



EFFECTS OF AIR CONTAMINATION ON MACHINERY AND LUBRICANTS: WHAT DOES AN AUTOMATED AIR RELEASE VALUE ANALYZER MEASURE AND WHY IS IT IMPORTANT ?

Air can be found anywhere, in an equipment's hydraulic system, in reservoirs used to separate solid impurities in fluids, and in lubricating oils themselves. Air found in fluids not only shortens a lubricant's life but can also cause numerous problems in a hydraulic and lubricating oil system such as unacceptable noise, poor component response due to spongy behavior of aerated fluids, thermal degradation, cavitation damage, and severe fluid degradation [1]. Although air is always present in lubricating oil, how this air affects operations depends on how much air is involved, how finely it is dispersed, and whether it is on or under the surface of the oil. Lubricants and hydraulic fluids are often formulated with a primary focus on viscosity, oxidation resistance, and other properties, with air entrainment and release properties being the last priority taken into account [2]. However major trends within industrial manufacturing towards a reduction of size in hydraulic systems have spotlighted the issue of fluid aeration [3]. New and innovative testing techniques have been introduced to measure air quantities in oil and for the determination of the ability of an oil to separate entrained air in hydraulic, turbine, and other lubricating oils.

Air can exist in oil in three different states of coexistence: dissolved, entrained, and foam. Dissolved air can be described as micro air bubbles, not visible to the naked eye, dispersed in the oil at the molecular level, and can represent as much as 10 percent of the total volume. This form of contamination is quite common, as most new and in-service lubricants will have dissolved air but if high levels of dissolved air from pressurized oil are found it can accelerate additive depletion and oxidation. Another form of fluid aeration is entrained air, bubbles with diameters smaller than 1mm dispersed through the oil, which results in the clouding of the oil. This type of air contamination is arguably the most damaging and has the potential to impact the oil's compressibility, heat transfer, film strength, oxidation, cavitation, and varnishing. Entrained air bubbles act as nuclei for dissolved air to come out of the solution, forming a larger air bubble, which then collapses rapidly, and the resultant shock wave can severely damage metal parts [4]. The last state of air contamination is categorized as foam, which refers to bubbles 1mm in diameter that accumulate at the surface of the oil as a stable layer. In some systems foam at the surface may not cause a lot of damage, but foam causes problems when it overflows the reservoir and can cause hydraulic compressibility

issues, corrosion, vapor lock, and loss of system controls. Air interacts significantly with a lubricant and can even present itself as all three states of coexistence which negatively affects both the physical and chemical properties of the lubricant and system.

There are several conditions that can cause excessive air contamination that leads to negative effects on the machine and lubricant. The most common condition found shows to be water contamination. When oil becomes contaminated with water its surface tension is lower, thereby allowing bubbles in the oil to separate into smaller particles that are more easily suspended [5]. Other contaminants have similar effects such as solvents, numerous chemical contaminants, and oil oxidation by-products. Other causes for air contamination include loss of antifoam additives, suction leaks, poor reservoir design, using the wrong viscosity, or using too much antifoam additive [5]. Entrained air changes both the physical and chemical properties of lubricants and hydraulic fluids. Due to the fact that air is more compressible than the surrounding fluid, the presence of air bubbles reduces the bulk modulus of hydraulic fluid, decreasing the fluid's ability to transmit pressure. This results in poor component response due to the spongy behavior of the aerated fluid. Cavitation also can occur



Figure 1 Koehler Automated Air Release Value Analyzer [9]

Table 1 Fluid Properties of five hydraulic fluids in accordance with ASTM D3427 [11]

Fluid	A	B	C	D	E
Base Oil Type	Group I	Group IV	Group III	Group II	Group III
Air release, minutes (ASTM D3427)	5.03	0.17	0.17	1.51	6.03
KV40°C, mm ² /s (ASTM D445)	45.63	46.02	43.37	44.32	54.13
KV100°C, mm ² /s (ASTM D445)	6.721	7.795	7.532	6.825	10.86
Viscosity Index (ASTM D445)	100	139	141	109	197
Density, g/cc @20°C (ASTM D4052)	0.8718	0.8310	0.8266	0.8639	0.8332
Density, g/cc @50°C (Inline densitometer)	0.8515	0.8120	0.8047	0.8419	0.8097

Table 2 Air release characteristics using ASTM D3427 standard test [12]

Fluid	Temperature, °C	Minutes to 0.2% entrained air volume
PAG-based fluid neat	50	0.4
PAG-based fluid + 2000 ppm water	50	0.7
PAG-based fluid + 4000 ppm water	50	1.0

when air bubbles experience an implosion on a surface at a low-pressure zone where the air bubbles expand and collapse as they pass through pressure change zones. Systems that can experience cavitation include engines, plain bearings, pump inlets, and other sliding surfaces [6]. In any mechanical working environment, the temperature of the lubricants is a primary concern. When excessive oxygen from the air dissolves in a lubricant it enhances oil degradation by oxidation and thermal degradation. Oxidation is the primary way a lubricant degrades over time from normal service, shortening even quicker when presented with excessive air contamination [7].

Standard testing methods provide essential information to determine the condition of different lubricants and hydraulic systems. Hydraulic and lubricant fluid manufacturers frequently cite the air-release properties of their products based on air-release times determined using the ASTM D3427 method [8]. This test method measures the time for entrained air content to fall to the relatively low value of 0.2% volume under a standardized set of test conditions. A sample of oil is heated to a standard temperature (commonly 50°C) and compressed air is blown through the oil. The oil sits while the entrained air rises to the surface and is released. The following testing method permits the comparison of the ability of oils to separate entrained air under conditions where a separation time is available. The Koehler Automated Air Release Value Analyzer conforms to ASTM D3427, IP 313 and determines air release properties by heating a sample to a specific test temperature and blowing compressed air to later measure the time required for the air entrained in the oil to reduce to a volume of 0.2% [9]. The apparatus includes an integrated touch screen control panel that guides users from start to finish of test operations and provides density calculations and timing operation for measuring the air release value of the test sample. The air release test not only measures how quickly air bubbles rise and leave an oil sample but also measures the time it takes for entrained air content to fall which informs manufacturers if residence times in reservoirs are too short to allow air bubbles to rise to the oil surface. If there is not enough time to filtrate out air contamination in oil it can result in the inability to maintain oil pressure, incomplete oil films in bearings and gears, and poor hydraulic system performance or failure.

Using ASTM D3427 testing methods, Group I oil, which are classified as less than 90 percent saturates, have air-release values of 6 to 20 minutes, and Group II oils, defined as being more than 90 percent saturates, range from 3.5 to 6 minutes,

which is longer than the oil's residence time in a typical reservoir [10]. One research study examined five hydraulic fluids, fluid "A" was a Group I mineral oil, fluid "B" was a polyalphaolefin (PAO) based Group IV synthetic fluid, fluid "C" was a Gas-to-Liquid (GTL) Group III based synthetic, fluid "D" was a Group II mineral oil, and fluid "E" was a GTL Group II-based experimental synthetic hydraulic formulation [11]. The air release properties were evaluated in accordance with ASTM D3427. Table 1 shows each fluid type and the time required to finely disperse air in the oil. Fluids "B" and "C" demonstrated fast air release times where both formulations used synthetic base stocks that contained greater than 99.9% saturated hydrocarbons. Another test study using the following testing method for air-release properties for PAG-based synthetic turbine fluid showed to have excellent air release for both neat fluid and fluid contamination with water as seen in Table 2 [12]. The following air release times were much lower than those typical of petroleum-based and hydrocarbon-based turbine fluids with PAG-based fluid neat only taking 0.4 minutes to drop to a 0.2% volume of entrained air and PAG-based fluid with 4000 ppm water only taking 1 minute.

As industries and manufacturers seek lightweight and high-reliability equipment that will maximize power while minimizing component size, there also needs to be a bigger interest in measuring air contamination and identifying the root cause to eliminate the problem. Air contamination has been shown to cause several adverse effects when found excessively in oil that can be a costly expense for production and maintenance. To minimize the negative effects of excess air or exclude them altogether, an oil needs to be able to separate surplus air as quickly as possible. This behavior is determined by measuring the air release properties. While air can be challenging to quantify, innovative test techniques and equipment have been introduced to observe these certain behaviors that may lead to a better understanding of this phenomenon. Good output values through these testing techniques can guarantee that oil can be used for a relatively long time.

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https://www.astm.org/DIGITAL_LIBRARY/MNL/SOURCE_PAGES/MNL37-2ND_foreword.pdf

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