safety gears.

Just because an individual lift sub-system or component wears out, the total assembly does not need to be replaced. There are specialised manufacturing companies who can and will supply components for old lifts which have the same design and safety characteristics as the original components.

4. FORENSIC ENGINEERING

The modernisation engineer must be aware of code or standard recommendations to reduce energy consumption but should not be restricted by modern technology, traffic handling or aesthetics.

Wooden lift cars with wrought iron enclosures and stained glass decoration, lifts with original machines and mechanical equipment do not need to be mission critical if a sensitive modernisation and restoration process is undertaken. Since a standard modern lift typically cannot be sensitively blended into an historic environment, a modernisation engineer should utilize the tool of forensic engineering.

Forensic Engineering is considered to be the 'investigation of materials, products and structures of components which have failed or do not operate or function as intended thus causing damage, consequently the Forensic investigation aims to locate causes of failure with a view to improve performance or extend the life of a component'.

In the lift motor room the components considered to be mission critical are the motor and gearbox assembly as well as controller. There may also be an over speed governor which could be "old" and not up to the current code requirements. However, as long as it operates in accordance with the code applicable at the time of installation it should match with the safety gear installed.

When considering the geared or gearless machines, some even older than 50 years, the simple option would be to remove them along with any associated problems and blending the new equipment with the existing structural steel bedplate. This would require a structural analysis of the original bedplate plate design as the new equipment load paths could vary dramatically from the existing structure. The new arrangement, however, will very likely deflect causing premature failure of the new equipment. On the other hand, if modernisation is considered the equipment load paths would remain the same requiring reduced design development and lower capital costs making it a much more cost effective solution.

It is very difficult or nearly impossible to visually inspect the internal components of a worm geared traction machine and give an assessment of the expected remaining life expectancy for the unit [5]. In such case, it is recommended that a Forensic Engineering survey is carried out on the unit(s)

A considerable amount of information can be obtained from the analysis of the oil and grease taken from the gearbox reservoir and bearing housings. Also non-destructive testing techniques could be undertaken such as thermal imaging on bearings.
The alternative means of extracting such information would require destructive testing or sending the unit back to the original manufacture [5], assuming they are still in business.

The oil analysis report provides specific site inspection information and an estimation of the oil condition by detailing its state, presence of any additive elements and an elemental analysis of the oil contamination by potential wear metals.

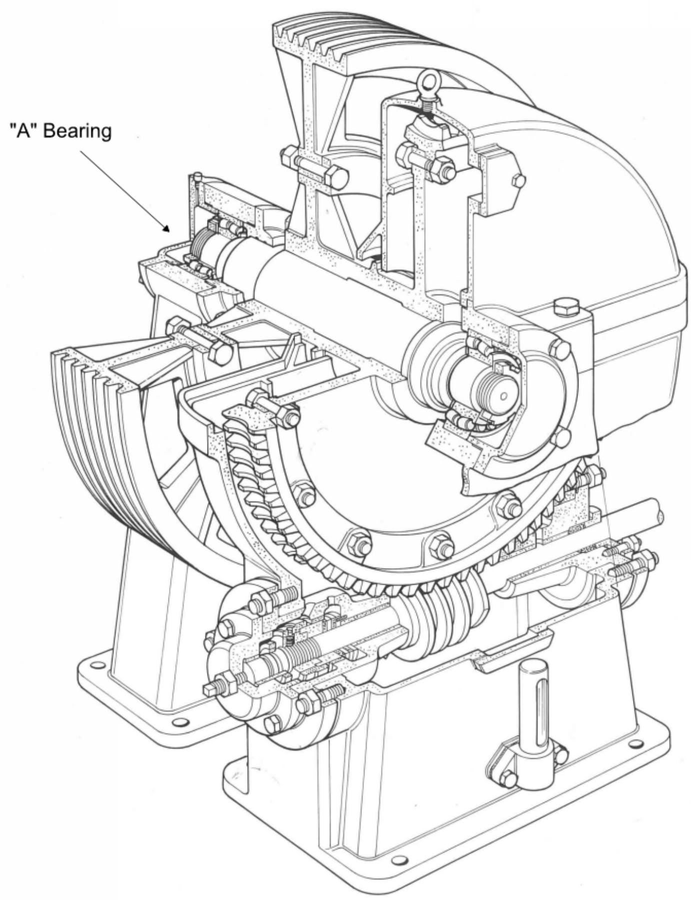
Table 1 Example of the oil sample analysis

An No.	Sample Date	Oil Condition												Additive Elements ppm				
		Visc. 40°C	Appearance	Dispersancy	Water	Glycol	Fuel	Initial pH	TAN	Oxidation	TBN	Ferrous Debris	ISO	Ba	Ca	Mg	P	Zn
1	19/01/09	288	70	n/a	N	n/a	n/a	n/a	n/a	n/a	n/a	90	n/a	2	6	2	304	22

An No.	Sample Date	Elemental Analysis - Contamination & Wear Metals ppm																	
		B	Na	Si	Li	Al	Cr	Cu	Fe	Pb	Sn	Mo	Ni	Ti	Ag	Mn	V		Oil Chg	Oil Age
1	19/01/09	1	< 1	7	< 1	< 1	1	566	181	26	71	1	4	< 1	< 1	2	< 1		Y	-1

An example of such an analysis (Table 1) shows that the oil sampled was either replaced at some point or contaminated with an unsuitable grade or the lubricant has deteriorated over time. The forensic investigation showed that fairly significant levels of ferrous debris were present. Further investigation showed that the "A" bearing had failed (Sketch 1) – such detailed information could not have been obtained from a visual inspection or without dismantling the machinery.

Sketch 2 Sectional Perspective of a Single Worm Geared Machine [1]



The forensic analysis also showed high levels of 'wear metal' elements (Copper -Cu and Tin -Sn) in both samples – these 'wear metals' originated from the sliding friction between the phosphor bronze worm wheel and the worm shaft as well as from the shaft rotation in the plain sleeve bearings. These characteristics are typical for the traditional worm and wheel traction lift winding units.

The Elevator Vibration Analyser is a tool that also can be classified as a forensic aid which can be used to determine the condition of a component. It is well known that lift noise and vibration analysers are used to determine limits of noise and vibration within a moving lift car, but they can also be used to determine where the noise and vibration originate from. The source could be the machinery, the ropes, the pulleys, the guide rails or even the guide shoes. Lateral quaking, is for example, the horizontal swaying of the lift car and can be caused by bends in the guide rails and/or inadequate operation of the roller or sliding guide shoes. Vertical vibrations mainly originate from the hoist machine or the pulleys. It is transmitted though the ropes and it can potentially occur due to the dynamic balancing of the drive motor. The acceleration, deceleration and jerk, in turn, give the passengers a sensation of their weight increasing or decreasing, and can be a result of the lift sticking to the guide rails due to high pressure and/or high friction.

5. MAINTENANCE

The first truly modern use of electronics in the lift controllers took place in the 1970's. Before this date, the controller was referred to as "relay logic" and was both generally simple and reliable. For office buildings however this type of controller did not have the quick response time demanded by the lift system engineers for the traffic patterns occurring in new office buildings. Also, this control system did and still does suffer when installed in a "dusty" environment which has been made worse by lift maintenance companies reducing the time spent performing routine maintenance and adjusting the relays.

These relay logic switches are still very common and are easily maintained and repaired. Moreover, if quick electronic response times are not required, there is no real reason why they cannot be incorporated into an historic lift modernisation ahead of a new microprocessor based lift controller. Unfortunately, a less experienced lift modernisation engineer will likely opt for the easy replacement option, probably due to the skill base focused on modern technology rather than maintain and adjust the old lift.

The maintenance company's approach to the allocation of time and resources for routine maintenance has recently been typically centred around new complex lift technology. As a result, the time allowed for each maintenance visit has been reduced to a minimum and it is now insufficient for proper lift care, possibly preparing the customers for new lift sales driven by the existing lift reliability issues.

6. A DIFFERENT APPROACH TO MODERNISATION

The continuing upkeep and maintenance of the 25.000 historic lifts in Poland suggest that it is possible to preserve a higher skill base which encourages the re-manufacture of components to match their original design and specification. This also suggests that the engineers and architects understand the social need for modernisation.

Poland has one of the largest skill bases which are actively pursuing the modernisation of old and historic lifts, with approximately 32% of these lifts running over 60 years. This is no reflection on the skill of the younger lift engineer, but a living proof that there is a room for both, the restoration engineers and the standard new installation lift engineers within our industry.

7. CODES, STANDARDS AND GOOD PRACTICE

It is only in relatively recent times that codes and good practice guidelines for lifts have been published. In the UK, British Standard 2655: Part 3; 1971 [6], sets out the recommended arrangements for standard electric lifts in metric units. Prior to this date, the units for manufacturing, installation and buildings were in the imperial measurements of feet and inches. (Note: British Standard 2655: Part 3; 1971 was superseded in 1989 and replaced by EN81-3:2000+A1 2008 [7].)

This date is important to the original understanding of design limitations of lifts installed in the UK. The lifts could have originated from a British manufacturer, a European supplier, or in the case of prestigious, relatively tall buildings at the time, from the USA which although using imperial units of measurement, would use American standard screw threads which would be not compatible with the British Standard screw threads or spanners.

Prior to the European Lift Directive being put into practice there had been lift installations fully imported from Japan, for example. In these instances, the code of manufacturing and component design had followed the Japanese Standard (JIS). These lifts will require modernisation in the near future. Consequently it has to be assumed that the components of these installations will have different design characteristics to those of the modern components, thus requiring a detailed site investigation and inspection of all components for wear, damage and proper installation.

Another example of conflicting codes is a situation where a lift guide rail has a 'bend' which has probably been there since installation and needs to be replaced. The modernisation engineer is faced with a decision whether or not to remove the damaged rail and lower the sections above the damaged section so the keyways slot into place as they have the same design characteristics. What specification should the new rail be? Should it be to ISO 7465:2007, was it a British Guide Rail with imperial dimensions, an A17.1 or JIS standard?

It is still possible to find lifts with wooden or round car or counterweight guide rails which although not modern code compliant, have probably given over 60 years of reliable service while correctly matched with a compatible safety gear. Removing and replacing this type of guide rails with modern Tee section guide rails would require a full structural assessment of the shaft walls, as well as possibly a new car sling and car.

In the majority of instances re-fixing or repositioning of lift guide rails in an old lift shaft, which were mainly constructed in masonry, can be a real design challenge not only for the guide brackets but also door frames as the existing construction cannot always be properly identified and assessed.

The lift modernisation engineer, when confronted with shaft walls of unknown construction, has several design options depending on the possible fixings being considered. In any case loading tests should be carried out on site, where a load application device is used to test the masonry to see if it detaches from the bond.

8. FINAL THOUGHTS

Just because a lift is being modernised, it does not mean that it cannot comply with the requirements of universal access. Although the physical size of the lift can have an effect on full lift compliance and the repositioning of the car operating stations can destroy the architectural features of wooden decorative lift cars, the introduction of a modern LCD indicator would be totally out of character with the old lift. Therefore, the lift modernisation engineer must not only be a skilled engineer who understands the limitations of the lift being modernised but also must be aware of the options available and understand which components can be overhauled or remade. Probably the most important virtue they must possess is to be a sympathetic lift conservationist, so that the specified modernisation works do not end up being nothing more than historic vandalism.

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BIOGRAPHICAL DETAILS

The Authors would like to thank all colleagues at ARUP for all their advice and assistance and more importantly their enthusiasm for promoting the modernisation of lifts.

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