Designation: D 6424 – 03

An American National Standard

Standard Practice for Octane Rating Naturally Aspirated Spark Ignition Aircraft Engines[1]

This standard is issued under the fixed designation D 6424; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers ground based octane rating procedures for naturally aspirated spark ignition aircraft engines using primary reference fuels.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 2700 Test Method for Motor Octane Number of Spark-Ignition Engine Fuel

3. Terminology

3.1 *Definitions:*

3.1.1 *amine number of reference fuels above 100, n*—determined in terms of the weight percent of 3-methylphenylamine in reference grade *iso*octane. No attempt has been made to correlate performance number of leaded reference fuels to the amine number of unleaded reference fuels, and none is implied.

3.1.2 *engine motor octane requirement*—one full motor octane number greater than the maximum motor octane number that results in knock (graphic knock level descriptions can be seen in Annex A1). For example, a test engine knocks on primary reference fuels with 96 and 97 motor octane numbers. The test engine does not knock on a primary reference fuel with a 98 motor octane number. The maximum motor octane number that results in knock is 97, so the motor octane requirement is 98.

3.1.3 *full rich*—condition in which the mixture control is at the full stop position with the fuel flow within manufacturer's recommended settings.

3.1.4 *house fuel, n—for octane rating*, an unleaded, straight hydrocarbon fuel used for engine warm-up and all non-octane rating testing.

3.1.5 *knock, n—in an aircraft spark ignition engine*, abnormal combustion caused by autoignition of the air/fuel mixture.

3.1.6 *knock condition, n—for octane rating*, when the knock intensity in any cylinder is light knock or greater as described in Annex A1.

3.1.7 *knock number, n—for octane rating*, a numerical quantification of knock intensity.

3.1.8 *motor octane number of primary reference fuels from 0 to 100*—the volume % of *iso*octane (equals 100.0) in a blend with *n*-heptane (equals 0.0).

3.1.9 *motor octane number of primary reference fuels above 100*—determined in terms of the number of millilitres of tetraethyl lead in *iso*octane.

3.1.10 *naturally aspirated aircraft engine, n*—aircraft piston engine that breathes without forced means from either turbochargers or superchargers.

3.1.11 *no-knock condition, n—for octane rating*, when the combustion instability in all cylinders is less than light knock. Refer to Annex A1 for description of knock intensity.

3.1.12 *peak EGT, n—for octane rating*, as the mixture is manually leaned from a state rich of stoichiometric, the exhaust gas temperature will increase with the removal of excess fuel. As the mixture is continually leaned, a peak temperature will be attained, after which continued leaning will result in lower exhaust gas temperatures.

3.1.13 *primary reference fuels, n—for octane rating*, blended fuels of reference grade *iso*octane and *n*-heptane.

3.1.14 *stable engine conditions, n—for octane rating*, cylinder head temperatures change less than 5°C (9°F) during a 1 min period. Any changes or minor adjustments to throttle, mixture, or engine conditions mandate restarting the clock for determining stable conditions.

3.2 *Symbols:*

3.2.1 *CHT*—cylinder head temperature.

3.2.2 *EGT*—exhaust gas temperature.

3.2.3 *inHg*—inches of mercury.

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[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.J0 on Aviation Fuels.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.4 *MAP*—manifold absolute pressure.

3.2.5 *mmHg*—millimeters of mercury.

3.2.6 *MON*—motor octane number.

3.2.7 *PRF*—primary reference fuel.

3.2.8 *psig*—pounds per square inch gauge.

3.2.9 *rpm*—revolutions per minute.

3.2.10 *TDC*—top dead center.

4. Summary of Practice

4.1 A recently overhauled, remanufactured, or new, naturally aspirated aircraft engine is octane rated, using PRFs, to determine the minimum motor octane requirement. Minimum motor octane requirement is defined as one number above the highest MON in which knock was detected. The engine is tested at three or more of the worst power points subject to detonation behavior. These points usually involve high manifold pressures. At the very least takeoff power, a maximum continuous or climb power, and a cruise configuration shall be tested. Takeoff power and climb power are tested under full rich mixture conditions, and cruise power is tested under full rich and lean mixture configurations in 5 % increment reductions from full rich fuel flow. Engine operating temperatures and oil temperatures are kept at maximum allowable limits, while induction and cooling air temperatures are maintained at extreme hot day conditions for severe case testing.

4.2 Octane ratings are determined under stable engine conditions using PRFs of known MON.

4.3 Knock sensor installation and knock quantification are described in Annex A1.

5. Significance and Use

5.1 This practice is used as a basis for determining the minimum motor octane requirement of naturally aspirated aircraft engines by use of PRFs.

5.2 Results from standardized octane ratings will play an important role in defining the actual octane requirement of a given aircraft engine, which can be applied in an effort to determine a fleet requirement.

6. Apparatus

6.1 *Instrumentation*:

6.1.1 The engine shall be equipped with the following instrumentation, which shall be accurate within ±2 % of full scale unless noted otherwise.

6.1.1.1 *Absolute Manifold Pressure Transducer*—Location of MAP sensor shall conform to engine manufacturer's specified location. Manifold pressures shall be measured with an accuracy of less than 2.5 mmHg and recorded to ensure proper engine behavior and repeatability.

6.1.1.2 *Cooling Air Pressure Transducer*, located so as to determine the pressure within the cowling.

6.1.1.3 *Cooling Air Temperature Sensor*, located either within the cowling or at the entrance to the cowling. If a thermocouple is utilized, it should extend at least a third of the way across the measured area.

6.1.1.4 *Crankshaft Angle Encoder*, if required for knock detection. The encoder shall have a sample resolution of at least 0.4° of crank shaft rotation. The encoder TDC pulse shall be aligned with the TDC of cylinder number one prior to octane rating.

6.1.1.5 *Cylinder Head Temperature Sensors*, installed in each cylinder. The sensing locations and types of thermocouples shall conform to the engine manufacturer's recommendations. The CHT measurements shall be accurate to within 1 % of full scale.

6.1.1.6 *Exhaust Gas Temperature Sensors*, on all cylinders. Installation shall conform with manufacturer's recommended location and proper material selection. EGT probes are usually installed within 5 cm (2 in.) of the exhaust stack flange. The EGT probes shall be accurate to within 1 % of full scale.

6.1.1.7 *Engine Speed Sensor*—The dynamometer or propeller stand shall measure the engine shaft speed to determine power development. The engine speed sensor shall be accurate to within ±5 rpm.

6.1.1.8 *Fuel Flow Meter*—If the device is calibrated for a particular fuel, then the device shall be recalibrated for each different and subsequent fuel. Data should be reported in mass flow units.

6.1.1.9 *Fuel Pressure Transducers*—Locations of fuel pressure transducers shall conform with those recommended by the engine manufacturer. One transducer is required for the metered fuel pressure, if necessary, and another is required for the pump pressure. The fuel inlet pressure shall not fall below the minimum specified by the engine manufacturer during the rating process.

6.1.1.10 *Induction Air Pressure Transducer*, located so as to measure the pressure of the induction stream prior to the throttle plate.

6.1.1.11 *Induction Air Temperature Sensor*, located so as to measure the temperature of the induction stream prior to the throttle plate.

6.1.1.12 *Knock Sensors*—The referee method for knock detection is described in Annex A1. This method requires flush mounting piezoelectric transducers. At the very least, the four cylinders with the highest CHTs shall be monitored. These transducers are connected to charge amplifiers and shall be capable of measuring combustion pressures under a high temperature environment.

6.1.1.13 *Oil Pressure Transducer*—Location of pressure measurement shall conform to engine manufacturer's specified location.

6.1.1.14 *Oil Temperature Sensor*—Location of temperature measurement shall conform with manufacturer's specified location.

6.1.1.15 *Torque Meter*—The dynamometer or propeller stand shall measure the torque to determine power development. The torque measurement shall be accurate to within 1 % of full scale.

6.1.2 The engine should be equipped with the following instrumentation, which shall be accurate within ±2 % of full scale unless noted otherwise.

6.1.2.1 *Induction Air Flow Meter*—Data should be presented in mass flow units.