

Draft for Public Comment

Draft Zambian Standard

**AVIATION GASOLINE: GRADES UL91 AND 100LL –
Specifications**

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The preparation of this Zambian Standard was undertaken by the Petroleum Products Quality Standards Technical Committee (TC 4/14) and reference was made to the British Defence Standard 91-090.

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ZAMBIA BUREAU OF STANDARDS

Draft Zambian Standard

AVIATION GASOLINE: GRADES UL91 AND 100LL – Specifications

1 SCOPE

This Zambian Standard specifies the general and quality requirements for two grades (AVGAS UL91 and AVGAS 100LL) of gasoline type aviation fuel intended primarily for use in aircraft spark ignition reciprocating engines. Fuel provided to this specification shall possess satisfactory performance and properties when used in appropriate aircraft or engines.

2 NORMATIVE REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this Standard. All documents are subject to revision and, since any reference to a document is deemed to be the latest reference to the latest edition of that document, parties to agreements based on this Standard are encouraged to take steps to ensure the use of the most recent editions of the documents indicated below. Information on currently valid national and international documents may be obtained from the Zambia Bureau of Standards.

ASTM D86	<i>Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure</i>
ASTM D130	<i>Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test</i>
ASTM D323	<i>Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)</i>
ASTM D381	<i>Standard Test Method for Gum Content in Fuels by Jet Evaporation</i>
ASTM D873	<i>Standard Test Method for Oxidation Stability of Aviation Fuels (Potential Residue Method)</i>
ASTM D909	<i>Standard Test Method for Supercharge Rating of Spark-Ignition Aviation Gasoline</i>
ASTM D1094	<i>Standard Test Method for Water Reaction of Aviation Fuels</i>
ASTM D1266	<i>Standard Test Method for Sulfur in Petroleum Products (Lamp Method)</i>
ASTM D1298	<i>Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method</i>
ASTM D2386	<i>Standard Test Method for Freezing Point of Aviation Fuels</i>
ASTM D2392	<i>Standard Test Method for color of Dyed Aviation Gasolines</i>
ASTM D2622	<i>Standard Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry</i>
ASTM D2624	<i>Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels</i>
ASTM D2699	<i>Standard Test Method for Research Octane Number of Spark Ignition Engine Fuel</i>

ASTM D2700	<i>Standard Test Method for Motor Octane Number of Spark Ignition Engine Fuel</i>
ASTM D3237	<i>Standard Test Method for Lead in Gasoline by Atomic Absorption Spectroscopy</i>
ASTM D3338	<i>Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels</i>
ASTM D3341	<i>Standard Test Method for Lead in Gasoline - Iodine Monochloride Method</i>
ASTM D4052	<i>Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter</i>
ASTM D4171	<i>Standard Specification for Fuel System Icing Inhibitors</i>
ASTM D4176	<i>Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)</i>
ASTM D4809	<i>Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)</i>
ASTM D5191	<i>Standard Test Method used to determine the vapor pressure of volatile, liquid petroleum products and liquid fuels, including gasoline and ethanol blends</i>
ASTM D5059	<i>Standard international testing specification used to determine the concentration of lead and manganese additives in gasoline using X-Ray Fluorescence Spectroscopy (XRF)</i>

LIST OF ABBREVIATIONS AND SYMBOLS

% m/m	Percentage Mass
DVPE	Dry Vapour Pressure Equivalent
FSII	Fuel System Icing Inhibitor
gPb/l	Grams of Lead per Litre
IP	Institute Petroleum
ISO	International Standard Organisation
DEF	STAN 91-090
kPa	Kilopascal (Unit of Pressure)
LL	Low Lead
mg/100ml	Miligrams per 100 Millilitres
MJ/kg	Megajoule per Kilogram
ml	Millilitre
MoD	Ministry of Defence
pS/m	Pico-Siemens per metre (Fluids which have low electrical conductivity (below 50 pS/m), are called Accumulators. Fluids having conductivities above 50 pS/m are called Non Accumulators)
SDA	Static Dissipator Additive
TAME	Tert-Amyl Methyl Ether
UL	Unleaded

3 DEFINITIONS

3.1 Batch

A distinct quantity of fuel that can be characterised by one set of test results including types of additives and quantities added.

4 MATERIALS

The fuel shall consist wholly of hydrocarbon compounds and approved additives only as listed in Annex A.

- 4.1 Aviation gasoline is a complex mixture of hydrocarbons that varies depending on crude source and manufacturing process. Consequently, it is impossible to define the exact composition of aviation gasoline. This specification has therefore evolved primarily as a performance specification rather than a compositional specification. It is acknowledged that this largely relies on accumulated experience.
- 4.2 For operational performance Aviation Gasoline in this specification is a hydrocarbon based fuel. Ethanol is not permitted to ensure broad compatibility with aircraft fuel systems, good water separation characteristics and flight range.
- 4.3 Additives shall be identified by the appropriate RDE/A/XXX number or by name as shown in Annex A. The amount, including NIL additions, of all additive additions shall be reported on batch quality certificates.
- 4.4 Zambia Environmental Management Agency (ZEMA) reserves the right to require that the material and any components used are subject to toxicological and physiological tests to ascertain their suitability for use.

5 QUALITY ASSURANCE

Representative samples of each batch of the fuel shall be tested to show batch homogeneity and compliance with the requirements of Clause 4 and Table 1 of this standard.

5.1 SAMPLING

5.1.1 Sampling from storage tanks and fuel lines

For the purposes of this Zambian Standard all sampling shall be carried in accordance with the relevant procedures of ZS 396: Part 1, additionally, as detailed in 5.1.2.

5.1.2 Sampling cans

Sampling cans shall be of 5 litres capacity. The construction of the cans shall comply with the appropriate safety requirements for cans that are to hold highly flammable material. They shall be provided with screw caps incorporating a petroleum resistant washer in good condition. A stock of cans shall be kept solely for the purpose of taking fuel samples.

5.1.2.1 Preparation of can

New cans shall be rinsed with aviation turbine fuel before being used, to remove any residual traces of oil left during manufacturing operations and then allowed to dry. Before use, all cans shall be checked to ensure that they are sound and free from leaks.

5.1.2.2 Sampling procedure

From the pump nozzle, 5 litres of fuel shall be drawn carefully into 5 litres cans using a clean dry funnel. Immediately afterwards, this sample shall be declined carefully into the requisite number of 2 litre cans, using a funnel, filling the cans within 15mm of the brim.

If more than 5 litres are needed, the operation shall be repeated immediately and before the pump has been used for any other purpose. The screw caps shall be tightened fully and the cans checked to ensure that there are no leaks.

The sampling procedure shall not be carried out in direct sunlight.

NOTE 1: If carried out in direct sunlight, changes in fuel quality may occur.

5.1.2.3 Storage labeling and transport.

Samples shall be kept in a cool place although it is not necessary to keep them refrigerated. Full and legible information relating to the source of the sample shall be attached to the can in such a manner that it will not easily become detached subsequently.

NOTE 1: If required, the sample may be sealed and labeled to maintain its integrity.

NOTE 2: If the sample has to be sent to laboratory by public transport, it will be necessary to comply with the general regulations covering transportation of flammable materials and with the requirements of the transport authority concerned. Information of the appropriate procedures and the type of packaging required should be obtained from the transport authority involved.

5.2 TESTING

- 5.2.1 Properties of the fuel shall not exceed the maximum nor be less than the minimum values set out in Table 1 when tested by the methods referred to therein or Annex B.

NOTE: To determine conformance to the specification requirement, a test result may be rounded to the same number of significant figures as in Table 1. The IP 367 procedure, which covers the use of precision data, may be used for the interpretation of test results in cases of dispute.

- 5.2.2 Methods quoted in Table 1 are referee methods. In cases of dispute the referee methods shall be used. Approved alternative methods are listed in Annex B.
- 5.2.3 Results shall be reported on the appropriate batch certificate to show compliance with all requirements of the standard.

6 PACKAGING AND LABELLING

6.1 Packaging

The condition of the drums and bulk tankers into which the petrol (gasoline) is filled shall be such as not to be detrimental to the quality of the fuel during normal transportation and storage. Drums and containers shall be acceptably sealed and in addition shall conform to therelevant Zambian Standards and Regulations.

6.2 Labelling

The following information shall appear in legible and indelible marking on each storage tank and consignment documents of each road tank vehicle or rail wagon:

- a) the type of fuel, i.e., AVGAS UL91 and AVGAS 100LL
- b) the quantity in litres
- c) the batch/lot number

Table 1 - Test Requirements

TEST	PROPERTY	UNITS	LIMITS		TEST METHOD
			Grade UL91	Grade 100LL	
1	Appearance		Clear, bright and visually free from solid matter and undissolved water at ambient temperature		Visual examination
2	Colour, visual (see NOTE)		Undyed	Blue	
3	Corrosion Copper Strip		Max 1		IP 154/ ASTM D130
4	Density at 15 °C	kg/m3	Min 700 Max 750		IP160/ ASTM D1298
5	Total Sulphur	% m/m	Max 0.05		IP 107/ ASTM D1266
6	Existent Gum	mg/100ml	Max 3.0		IP 131/ ASTM D381
7	Freezing Point	°C	Max minus 58.0		IP 16/ ASTM D2386 (see NOTE 2)
8	Specific Energy	MJ/kg	Min 43.50		IP 12
9	Reid Vapour Pressure at 37.8 °C	kPa	Min 38 Max 49		IP 69/ ASTM D323
10	Knock Rating:				
10.1	Lean Mixture Motor Method Octane Number		Min 91.0	Min 99.6	IP 236/ ASTM D2700 (see NOTE 3)
10.2	Research Octane Number		Min 95.0	-	ASTM D2699 (see NOTE 3)
10.3	Performance Number		(see NOTE 4)	Min 130.0	IP 119/ ASTM D909 (see NOTE 3)
11	Distillation:				
11.1	Initial Boiling Point	°C	Report		IP 123/ ASTM D86 Group 2
11.2	Temperature at % fuel evaporated	°C	Max 75		
11.2.1	10% vol %	°C	Max 75		
11.2.2	40 vol %	°C	Min 75		
11.2.3	50 vol %	°C	Max 105		
11.2.4	90 vol %	°C	Max 135		
11.3	Final Boiling Point	°C	Max 170		
11.4	Sum of 10% + 50% Evaporated Temperatures	°C	Min 135		
11.5	Residue	% v/v	Max 1.5		
11.6	Loss	% v/v	Max 1.5		

12	Oxidation Stability, 16 Hours:				
12.1	Potential Gum	mg/100ml	Max 6		IP 138/ASTM D873
12.2	Precipitate	mg/100ml	Max 2		
13	Tetraethyl Lead Content	gPb/l	Max 0.013 (See NOTE 5)	Min 0.28 Max 0.56	IP 270/ ASTM D3237 (See NOTE 6)
14	Water Reaction				
14.1	Volume Change	ml	Max 2		IP 289/ASTM D1094
15	Electrical Conductivity	pS/m	(See NOTE 7)		IP 274/ASTM D2624
16	Colour, Lovibond				
16.1	Blue		-	Min 1.7	IP 569 (See NOTE 8)
16.2	Yellow		-	Max 3.5	

NOTE 1: The visual colour must also comply with test 16 of this table.

NOTE 2: If no crystals appear when the thermometer indicates a temperature of -58°C , the freezing point shall be recorded as below -58°C .

NOTE 3: Knock rating shall be reported to the nearest 0.1 for Octane Number and Performance Number.

NOTE 4: If mutually agreed upon, a minimum 98 octane requirement as per test method IP119 / ASTM D909 may be specified.

NOTE 5: For grade UL91 the maximum lead limit applies at point of manufacture.

NOTE 6: For Grade UL91 ASTM D3237 is applicable. For Grade 100LL is applicable.

NOTE 7: When a Static Dissipator Additive has been added to the fuel the conductivity at the point, time and temperature of delivery shall be in the range 50 to 600 pS/m.

NOTE 8: IP 17 has been replaced by IP 569. A 50.8 mm cell shall be used. IP 17 is allowed as an alternative method, see Table 3.

APPENDIX A

List of Qualified Additives

A.1 Antioxidants

A.1.1 Antioxidants or mixtures of antioxidants, of a type detailed in A.1.2 and at a concentration detailed in A.1.3, may be added to the fuel.

A.1.2 The following antioxidant formulations are qualified:

Formulation	Qualification Reference
(a) 2,6-ditertiary-butyl-phenol	RDE/A/606
(b) 2,6 ditertiary-butyl-4-methyl-phenol	RDE/A/607
(c) 2,4-dimethyl-6-tertiary-butyl-phenol	RDE/A/608
(d) 75 percent minimum, 2,6-ditertiary-butyl-phenol	RDE/A/609
25 percent maximum, tertiary and tritertiary-butyl-phenols	RDE/A/610
(e) 55 percent minimum, 2,4-dimethyl-6-tertiary-butyl-phenol	RDE/A/611
15 percent minimum, 4 methyl-2,6-ditertiary-butyl-phenol	
Remainder, 30 percent maximum, as a mixture of monomethyl and dimethyl-tertiary-butyl-phenols	
(f) 72 percent minimum, 2,4-dimethyl-6-tertiary-butyl-phenol	
28 percent maximum, mixture of tertiary-butyl-methyl phenols and tertiary-butyl dimethyl phenols	

A.1.3 The total concentration of active material(s) shall not exceed 24.0 mg/l.

A.2

Antiknock Additive

A.2.1 Tetraethyl lead shall be present in Grade 100LL and added in the form of an antiknock mixture containing not less than 61% mass of tetraethyl lead and sufficient ethylene dibromide to provide two atoms of bromine per atom of lead. The balance shall contain no added ingredient other than kerosene, an approved oxidation inhibitor and blue dye as specified in **Clause A3**. The maximum lead concentration limit for each grade is specified in Table 1.

A.3 Dye (Grade Identification)

A.3.1 The following dye shall be used where applicable, within the concentration limits prescribed in Table 2, to give the finished fuel the appropriate grade identification colour:

- (a) Blue essentially 1,4-dialkylamino-anthraquinone
- (b) Yellow essentially diethylaminoazobenzene or 1,3-benzenediol 2,4-bis [alkyl (phenol) azo-]

Table 2 - Dye Requirements

Dye	Maximum Concentration (mg/l)	
		Grade 100LL
Blue		2.7
Yellow		None

A.4 Static Dissipator Additive (SDA)

A.4.1 An SDA of a type detailed in A.4.2 and at a concentration detailed in A.4.3 may be added to the fuel to impart electrical conductivity in accordance with test 15 of Table 1.

A.4.2 The following material is qualified:

Product	Manufacturer	Qualification Reference
Stadis® 450	Innospec LLC	RDE/A/621

A.4.3 The concentration of SDA shall not exceed 3.0 mg/l.

A.5 Fuel System Icing Inhibitor

A.5.1 An FSII, of a type detailed in A.5.2 and at concentrations detailed at A.5.3 and A.5.4, may be added to the fuel.

A.5.2 The following materials are qualified and must comply with Def Stan 68-252:

Product	Qualification Reference
Diethylene Glycol Monomethyl Ether (DiEGME)	RDE/A/630
Propan-2-ol (Isopropyl Alcohol)	ASTM D4171 (Type II)

A.5.3 The concentration of DiEGME shall not be less than 0.10% and not more than 0.15% by volume at the time of the delivery. A suitable method for determining DiEGME concentration is ASTM D5006.

NOTE: Concentrations of less than 0.02% by volume can be considered negligible and do not require agreement/notification. The assent to allow these small quantities of FSII without agreement/notification is to facilitate the changeover from fuels containing FSII to those not containing FSII where the additive may remain in the fuel system for a limited time. This does not allow the continuous addition of FSII at these low concentrations.

A.5.4 The concentration of Isopropyl Alcohol shall be recommended by the aircraft manufacturer at the time of delivery and typically not exceeding 1% v/v. Suitable methods for determining Isopropyl Alcohol concentration are IP 566 and ASTM D4815.

A.6 Corrosion Inhibitor Additive

A.6.1 The following corrosion inhibitors may be added to the gasoline in concentrations not to exceed the maximum allowable concentration listed for each additive.

Product	Manufacturer	Qualification Reference	Maximum mg/l
Hitec 580	Afton Chemical Ltd.	RDE/A/661	22.5
Octel DCI-4A	Innospec LLC	RDE/A/662	22.5
Octel DCI-6A	Innospec LLC	RDE/A/663	9
Nalco 5403	Nalco Chemical Co	RDE/A/664	22.5
Tolad 4410	Baker Petrolite	RDE/A/665	22.5
Tolad 351	Baker Petrolite	RDE/A/666	24
Unicor J	Dorf Ketel Chemicals	RDE/A/667	22.5
Nalco 5405	Nalco Chemical Co.	RDE/A/668	11
Spec Aid 8Q22	GE Betz	RDE/A/669	24.0

A.7 Contamination by Processing Additives

A.7.1 Experience has shown that refinery processing additives, such as corrosion inhibitors, might be carried over in trace quantities into aviation fuel during refinery production. In some cases, this has resulted in operational problems in aircraft fuel systems. Moreover, these additives can cause problems at levels which may not be detected by the standard specification testing detailed in Table 1. Whilst the standard (4.1) states that non-approved additives are not permitted, defining a zero level is not straightforward; particularly given that:

(a) modern analytical techniques are capable of detecting extremely low levels of chemical species;

(b) there could be a wide range of materials involved; and

(c) in most cases there are no data on their effects in aircraft systems to use to define a no harm level.

A.7.2 It is therefore not practical for this standard to require detailed chemical analysis of each production batch of aviation fuel beyond the requirements listed in this standard. Instead, it is recommended that manufacturing locations ensure that they have adequate quality assurance and management of change procedures in place to ensure that refinery processing additive use is well defined and controlled. Any changes in additive composition/manufacturing source or refinery processing conditions should be subject to a formal risk assessment to ensure maintenance of finished product quality.

A.7.3 Due to known problems arising from the carryover of the refinery processing additive (corrosion inhibitor) 1,2-diaminoethane (ethylene diamine), its use is specifically not recommended in the manufacture of aviation gasoline.

ANNEX B

Alternative Test Methods for Use with Table 1 Test Requirements

Table 3: Alternative Test Methods

Table 1 Test Number	Property	Alternative
1	Appearance	ASTM D4176 Procedure 1
4	Density at 15 °C	IP 365/ ASTM D4052
5	Total Sulphur	IP 243 ASTM D2622 ASTM D5453
8	Specific Energy	ASTM D3338 ASTM D4809
9	Vapour Pressure	See NOTE 1 IP 394 ASTM D5191
13	Tetraethyl Lead Content	IP 228/ASTM D5059 IP 428/ASTM D3341
16	Colour, Lovibond	IP 17, see NOTE 2 ASTM D2392, see NOTE 3
NOTE 1: Results shall be reported as dry vapour pressure equivalent (DVPE), as defined in the approved alternative method used. NOTE 2: Use test method IP 17 (Method A) using a 50.8 mm cell.		

NOTE 3: When ASTM D2392 is utilised, the fuel shall meet the requirements of the test and not require the reporting of Lovibond colour units.

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