# The Necessity for Oil Analysis and Offline Filtration in Hydraulic Elevators

By Michael Johnson

The hydraulic oil is the lifeblood of the hydraulic system; it is estimated that 80% of failures in an oil system are related to oil quality and cleanliness [1]. However, little attention has been given to the oil in the hydraulic elevator over the past 40 years.

The elevator code has no specific requirements for the hydraulic oil and the elevator service contract rarely addresses oil quality or ownership; as a result the oil is not addressed resulting in failures in covered components like the seals, valves, submersible motors and piston rods.

Mineral based AW32 is the most common oil used in the elevator industry, however vegetable and synthetic based oils are beginning to see additional use. If a baseline sample of the oil is available, it is possible to determine the rate of oxidation in the oil, or the oils ability to perform as required by the hydraulic system.

**TAN**

The Total Acid Number (TAN) is a measure of base oil degrading and is a reliable indication of oil aging. Most AW32 have a TAN of (0.3) due to the addition of additives; as the additives are depleted the TAN will drop to zero before beginning to increase rapidly. A TAN delta increase of 1 is considered to be out of tolerance for most hydraulic oils; once it gets passed +2 the oil is no longer fit for further use and continued use can lead to failures. The most common problem associated with high TAN is early seal failure.

**Viscosity**

Viscosity is a measure of the oils resistance to flow; most elevator components including, seals, valves and pumps are designed to operate with an oil viscosity of 32 – 46 centistokes. When the viscosity is too low, a delta of -6 centistokes, adhesion between the seal and rod will result in low speed vibrations and burnishing of the piston rod. A burnished piston will have increased surface contact between the seal and the rod resulting in premature seal failure.

An increase in viscosity, a delta of +2, can be a result of oil contamination or oil oxidation. When the oil viscosity is too high, increased heat loads are placed on the power units, and leveling issues will develop due to the reduction in viscosity index.

**Viscosity Index**

Viscosity Index (VI) is a measure of the stability of the oil's viscosity between 40°C and 100°C. AW32 has a viscosity of 32 centistokes at 40°C and around 5 centistokes at 100°C. As the low temperature viscosity increases the swing between the high and low temperature viscosity becomes wider and the

valve becomes difficult to set. This is observed by cars that overshoot the floor early in the day and struggle to reach the floor later in the day.

Contamination can alter the VI of the oil resulting in excessive component wear and relevels due to down leaks; there is no standard in the elevator industry for VI. New mineral based oils have a VI between 90 and 120; vegetable and synthetic oils can have a VI up to 200. Contaminated oil can have a VI as low as 50 or 60; cleaning the oil can restore the VI closer to its original levels. Please note, cleaning the oil does not alter the VI, it removes contaminates that effect the oils performance increasing the VI reading. It is my recommendation that the VI be monitored and kept above 90.

**Water**

Water is the most common contaminant in the hydraulic elevator system due to the hydroscopic nature of hydraulic oil and the open reservoir utilized in hydraulic elevators; new oil can have up to 500ppm water content, depending on the oil. Even small amounts of water, 250 ppm, can alter the transition and leveling times of the elevator resulting in excessive heating and rapid oil oxidation. Water will react with the common oil additive ZDDP when reservoir temperatures are over 130°F, resulting in seal and pump wear as well as increased oxidation of the oil and acid formation.

Water entrains air in the oil resulting in pump cavitation and micro-dieseling. Micro-dieseling is the fracturing of the hydrocarbon molecules as air bubbles travel from an area of low pressure, the reservoir, to an area of high pressure, the pump. Due to the frequent and prolonged bypass times present in hydraulic elevators, micro-dieseling is a common source of oil degrading. This change is permanent and cannot be reversed.

The moisture level has a direct impact on the life of the oil and of the hydraulic system components; there is a direct correlation between moisture content and machine life.

| LEM - Moisture Level | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Current moisture level, ppm | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 50,000 | 12,500 | 6,500 | 4,500 | 3,125 | 2,500 | 2,000 | 1,500 | 1,000 | 782 |
| 25,000 | 6,250 | 3,250 | 2,250 | 1,563 | 1,250 | 1,000 | 750 | 500 | 391 |
| 10,000 | 2,500 | 1,300 | 900 | 625 | 500 | 400 | 300 | 200 | 156 |
| 5,000 | 1,250 | 650 | 450 | 313 | 250 | 200 | 150 | 100 | 78 |
| 2,500 | 625 | 325 | 225 | 156 | 125 | 100 | 75 | 50 | 39 |
| 1,000 | 250 | 130 | 90 | 63 | 50 | 40 | 30 | 20 | 16 |
| 500 | 125 | 65 | 45 | 31 | 25 | 20 | 15 | 10 | 8 |
| 250 | 63 | 33 | 23 | 16 | 13 | 10 | 8 | 5 | 4 |
| 100 | 25 | 13 | 9 | 6 | 5 | 4 | 3 | 2 | 2 |
| 1% water = 10,000 ppm. \| Estimated life extension for mechanical systems utilizing mineral-based fluids. | | | | | | | | | |
| Example: By reducing average fluid moisture levels from 2,500 ppm to 156 ppm, machine life (MTBF) is extended by a factor of 5. | | | | | | | | | |
| Courtesy Noria Corporation | | | | | | | | | |

Water reverses the chemical process that is used to make ester based oils, vegetable, and leads to oil breakdown, polymerization and rancid smells. Hydrolysis changes the oil chemically, and cannot be reversed. Keeping a vegetable oil dry is of paramount concern.

**Particles**

Small particles, 5 microns to 15 microns are the most detrimental to moving and sliding components, because they can enter the small clearances in the system causing pump and valve wear. Typically, the hydraulic elevator does not have any form of oil filtration.

Inline filtration is not practical due to the high oil flow rates of the elevators. To filter under 5 microns, the filter would have to be impractically large to allow a sufficient flow rate for proper elevator operation. Offline filtration is a practical way to filter properly without affecting oil flow or the operation of the elevator.

The ISO Cleanliness code (ISO 4406-99) measures the number of particles greater than 4 microns per ml of oil. This standard is common in other industries with specific limits for different types of equipment, for example CNC milling machines and plastic injection machines, however there is not currently a standard for elevators. Maxton Valve recommends filtration is 5 microns or smaller.

Maxton Manufacturing Company reported that "Approximately 20% of the valves sent back for warranty are contaminated. The other 80% are misadjusted or no problem was found and 90% of all valves sent back for repair are contaminated." (www.maxtonvalve.com)

Improvements in ISO Cleanliness codes can be correlated to show increases in equipment dependability and life extension. A decrease of ISO code from 22 to 18 represents a life extension factor of 3X. It is my recommendation that the maximum ISO Code for a hydraulic elevator be 20, which is 5000 – 10,000 particles per ml of oil; the ISO target should be a code of 18 which is 1,300 – 2,500 particles per ml of oil.

Life Extension Table - Cleanliness Level, ISO Codes

| | 21/19/16 | 20/18/15 | 19/17/14 | 18/16/13 | 17/15/12 | 16/14/11 | 15/13/10 | 14/12/9 | 13/11/8 | 12/10/2007 |
|---|---|---|---|---|---|---|---|---|---|---|
| 24/22/19 | 2 | 3 | 4 | 6 | 7 | 8 | >10 | >10 | >10 | >10 |
| 23/21/18 | 1.5 | 2 | 3 | 4 | 5 | 7 | 9 | >10 | >10 | >10 |
| 22/20/17 | 1.3 | 1.6 | 2 | 3 | 4 | 5 | 7 | 9 | >10 | >10 |
| 21/19/16 | | 1.3 | 1.6 | 2 | 3 | 4 | 5 | 7 | 9 | >10 |
| 20/18/15 | | | 1.3 | 1.6 | 2 | 3 | 4 | 5 | 7 | >10 |
| 19/17/14 | | | | 1.3 | 1.6 | 2 | 3 | 4 | 6 | 8 |
| 18/16/13 | | | | | 1.3 | 1.6 | 2 | 3 | 4 | 6 |
| 17/15/12 | | Hydraulics and | | | | 1.3 | 1.6 | 2 | 3 | 4 |
| 16/14/11 | | Diesel Engines | | | | | 1.3 | 1.6 | 2 | 3 |
| 15/13/10 | | | | | | | | 1.4 | 1.8 | 2.5 |

Courtesy Noria Corporation

An Elevator Maintenance Control Program that includes TAN, Viscosity, VI, Water Content and ISO Cleanliness Code will increase the service life of the equipment and provide achievable goals that can be quantified by existing tests which are currently utilized in other industries.

The system components of the hydraulic elevator system are very robust; by introducing standards and regularly monitoring the oil condition, we can reasonably expect to increase the service life of the hydraulic equipment by 2 to 4 times. As a minimal step, an annual oil analysis should be conducted to identify potential problems to prevent unplanned shutdowns.

Because oil analysis and maintenance has a direct impact on the service life and reliability of the elevator equipment, it is more critical to sites with fewer vertical transportation options. The cost of an elevator failure or outage at a location with one elevator is higher than when there are multiple elevators. For example, an assisted living center with one elevator has a more critical need than a hospital that has a bank of four elevators to spread out the risk.

The cost of regular testing and remediation far outweighs the cost of a single breakdown. The annual cost of an offline filtration unit for an elevator is around $600.00 per year* and does not require the elevator to be shut down to maintain the oil. (* Annual cost is based on purchase of a filtration unit with a 30 year life expectancy and 1 filter insert per year. JFI Management, LLC)

| Service Provided | Estimated Costs | Estimated Elevator Downtime | Inspection Required in some states |
|---|---|---|---|
| **Oil Change** | **$1,000 per Barrel** | **1-2 days** | **No** |
| **Pump Replacement** | **$8,000 - $15,000** | **3 days** | **Yes** |
| **Valve Replacement** | **$8,000 - $12,000** | **3 days** | **Yes** |
| **Packing Replacement** | **$1,000 - $2,500** | **3 - 8 Hours** | **Yes** |

In critical locations with limited numbers of elevators, it is reasonable to increase the frequency of the oil analysis and filtration to prevent expensive breakdowns and outages.

**Data Tracking**

Data tracking is valuable to the building owner and the prospective service company. As part of an effective MCP, historical data of oil condition and oil trending will alert the building owner of possible problems that may be developing allowing remediation steps to occur, prior to a failure. Annual maintenance with predictable outages will allow the building owner to manage downtime instead of being forced to react to it.

Clean oil is also a negotiating tool for building owners, as it reduces the service company's unknowns. Considering 80% of the failures in an oil system are oil related, oil that has been maintained and documented is more desirable because it is less likely to cause a failure of the oil system.

## Conclusion

Standardized test for TAN, Viscosity, Water, VI and Oil Cleanliness make Oil Analysis a reliable tool to increase the service life and dependability of hydraulic elevators through proactive maintenance. Offline filtration protects the oil, the lifeblood of the hydraulic system, and can extend the service life of the equipment and increase the reliability of the elevator system. Both oil analysis and offline filtration should be considered an essential part of elevator maintenance.

References
[1] CC Jensen A/S. Clean Oil Guide – "The importance of Oil Maintenance"

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Summary:

Frequency of Oil Analysis:

- Minimum of Annually when multiple vertical transportation alternatives are available
- Every four to six months if alternatives are limited or non-existent

Total Acid Number (TAN)

- Δ less than 1 from initial point for mineral oils
- Δ less than 2 for vegetable oils

Viscosity:

- +2 centistokes for 32
- -6 centistokes for 32

Viscosity Index

- ASTM D2270-98
- Minimum 90
- No Maximum

Water:

- Less than 250 ppm for mineral oil
- Less than a trace for vegetable oil

Particles:

- ISO 4406/99 Standard
- Target 18
- Maximum 20

Filtration:

- 3 Microns or smaller
- Offline filtration recommended