Diesel fuel is an important contributor in powering the U.S. economy, moving more than 80 percent of all cargo in the U.S. and more than 90 percent throughout the world [1]. Most of the diesel fuel produced and consumed in the United States is refined from crude oil at petroleum refineries. U.S. petroleum refineries produce an average of 11 to 12 gallons of diesel fuel from each 42-gallon barrel of crude oil [2]. In 2020 distillate fuel consumption by the U.S. transportation sector was about 44.61 billion gallons, an average of about 122 million gallons per day. This amount accounted for 77% of total U.S. distillate consumption, 16% of total U.S. petroleum consumption, and on an energy content basis, about 27% of total energy consumption by the U.S. transportation sector [3]. Due to commercial, environmental, quality, processing, and safety regulations, there is an immense number of specifications and related test methods that must be performed for verifying the quality of diesel fuel. These testing methods range from testing for the cetane rating, flashpoint, suspended water, and particulate contaminant value, distillation temperature, oxidation, and storage stability, etc. In recent years new equipment and instrumentation now allow for easy to use and cost-efficient ways to test for important performance and safety properties of diesel fuel.

Every diesel fuel has a cetane rating that represents the quality and performance of that specific fuel. Cetane is a chemical compound found naturally in diesel, and it ignites easily under compression with heated air. Due to its high combustibility, the diesel cetane rating serves as the industry-standard measure for evaluating fuel combustion quality [4]. As the displacement of petroleum-based ultra-low-sulfur diesel (ULSD) with low-net-energy biofuels becomes necessary to help mitigate potential effects on global climate change, problems may arise if these new blends cause significant changes to the combustion phasing of the conventional diesel combustion process, particularly the ignition delay [5]. Cetane number (CN) is the most conventional and universally accepted ignition quality measurement that helps evaluate the expected ignition delay of a fuel. Alternatively, several other constant-volume combustion chamber-based cetane rating devices have been developed to rate fuels with an equivalent derived cetane number (DCN) or indicated cetane number (ICN) [6]. The ASTM D6890 test method [7] defines and determines the measurement produced for the DCN. The ignition delay, which is the pressure recovery time after the injection of liquid fuel at around 21 atm and 830 K, is measured in an ignition quality tester and then transformed to the DCN. This measurement method requires less fuel to operate than does the CN test method D613 [8]. The ASTM D8183 [9] test method covers the quantitative determination of the ICN of different diesel fuels containing CN improver additives by utilizing a constant volume combustion chamber with direct fuel injection into heated compressed air. ICN is determined directly from ignition delay using an instrument-specific reference fuel calibration curve. The ADA5000 Automatic Distillation Analyzer by Koehler Instruments (Figure 1) calculates the cetane index for estimating ASTM D4737 cetane number where a test engine is not available for determining this property [10,11]. Higher cetane number fuels tend to lessen combustion noise, increase engine efficiency, increase power output, start more easily, reduce exhaust smoke, and reduce exhaust odor.

The flashpoint of fuel often has no significant relation to its performance. Auto-ignition temperature is not influenced by variations in the flashpoint, but flashpoint is specified primarily for safety during transport, storage, and handling. A low-flashpoint fuel can be a fire hazard, subject to flashling, and possible continued ignition and explosion [12]. The Automatic Pensky-Martens Closed Cup Flash Point Tester by Koehler Instruments (Figure 2) represents a perfect union of next-generation technology with traditional robust quality [13]. The analyzer conforms to ASTM D93 and related specifications for flash point determination of different petroleum products such as diesel [14]. One experiment revealed the dependence of flashpoints on reduced pressures at high altitudes, by performing a series of field flash point determinations at six different altitudes on the Qinghai-Tibet Plateau [15]. The ASTM D93 standard followed in this work, which is the close cup method, was used due to the close cup method giving lower values than the open cup method. Liquid fuel samples were heated at a specified rate in a copper cup and an ignition source with specified strength was equipped 10-14 mm above the sample surface to ignite the vapor-air mixture. The temperature at which flashover occurs and propagates through the vapor-air mixture to the liquid surface was taken as the flashpoint of this sample. In the closed cup method, there is a cover on the copper cup, with a shutter on the cover as well where the fuel vapor accumulates in the cup until the shutter opens for ignition, so the fuel vapor in the cup is easier to reach its lower flammability limit than an open cup method. The results of the field determinations indicate that flashpoints of liquid fuels decrease nonlinearly with the reduced pressure at high altitudes, and the influence of atmospheric pressure on flashpoints is strengthened with the increasing of altitudes. Compared with the field-determined flashpoint temperatures, the predictive accuracy of the two methods is similar, and both methods give more accurate predictive flashpoints than the linear relationship. The higher the flashpoint, the safer the material is to handle [16], noting the dependence upon the pressure in the air which can change the flashpoint.

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**Figure 1**: ADA5000 Automatic Distillation Analyzer by Koehler Instruments [10].

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**Figure 2**: Automatic Pensky-Martens Closed Cup Flash Point Tester by Koehler Instruments [15].
Manuscript title: Particle Counting in Diesel Fuel and Biodiesel Blends

Abstract: This paper presents the results of diesel fuel contamination with abrasive particles in various size ranges, determined following ASTM D7619 [21]. The purity of diesel fuel is a critical issue in the face of modern injection systems operating under very high pressures with very precisely fitted mating parts. At these high pressures and temperatures, injectors are exposed to abrasive wear due to the presence of fine, hard-abrasive particles in diesel fuel. Based on the results of the tests carried out, it can be concluded that exceeded number of particles in individual size ranges are not always related to the content of impurities in a form of metallic pulp, nevertheless, they may be one of the factors contributing to damage to precision fuel injection systems. As the use of synthetic and bio-derived fuels increases with the introduction of modern engines utilizing high-pressure fuel injectors the method of measurement and freedom from particulate materials are becoming an increasingly important product specification that must be measured within stringent standards [22]. The ASTM D8148 Standard Test method covers a spectrometric method for determining the level of suspended water and particulate contaminants, known as the haze, in liquid diesel fuels including those blended with synthesized hydrocarbons or biofuels [23,24]. This method generates an ordinal, whole-number, instrument Haze Rating (IHR) from 1 to 6 and a Haze Clarity Index (HCI) from 50.0 to 100.0. HCI can be used to evaluate haze intensity changes to a much finer degree than could ever be achieved with visual inspection procedures. The new ASTM test method D8148 delivers the rapid, precise, and reliable Haze and Clarity determination measurement capabilities needed for today’s demanding petroleum-based process control and product quality assurance applications [25]. The Clarity Choice Hz (Figure 3), developed by Choice Analytical, is a compact and lightweight analyzer that can readily measure Haze and Clarity in petroleum products within 195 seconds, as per ASTM D1481. The achievement of obtaining the ASTM method is a significant step in the continued growth of new technologies and equipment for measuring Haze and Color.

Keywords: Particle Counting, Diesel Fuel, Biodiesel Blends, Diesel Particulate Matter, ASTM D8148, Particle Counting in Diesel Fuel and Biodiesel Blends

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Dr. Raj Shah is a Director at Koehler Instrument Company in New York, where he has worked for the last 25 years. He is an elected Fellow by his peers at IChemE, CMI, STLE, AIC, NLGI, INSTMIC, The Energy Institute and The Royal Society of Chemistry. An ASTM Eagle award recipient, Dr. Shah was recently awarded the title of an eminent engineer with Tau beta pi, the largest engineering society in the USA. More information on Dr. Shah can be found at https://www.cheme.psu.edu/news-archive/2018/alumni-spotlight-raj-shah.aspx

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Mr. David Forester recently retired after 44 years’ experience in the fuel and refining additive business. He has over 35 US patents on development of diesel and jet fuel additives, refinery antifoulants, and other refinery and process related additives. He has designed, implemented and/or automated many fuel test methods, including many ASTM standards. Mr. Forester most recently received the ASTM Award of Merit. He has been a member of ASTM Committee D02 for over 25 years and currently serves as Chairman of Subcommittee D02.14 Stability and Cleanliness of Liquid Fuels. He served along with Dr. Shah as the editor of the ASTM bestseller “The Fuels and Lubricants Handbook – 2nd Edition, now available/2792

Alexandra Przyborowski is a senior chemical engineering student from Stony Brook University, where Dr. Shah is the chair of the external advisory board of directors. She is also a part of a thriving internship program at Koehler Instrument Company.

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