

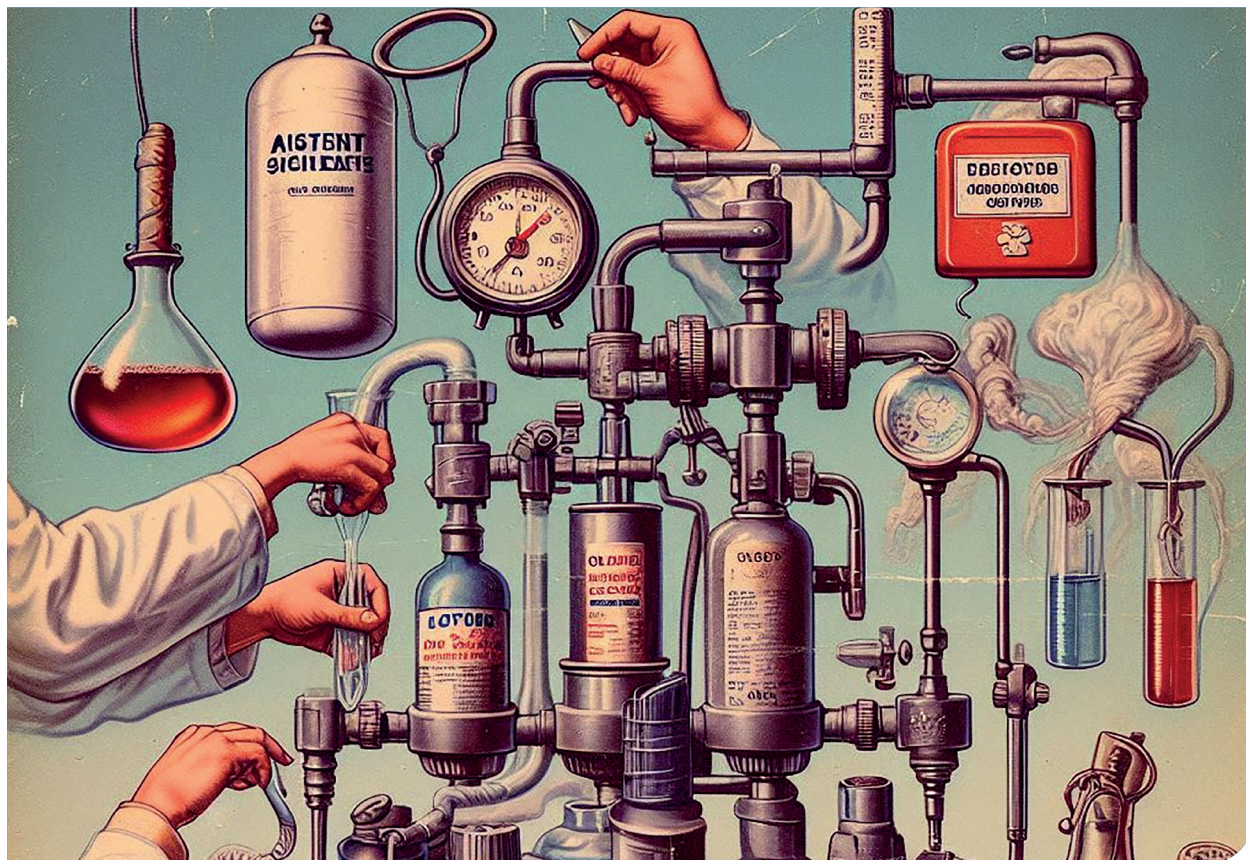
## WHY THE AIR RELEASE PROPERTY OF AN OIL IS AN IMPORTANT CHARACTERISTIC TO MEASURE AND UNDERSTAND FOR LUBRICANTS

### Introduction

The ability of lubricating oils to manage entrained air is a critical performance characteristic, as excessive air entrainment can lead to various issues, such as reduced lubrication effectiveness, increased wear, accelerated oxidation, and cavitation damage. Koehler's Automated Air Release Value Analyzer provides a standardized and controlled testing environment conforming to methods like ASTM D3427 to quantify this crucial property. Air can coexist in oil in three states: dissolved, entrained, and foam. Dissolved air refers to the microscopic air bubbles dispersed throughout the oil at the molecular level, accounting for up to 10% of the oil's total volume [9]. This contamination is common in new and in-service lubricants, becoming problematic as high levels of dissolved air from pressurized oil accelerate additive depletion and oxidation [9]. Entrained air consists of bubbles smaller than 1mm dispersed in the oil, causing a cloudy appearance. Entrained air bubbles act as nucleation sites for dissolved air to form larger bubbles, which rapidly collapse, generating shock waves that can severely damage metal surfaces. This type of contamination is potentially the most damaging, negatively affecting the oil's compressibility, heat transfer, film strength, oxidation, cavitation, and varnish formation [9]. The third state, foam, refers to 1mm bubbles accumulating as a stable layer on the oil's surface. While surface foam may not cause significant damage in some systems, it can lead to hydraulic compressibility issues, corrosion, vapor lock, and loss of system control when it overflows the reservoir [9]. Air can significantly interact with lubricants, presenting itself in all three coexistence states and negatively affecting the lubricant's physical and chemical properties and the system's performance.



Figure 1: Above is an image of the Air Release Value Apparatus [10]



### Koehler's Automated Air Release Value Analyzer

The Automated Air Release Value Analyzer, which can be seen in Figure 1, automates determining air release properties [1]. The instrument consists of a test vessel with airflow control equipment that delivers heated air at a specified rate to an oil sample maintained at a constant temperature. An integrated touchscreen guides the user, provides density calculations, and measures timing as depicted in Figure 2. The oil is heated (commonly to 50°C) and compressed air is blown through it [6]. After stopping airflow, the apparatus measures the time for the entrained air content to reduce to 0.2% volume. This separation time is the air release value [1]. Accessories which include drying ovens, circulating baths, compressed air heaters, and over-temperature/pressure protection circuitry, support the testing process. The drying oven allows pre-warming test oils up to 100°C. A circulating bath and air bath ensure temperature control for the sinker component used to detect the 0.2% air level. The results will depict a graph that can give information on the target density time and value as seen in Figure 3.

The Air Release Value Apparatus uses a borosilicate glass test vessel consisting of a jacketed sample tube fitted with an air inlet capillary, baffle plate, and air outlet tube. This sample tube and an accompanying set of components (inlet capillary, baffle plate, outlet tube) are marked and intended to be used as a pair, though interchangeable parts can be used if the resulting vessel conforms to the stated dimensions. A pressure gauge spanning 0 to 35 kilopascals with 2 kilopascal divisions and 1.5 kilopascal accuracy measures compressed air pressure as seen in Figure 4. Two thermometers are employed: an air thermometer ranging from -20°C to 102°C for monitoring compressed air temperature, and a sample thermometer for tracking the oil sample's temperature during preparation and trials [6]. A heater brings the compressed air up to the desired measurement temperature before introduction into the sample. This carefully designed apparatus, with its instrumented test vessel, pressure and temperature monitoring, and controlled heating, enables precise, standardized testing of lubricating oils' air release properties.

### Importance of Air Release Testing

Air contamination in lubricating oils and hydraulic fluids can significantly impact machinery performance and longevity. Excessive air in these fluids can cause sponginess and lack of sensitivity in the control of turbine and hydraulic systems [1]. Air bubbles dispersed in the oil affect its physical properties, reducing its bulk modulus and ability to transmit pressure effectively. This spongy behavior results in poor component response [4]. Entrained air bubbles also act as nuclei for cavitation, where rapid expansion and collapse of the bubbles from pressure changes create shock waves that can severely damage metal parts like engines, plain bearings, pump inlets, and other sliding surfaces [4,5]. Checking the air-release properties of lubricants is crucial because it expresses their ability to separate

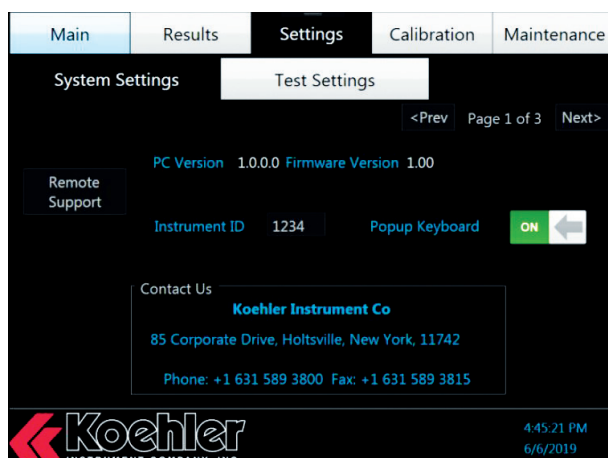


Figure 2: This displays the apparatus' integrated touchscreen [12]

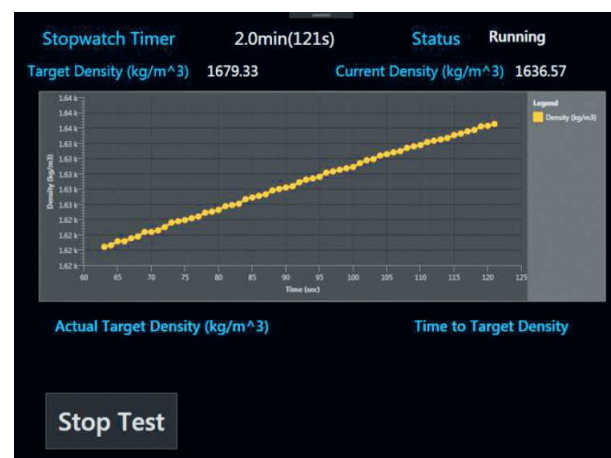


Figure 3: This image represents the graph that is generated while running the apparatus [12]

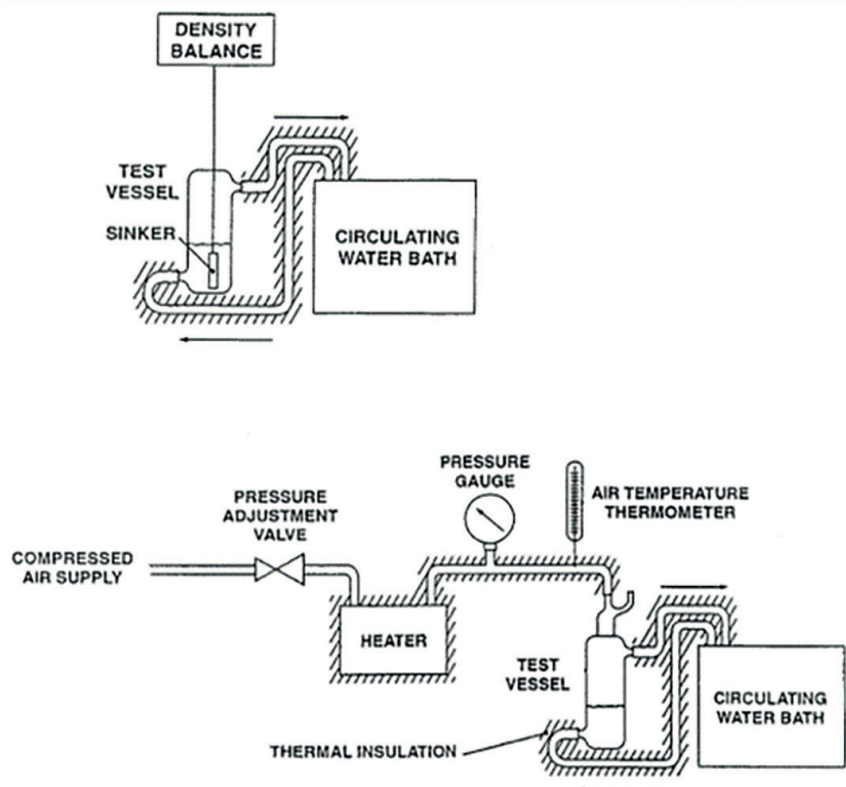


Figure 4. Apparatus diagram of the determination of release time [6]

these entrained air bubbles, preventing the adverse effects associated with air contamination. While lubricants are made with viscosity, oxidation resistance, and other properties in mind, air entrainment and release characteristics are not always prioritized leading to a degradation of the intended properties [2]. However, as industries move towards more compact and high-reliability equipment, fluid aeration becomes increasingly important [3].

Lubricants with poor air release values struggle to remove entrained air bubbles, leading to reduced bulk modulus, cavitation, and poor component response [6]. Good air release properties ensure quick air separation within available reservoir residence time, preventing issues like pressure loss, incomplete oil films, and hydraulic system failures. Companies conduct air release tests to evaluate products, compare formulations, optimize air separation, ensure compliance with industry standards, and mitigate potential air contamination issues that could lead to costly equipment failures. Ensuring compliance with industry standards like ASTM D3427 [6] can help identify potential air contamination issues, reducing the risk of costly equipment failures.

## Experimental Results

One study conducted by Gullapalli et al. investigated the effects of hydraulic fluid composition on aeration, pump efficiency, and noise generation in an axial piston pump. The researchers examined five hydraulic fluids: fluid A (Group I mineral oil), fluid B (Group IV polyalphaolefin (PAO)-based synthetic), fluid C (Group III Gas-to-Liquid (GTL)-based synthetic), fluid D (Group II mineral oil), and fluid E (experimental Group II GTL-based synthetic hydraulic formulation) [7]. The air release properties were evaluated using ASTM D3427. Fluids B and C exhibited fast air release times, as both formulations used synthetic base stocks containing over 99.9% saturated hydrocarbons. Another study was conducted by Govind Khemchandani from The Dow Chemical Company. It investigated the use of a new polyalkylene glycol (PAG)-based synthetic turbine fluid as an alternative to conventional petroleum-based turbine oils in heavy-duty gas turbines. The research examined the non-varnishing and tribological characteristics of the PAG-based fluid compared to petroleum-based oils, including tests of oxidation stability, wear performance, and air release properties, as well as field trials in four GE 7FA gas turbines. The finding of this study is depicted in Table 1.

Table 1: Air release characteristics using ASTM D3427[8].

| Fluid                               | Temp °C | Mins to 0.2% air volume |
|-------------------------------------|---------|-------------------------|
| PAG Based Fluid Neat                | 50      | 0.4                     |
| PAG Based Fluid + 2000 ppm of water | 50      | 0.7                     |
| PAG Based Fluid + 4000 ppm of water | 50      | 1.0                     |

The air release times were much lower than typical petroleum-based and hydrocarbon-based turbine fluids, with the neat PAG-based fluid taking only 0.4 minutes to reach 0.2% entrained air volume, and the PAG-based fluid with 4000 ppm water taking 1 minute [9].

## Conclusion

Air contamination in oil is a growing concern as industries pursue lightweight, high-reliability equipment. Excessive air in oil can cause costly adverse effects, necessitating quick air separation for optimal performance. Air release testing is crucial for evaluating lubricants' ability to separate entrained air bubbles, impacting machinery longevity and efficiency. Advanced testing techniques and equipment, such as Koehler's Automated Air Release Value Analyzer, enable companies to optimize products, meet standards, and prevent costly air contamination issues in real-world applications.

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