The term [*lubricity*](https://www.dieselnet.com/tech/fuel_diesel.php#lubricity) is often defined as the ability of a lubricant—in this case diesel fuel—to minimize friction between and damage to surfaces in relative motion under load. Generally the tests used to evaluate diesel fuel lubricity try to create conditions of boundary lubrication. More specifically, test results that quantify a fuel’s lubricity are a measure of the fuel’s ability to minimize friction between and/or damage to surfaces in relative motion under boundary lubrication conditions.

Different types of methods have been developed to measure fuel lubricity:

* **Vehicle tests.** In a vehicle test [Mitchell 1995], the vehicle is operated on the fuel for a specified length of time or a specified distance. The fuel system components can then be disassembled and examined for wear. This test has the advantage of being the most representative of real-world conditions and can measure all possible wear related failures not just those associated with boundary lubrication. Tests of this nature are however very expensive and time consuming and do not lend themselves to testing a large number of fuel combinations.
* **Pump rig tests.** An alternative to the vehicle test is a pump rig test (ASTM D6898) [Mitchell 1998][Mitchell 1996][Meyer 2003][Mozdzen 1998][Caprotti 2004][Terry 2005]. In a pump rig test, a fuel injection pump is mounted on a test stand and is driven by an electric motor. Fuel is circulated through the pump for a specified period of time. The pump and any other equipment attached to it can then be disassembled and examined for wear and other deleterious effects. This test has the advantage of being less costly than a full vehicle test while maintaining the ability to test for many wear related failures beyond those associated with boundary lubrication. It is still time consuming and expensive to operate. One test can require as much as 500-1000 hours of test time. Pump rig tests are often necessary to evaluate the effectiveness of much simpler bench tests.
* **Bench tests.** A number of bench tests that try to recreate boundary lubrication conditions similar to those found in fuel injection equipment have been developed to allow rapid and relatively inexpensive measurements of fuel lubricity:
	+ The *Ball-on-Cylinder Lubricity Evaluator* (BOCLE) was developed for aviation jet fuels. It continues to be used for this application. It is particularly useful for measuring the effects of fuels and additives on oxidative wear—an important wear mechanism in aviation fuel systems.
	+ The *Scuffing Load Ball-on-Cylinder Lubricity Evaluator* (SLBOCLE) was developed in the mid 1990s in response to diesel fuel system failures resulting from the introduction of low sulfur diesel fuels. It is similar to the BOCLE test but with modifications to make it less sensitive to oxidative wear and more sensitive to adhesive scuffing.
	+ The *High Frequency Reciprocating Rig* (HFRR) was also developed in the 1990s to make it useful for evaluating diesel fuel lubricity. It can produce a wide range of wear mechanisms depending on the fuel being tested.
	+ The *Ball on Three Disks* (BOTD) method is fairly recent and is still in the development phase. It is a compact and more economical version of the Ball on Three Seats apparatus.

Of the bench test methods, the HFRR is most commonly used to evaluate diesel fuels. The SLBOCLE was common in the 1990s but has seen little use since about 2005. Both methods are discussed in more detail in the following sections, and their main specifications are listed in Table 1. Care must be taken when interpreting the results of lubricity tests with any of these bench tests. They only reproduce a limited number of wear mechanisms that may affect diesel fuel systems. While the wear mechanisms they reproduce are generally important for diesel fuel systems, their relative importance in any particular fuel system is very much affected by fuel system design and operating conditions.

| **Table 1**Summary of Main Specifications of Different Bench Lubricity Test Methods |
| --- |
|  | **ASTM D6078 SLBOCLE** | **ASTM D6079 HFRR** | **ISO 12156-1 HFRR** |
| **Parameter** | min. load where friction coefficient is ≥ 0.175 | wear scar on ball | wear scar on ball |
| **Fluid Temperature** | 25°C | 25 or 60°C. 60°C preferred unless volatility or degradation is a problem | 60°C |
| **Fluid Volume** | 50 ml | 2 ml | 2 ml |
| **Air** | 25°C, 50% RH | > 30% RH | see Figure 6 |
| **Load** | 500 g - 5000 g | 200 g | 200 g |
| **Duration** | 60 s at each load increment | 75 min | 75 min |
| **Ball:** | stationary | reciprocating, 50 Hz / 1 mm stroke | reciprocating, 50 Hz / 1 mm stroke |
| - diameter | 12.7 mm | 6 mm | 6 mm |
| - material | AISI E-52100 | AISI E-52100 chromium ally steel | AISI E-52100 |
| - finish | 5-10 EP | Ra < 0.05 µm | Ra < 0.05 µm |
| - hardness | Rockwell hardness C 64-66 | Rockwell hardness C 58-66 | Rockwell hardness C 58-66 |
| **Ring/Disk:** | Ring | Disk, stationary | Disk, stationary |
| - speed | 525 rpm |  |  |
| - size | 49.2 mm | 10 mm | 10 mm |
| - material | SAE 8720 | AISO E-52100 chromium alloy steel, annealed. Turned lapped and polished. | AISO E-52100 chromium alloy steel, annealed. Turned lapped and polished. |
| - finish | 0.04-0.15 µm | Ra < 0.02 µm | Ra < 0.02 µm |
| - hardness | Rockwell hardness C 58-62 | Vickers “HV 30”: 190-210 | Vickers “HV 30”: 190-210 |
| - velocity | 1.3 m/s constant | 0.1 m/s average, reciprocating | 0.1 m/s average, reciprocating |
| **Fuel** | fuel is aerated |  |  |
| **Contact** | contact surface not submerged in fuel | contact surface is submerged | contact surface is submerged |
| **Range of precision data** | 1100-6200 g | 143-772 µm @ 25°C,175-1000 µm @ 60°C | 360 - 600 µm @ 60°C |
| **Repeatability** | 900 g | 62 µm @ 25°C,80 µm @ 60°C | 63 µm @ 60°C |
| **Reproducibility** | 1500 g | 127 µm @ 25°C,136 µm @ 60°C | 102 µm @ 60°C |

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