Hydraulic Elevators: Importance of Oil Cleanliness

by Dr. Ferhat Celik and Parag Mehta

Learning Objectives

After reading this article, you should have learned about:

- Why hydraulic systems fail
- How particle contamination of hydraulic oil occurs
- Which parts of a power unit are the most sensitive to oil cleanliness
- How oil cleanliness levels can be determined
- Consequences of particle contamination

The main cause of failure of a hydraulic system is due to solid particle contamination of the hydraulic oil. Even new oil contains some level of contaminants; hence, filtration of the contaminants is one of the most important assignments to satisfy in a hydraulic system. Contaminants can be in the form of dust, dirt, worn-out metallic parts, sand, water and air, as well as chemical residuals. Entrained water and air can be avoided by using submersible motor-pump systems, a baffle plate or a diffuser and applying general tank design practices. Oxidation rate of the oil can also be slowed to an acceptable level by keeping the maximum working temperature below 65°C. On the other hand, keeping particle contamination at an acceptable level is a process that should be fulfilled throughout the service life of the hydraulic system.

Sources of particle contamination can be listed as:

1. Manufacture-borne contaminants, which are metal chips, welding scales, sand from casting or debris produced during the manufacturing process
2. System-borne contaminants, which are wear products generated inside the mating components
3. Maintenance-borne contaminants, which are added by servicing people, opening and closing system components like valves, piping, etc.

Whether contaminants are introduced into the system from outside or generated within the hydraulic system, they are circulated throughout the hydraulic circuit. These contaminants, which cause machine parts to wear out, are cleaned from the oil through filtration. The ones that cannot be filtered deposit at component clearances and cause wear of critical component surfaces. Likewise, increased oil temperature (decreased oil viscosity) adversely affects lubricating properties, which accelerates abrasion or erosion type wear. Additional abrasion wear creates more debris, which, in turn, generates additional particle contamination. The resultant metallic and non-metallic particles then start a chain reaction of abrasion that may lead to the formation of other undesirable products through oxidizing the hydraulic oil.

The presence of contaminants can cause a catastrophic failure, which takes place when a component suddenly fails to function, such as the jamming of a check valve or when a fiber of a critical size goes between

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*This article and "**Hydraulic Elevators: Taking Care of the Oil**" on page 89 combined equal a continuing-education value of :*

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the seat and plugging, causing excessive leakage or malfunction of the system. A progressive failure, however, happens when a wear process produces a slow deterioration of component performance over a period of time, such as the drop of pump (volumetric) efficiency. Catastrophic failures occur due to particles above component internal clearances, and they are not necessarily dangerous for service life. The progressive failure takes place due to the particles that are smaller than the component's internal clearances; particularly those smaller than 5 µm are highly abrasive. The rate of progressive failure is also strongly related to the size and quantity of particles present in the oil, as well as the internal clearances of the components. Moreover, the progressive failure is highly dependent on the system pressure, temperature and oil velocity. Typical internal clearances of hydraulic components are shown in Table 1.

Some level of particle contamination is always present in hydraulic fluid. It is the size and quantity of these particles with which we are concerned. The level of contamination, or, conversely, the level of cleanliness considered acceptable, depends on the type of hydraulic system. Typical oil cleanliness levels for hydraulic elevator systems, defined according to International Organization of Standards (ISO), National Aerospace Standard (NAS) and Society of Automotive Engineers (SAE) standards, are shown in Table 2.

Most manufacturers of hydraulic equipment specify an optimum or target cleanness level for their components. Exposing components to hydraulic fluid with higher than optimum contamination levels may shorten the component's service life. Therefore, oil cleanliness levels recommended by component manufacturers should be targeted and then maintained on a continuous basis.

Regarding the oil cleanness level, the most sensitive components on a hydraulic elevator power unit are the pump (normally a screw pump) and the elevator control valve. Though their internal clearances are similar, pumps wear out more rapidly than the control valve. In fact, a well designed elevator control valve under good maintenance of hydraulic oil should give a long service life of 25-30 years. Occurrences of internal leakage during the service life of the valve generally results from large particle contaminations. Unless the valve is damaged, servicing the valve (cleaning) would correct the problem most of the time. This is because the regulating parts of an elevator control valve work at pilot pressures, which is 30-50% less than the system pressure, and the velocities between mating parts are much slower than a pump. When these advantages are brought together with effective filtration of the pilot chambers and the design of self cleaning internal filters, then a long service life of the valve can be guaranteed.

The ISO DIS 4406 cleanness level standard has gained wide acceptance in most industries today. It is a two-digit code, which gives the number of particles above 5 µm and 15 µm in size in a 100 ml sample of oil. A modified version of this standard additionally accounts for the number of particles greater than 2 µm, as well. The oil cleanness level for hydraulic elevators may be determined according to the pump manufacturers' recommendations,

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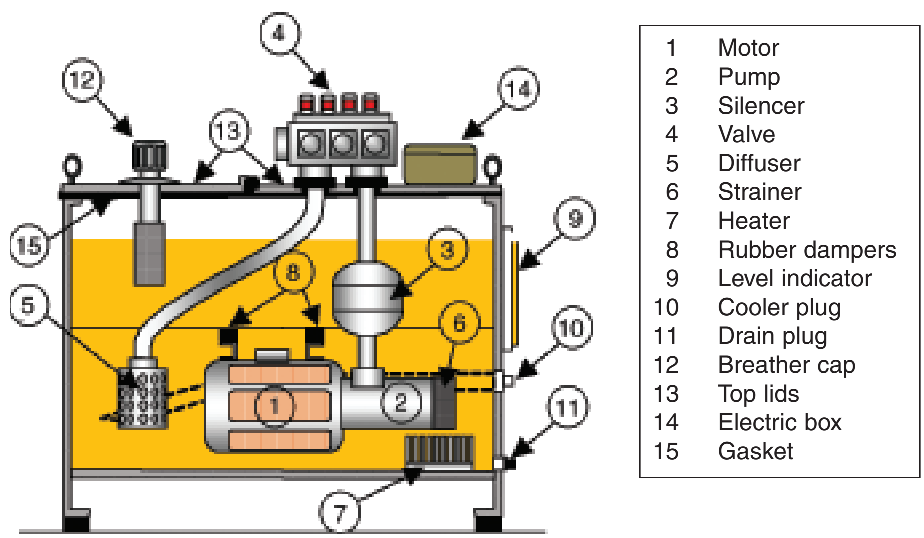

Figure 1: Hydraulic elevator power unit

Component Type	Typical Internal Clearance [µm]
Gear pump	0.5-5.0
Vane pump	0.5-10
Piston pump	0.5-5.0
Servo valve	1.0-4.0
Elev. control valve	10-40
Linear actuator	50-250

Table 1: Typical clearances of hydraulic components

Hydraulic Elevator System	ISO 4406	NAS 1638	SAE 749	Minimum Recommended Filtration Level [µm] ($\beta_X \geq 75$)
Medium pressure (50-150 bar)	18/15	9	6	12-15
Low pressure (< 50 bar)	19/16	10	-	15-25
Large clearance	21/18	12	-	25-40

Table 2: Level of oil cleanness and filtration

which is around 19/16 by ISO 4406 for screw pumps. Accordingly, the minimum filtration level can be chosen as 15-25 µm ($\beta_{25} \geq 75$).

It should be remembered that a good filtration practice alone does not provide satisfactory results. Therefore, the complete elevator power unit should be properly designed considering, heat dissipation, de-aeration, oil compatibility with used materials, water demulsibility and filtration. Figure 1 shows a tank design where access of particle contamination is prevented with gaskets, seals, a breather with filter and filtration. It is important that the suction filter size and surface area should be large enough to prevent quick clogging (mesh area of 0.2-0.3 mm^2). In fact, a properly designed and maintained unit would prevent fast particle contamination and thus a largely meshed suction filter would be sufficient just to avoid very large materials being sucked by the pump.

Consequences of Particle Contamination

1. Cylinders:
- Quick wear of seals and scratches on the cylinder rod
- Increased leakage

2. Elevator control valves:
- Erosion of flow orifices that varies flow characteristics
- Wear of seals increases leakage, causing frequent releveling of the elevator
- Large particles may prevent closing of the down valve and cause uncontrolled fall of the car on the buffers.
- Preventing pressure relive valve to close completely, that drops valve performance, creates chatter and heat
- Stopping on/off solenoid valves to function properly, causing late start or overshooting floor levels
- Sticking or jamming of solenoid valves on servo electronic valves, creating undesirable travels

3. Pumps:
- Excessive wear in pump components, screws, bearings, etc.
- Decreased volumetric efficiency
- Quick clogging of pump filter, when not realized, causes cavitation and complete damage to the pump.
- Slow response and erratic deliveries

4. Oil:
- Wear debris may accelerate the process of oxidation and break down molecular structure of the oil generating gummy residue, which may attract additives and change the composition of the oil, shortens the oil life and lowers the maximum operation temperature.

Filtration of the oil is the only practical method to prevent contaminants flowing into hydraulic components. The objective of filtration is to maintain a predetermined fluid cleanness level that will provide sufficiently long service life. The quality of oil, and the life and efficiency of filters are other important parameters that one should consider while designing an elevator system. If filter efficiency is too low, the contaminant level will continue to increase due to the wear particles generated within the system and new particles entering from outside the system. High filter efficiency decreases and stabilizes the contaminant level, extending the service life of the components and the hydraulic oil. Hence, it is necessary to determine the type of filter and filtration method to be adopted in a hydraulic elevator system at the design stage. The general practice suggests that a filter with more surface area is more economical, as the filter life is extended under identical flow conditions. Similarly, using a filter having more pores generates less pressure drop and longer service life. Therefore, the pump suction filters should be designed with more pores and larger surface area.

An important point is also to check the contamination level regularly and maintain the oil cleanness level through flushing of the complete oil. Flushing is a process to circulate and filter the complete oil through and additional cleaning circuit until the required cleanness level is obtained. If composition of the oil is acceptable, applying the flushing process every two years would reduce the cost of oil (EUR1.5-2 [US42.1-2.7] per liter) replacement every seven to 10 years, and provide a better environment friendly solution.

Learning-Reinforcement Questions

Use the below learning-reinforcement questions to study for the Continuing Education Assessment Exam available online at www.elevatorbooks.com or on page 149 of this issue.

- What is the main cause of hydraulic system failure?
- What are some sources of particle contamination for a hydraulic system?
- How does hydraulic oil manage a long service life?
- What are the four main consequences of particle contamination?
- What is a good way to maintain the oil cleanness level?

Parag Mehta is a mechanical engineer with more than a decade of experience in engineering design and project management. He specializes in computer-aided design (CAD) and works for Blain Hydraulics GmbH (Germany) in research and development of control valves for hydraulic elevators.

Dr. Ferhat Celik graduated as a Mechanical Engineer from Istanbul Technical University and later obtained his MSc and PhD degrees from the University of Manchester (UMIST). He worked for Istanbul University as an assistant professor for seven years before joining Blain Hydraulics, manufacturer of hydraulic elevator valves. He has published various technical articles on hydraulic elevators as well as on manufacturing processes, CAD and CAM.

Hydraulic Elevators: Taking Care of the Oil

by Roy W. Blain

Learning Objectives
After reading this article, you should have learned about:
- How to prevent contaminants from affecting hydraulic components
- Oil overheating

Oil Filtration and Leakage

In the case of the Blain EV 100 elevator control valve, it is not necessary to install an extra filter in to the power-unit system. Sensitive sections fo the EV 100 are protected against foreign substances by three built-in, self-cleaning filters: one in the cylinder main pressure line, one in the cylinder pilot pressure line and one in the pump pilot pressure line. Clogging of the filters in EV valves is prevented by the filters being positioned in flow turbulent sections of the valve so that contamination cannot settle on the filter's surface. Inspection of those filters need not be more frequent than one time per year.

Fine hair-like fibers in the oil stemming from cleaning rag, may on rare occasions settle on a sealing surface of a valve or solenoid seat causing a minor down leak and releveling of the car. The EV spare parts list shows the valve parts to check in the event of persistent releveling. Starting with solenoid D, cleaning the affected part or turning the solenoid seat over may be sufficient to cure the leak, otherwise its replacement will be necessary. It is not necessary to strive for perfect sealing in every valve in operation. Because code requirements assure a safe releveling system whether the descent of the car of a few millimeters is caused by valve leakage or through the cooling of the oil in the cylinder pressure system, a minor leakage of the control valve can be tolerated. The European Code EN 81-2 requires that the loaded elevator does not leak downward by more than 10 millimeters (3/8 inch) in 10 minutes. This is the standard used to determine if a valve must be serviced for leakage or not.

For practical reasons, a quicker method for judging valve leakage is to close the ball valve in the cylinder line and observe the gauge showing pressure in the cylinder chamber of the valve. If this pressure falls to zero in less than 20 seconds, it may be necessary to service the valve, depending on the diameter of the main ram and the sensitivity of the customer.

Overheating of the Oil

Oil temperatures above 55°C (130°F) should be avoided, otherwise the efficiency of the pump drops considerably, and its life is reduced. Aging of the oil is accelerated as well. Overheated oil also results in frequent releveling. Causes of overheating are:
- Up leveling being too long due to the leveling speed being slower than necessary or the slow down switch being set too low.
- Machine room ventilation inadequate.
- The frequency of operation is too high for the rate of heat dissipation from the installation. As a temporary measure to avoid overheating of the oil which would

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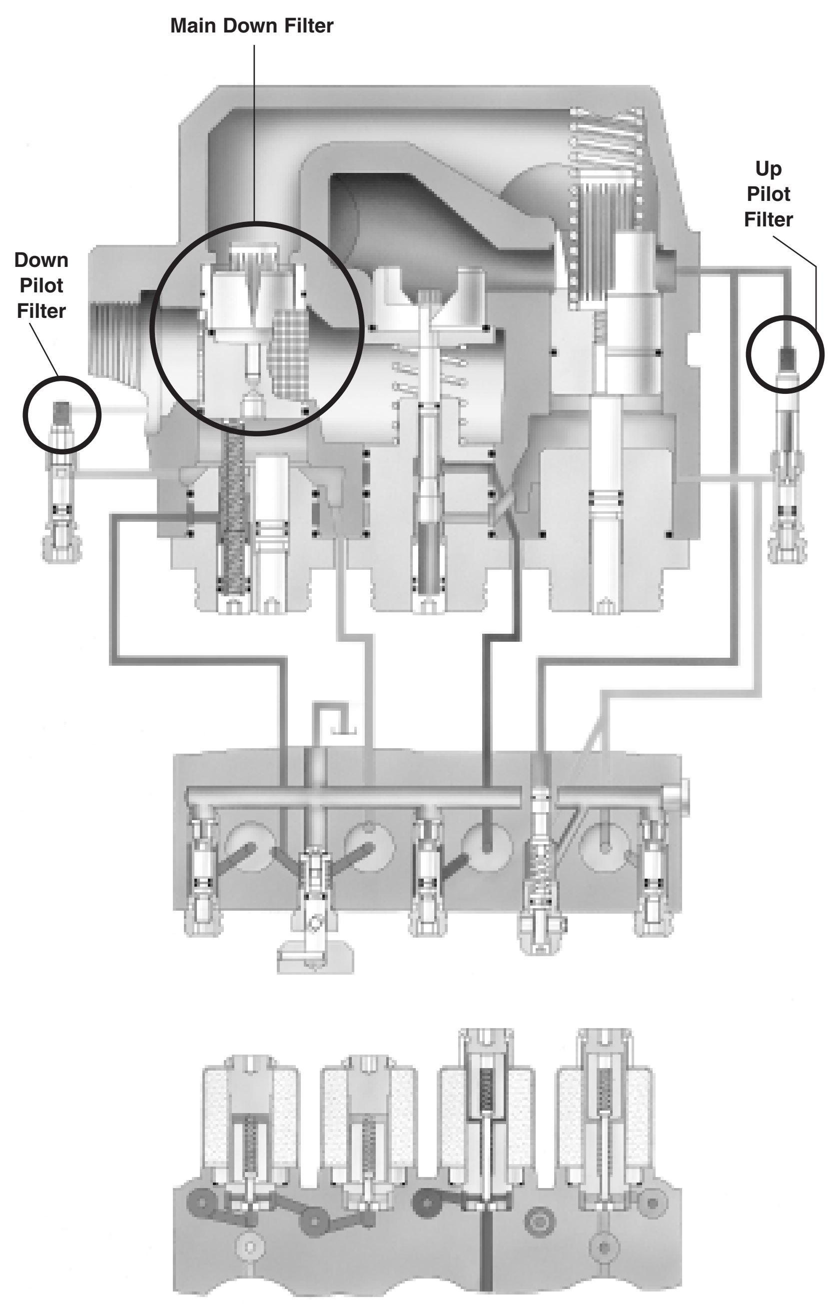
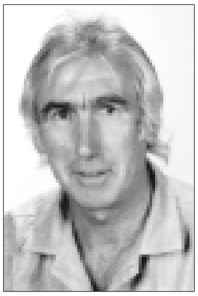
otherwise result in the automatic shut down of the elevator, the down speed can be slowed to reduce the frequency of operation, until a permanent solution is installed.

If the degree of overheating is not excessive, and it takes, for example, two to three hours for the oil temperature to rise from 20-55°C (70-130°F), it may be sufficient to improve air circulation around the power unit, for example through the installation of a 0.05-0.010-kW ventilator extracting air out of the machine room or through a fan of similar power, blowing air over the tank, or both.



BLAIN EV 100 elevator valve

Coolers are (rarely) necessary in hydraulic elevators. If extensive overheating nonetheless does occur through continuous operation of the elevator, the following measure can be taken. Depending on the size of the elevator, it will be necessary to install a (10-50 liter-per-minute [3-13 gallon-per-minute] pump) to circulate the hot oil through a fan cooled radiator of about 0.1-0.2 fan kW. It remains essential that there is sufficient extraction of warm air out of the machine room or that the cooler is outside of the machine room, for example in the elevator hoistway. The effective cooling power of a cooler need not be more than one-fourth of the main elevator motor drive and should not be confused with the power of its fan drive which normally need only be 0.1 or 0.2 kW. The cooling system should automatically switch into operation when the oil reaches 30-35°C (85-95°F). Below these temperatures, the small temperature difference between the air which cools and the warm oil may find the cooler running continually with little effect.



Roy W. Blain, an HNC mechanical engineer from Salford Tech in the U.K., has developed hydraulic extrusion presses in Bournemouth, the U.K. He has worked on synchronized heavy lifting gears. Blain founded Blain Hydraulics which is based near Stuttgart, Germany. Blain has also worked on reforming English spelling with the objective of simplifying spelling according to the rules of consistent phonetics. Known as Saaspel (SPA), the system works as a pronunciation guide to traditional spellings to replace the International Phonetic Alphabet or as a complete orthography in its own right (www.sasspel.com).

Learning-Reinforcement Questions

Use the below learning-reinforcement questions to study for the Continuing Education Assessment Exam available online at www.elevatorbooks.com or on page 149 of this issue.

- What is the EN 81-2 requirement for the distance over time that a loaded elevator does not leak downward?
- Why should high oil temperatures be avoided?

ELEVATOR WORLD Continuing Education Assessment Examination Questions

Instructions:

- Read the articles **"Hydraulic Elevators: Taking Care of the Oil"** (page 89) and **"Hydraulic Elevators: Importance of Oil Cleanliness"** (page 121) and study the learning-reinforcement questions at the end of each article.
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1. Which is NOT useful as an acceptable way to avoid entrained water and air?
   a. Oxidizing the oil before using it in the system.
   b. Using submersible motor-pump systems.
   c. Using a baffle plate or diffuser.
   d. Applying general tank design practices.

2. What comprises a catastrophic failure?
   a. The slow deterioration of a component over time due to the presence of contaminants.
   b. The slow deterioration of a component over time due to progressive leakage.
   c. The sudden failure of a component due to progressive leakage.
   d. The sudden failure of a component due to the presence of contaminants.

3. What do the size and quantity of particles present in the oil and internal clearances of the components affect?
   a. The result of a catastrophic failure.
   b. The rate of progressive failure.
   c. The running temperature of the hydraulic system.
   d. The length of time between oil changes.

4. Which should be considered in the proper design of a complete elevator power unit?
   a. Heat dissipation.
   b. De-aeration.
   c. Oil compatibility with used materials.
   d. Water demulsibility and filtration
   e. All of the above.

5. Wear debris can decelerate the process of oxidation.
   a. True.
   b. False.

6. What is the objective of filtration?
   a. To maintain a variable fluid cleanness level for the extension of service life.
   b. To provide a largely meshed suction filter to prevent materials from being sucked into a pump.
   c. To maintain a predetermined fluid cleanness level to provide a sufficiently long service life.
   d. To extend service life by providing a cool temperature in which fluid can flow.

7. It is necessary to determine the type of filter and filtration method to be adopted in a hydraulic elevator system at the design stage.
   a. True.
   b. False.

8. Using a filter with more pores:
   a. Generates more pressure drop and longer service life.
   b. Generates less pressure drop and shorter service life.
   c. Generates more pressure and longer service life.
   d. Generates less pressure drop and longer service life.

9. The European code EN 81-2 requires that the loaded elevator does not leak downward in:
   a. 10 minutes.
   b. 15 minutes.
   c. 20 minutes.
   d. 30 minutes.

10. Which oil temperatures should be avoided?
    a. Those above 95°C (203°F).
    b. Those above 55°C (130°F).
    c. Those above 40°C (104°F).
    d. Those below 10°C (50°F).

ELEVATOR WORLD Continuing Education Reporting Form

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Continuing-education credit: This article will earn you **one contact hour (0.1 CEU)** of elevator-industry continuing-education credit.

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