



AEROSPACE RECOMMENDED PRACTICE

ARP4865

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Superseding ARP4865

Gas Turbine Engine Fuel Nozzle Test Procedures

RATIONALE

This document has been determined to contain stable technology which is not dynamic in nature.

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FOREWORD

Fuel nozzle performance requires measurement of fluid flow and pressure as well as the quality or form and symmetry of the spray. The spray produced by most nozzles is measurable and must meet certain criteria. The test equipment used for these measurements must meet specific accuracy requirements for flow, pressure, and temperature. The test conditions, test fixturing for holding the nozzle, and the methods used to measure the various spray acceptance criteria must also be controlled.

There are two main categories of nozzle design; pressure atomizer and air blast. The pressure atomizer uses fluid pressure as the main mechanism for breakup of the fluid into droplets. The outlet orifice is small and a swirl device upstream of the outlet orifice establishes spray angle. This design provides a very distinct spray angle and air is introduced into this angle without causing distortions. Fluid pressure to the inlet of the nozzle nominally is between 25 to 550 psig. The air blast design uses the air as the main mechanism for breakup of the fluid into droplets. The air is directed at the sheet of fluid exiting from an internal prefilmer located at the exit of the nozzle. The spray angle is less apparent and the fuel distribution is less concentrated. Fluid pressure to the inlet of the nozzle nominally is between 2 to 50 psig. Both designs may incorporate flow divider valves that can change the inlet pressure versus outlet flow curve. Flow divider valves are common on designs with a primary and secondary flow channel. The valve secondary flow will begin at higher pressures after the engine start sequence is completed.

1. SCOPE:

The intent of this SAE Aerospace Recommended Practice (ARP) is to define and recommend to the Aerospace Industry standardized test procedures for establishing fuel nozzle operating performance including types of tests, controlled and measured parameters, and test configurations.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP598 The Determination of Particulate Contamination in Liquids by the Particle Count Method

ARP785 Procedure for the Determination of Particulate Contamination in Hydraulic Fluids by the Control Filter Gravimetric Procedure

2.2 ANSI Publications: Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 4402 Hydraulic Fluid Power. Calibration of Liquid Automatic Particle-Count Instruments-Method Using Air Cleaner Fine Test Dust Contaminant

ISO 10012-1 Quality Assurance Requirements for Measuring Equipment, Part 1: Meteorological Confirmation System for Measuring Equipment. This replaces the cancelled MIL-STD-45662A.

2.3 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-C-7024 Type II, Military Specification. Calibration fluid for Aircraft Fuel Systems Components

MIL-L-6081 Grade 1010, Military Specification. Preservative Oil

2.4 Terminology:

Use the following equalities for the purposes of this document, unless stated otherwise.

MIL-C-7024 Type II = Characteristics of this test fluid simulates jet fuel with less flammability hazard.

PHR = Pounds Per Hour. Units for flow measurement. Recommended.

PPH = Another designation for flow units still in use. Not recommended for new documents.

PSIG = Pounds per Square Inch Gauge. Units for pressure measurement.

2.4 (Continued):

QD	= Quick Disconnect. This two part device allows for a single action hydraulic connection and disconnection between the test stand and UUT. The first part called, the inlet adapter, is attached to the UUT to protect the inlet supply section of the nozzle. The opposing end of inlet adapter then inserts into the companion portion of the QD that is attached to the test equipment.
SCFM	= Standard Cubic Feet per Minute. Volumetric rate of airflow.
UUT	= Unit Under Test or the nozzle under test.

3. TEST CONDITIONS:

3.1 Test Fluid:

Standard test fluid for aerospace manufacturers is MIL-C-7024 Type II. This is also known as Stoddard solvent. Experience has shown that MIL-C-7024 Type II purchased from a single supply source will maintain stable properties. However, when purchased from multiple sources, these fluid properties can vary several percent. In comparing fuel property data taken from different sources, the differences must be taken into consideration. The flow measuring instrument calibration must account for the correct density and viscosity for the MIL-C-7024 Type II used or an equivalent fluid matching the MIL-C-7024 Type II properties.

The use of test fluids other than MIL-C-7024 Type II, such as actual jet fuels, is not recommended. The wide variance in fuel properties precludes convenient correlation of test data with other testing facilities. The use of jet fuels for fuel nozzle testing is also more hazardous, requiring more stringent safety considerations.

3.2 Filtration:

The minimum acceptance Beta ratio for MIL-C-7024-II filtration systems shall be as shown in Equation 1:

$$\beta_{6/11/15} = 2/20/75 \quad (\text{Eq.1})$$

See Appendix A.

3.3 Fuel Contamination Testing:

The acceptance level shall conform to the requirement MIL-C-7024 Type II fluid. The recommended contaminant testing method is the International Standards Organization Solid Contaminant Code (ISOSCC). The recommended ISOSCC rating acceptance level for all fuel nozzle test stands is 16/13 (see Appendix B). It is recommended that the fluid contaminant level be checked at intervals of 60 days.

3.4 Temperature:

- 3.4.1 Fuel: The calibration fluid shall normally be maintained at a temperature of 80 °F (26.7 °C) ± 2 °F (1.1 °C) measured at a point near as practical to the flow measurement device and not closer than 10 diameters from the static pressure measuring tap. Deviation from this range is allowed only if the measurement system contains corrections for the mass flow errors due to specific gravity and viscosity variations with temperature.
- 3.4.2 Air: The air shall be maintained at a temperature of 50 to 95 °F (10 to 35 °C) measured at a point not closer than 10 diameters from the static pressure measuring tap. The air supply shall be clean and dry with a dew point of 40 °F (22 °C) or less.

4. EQUIPMENT ACCURACY:

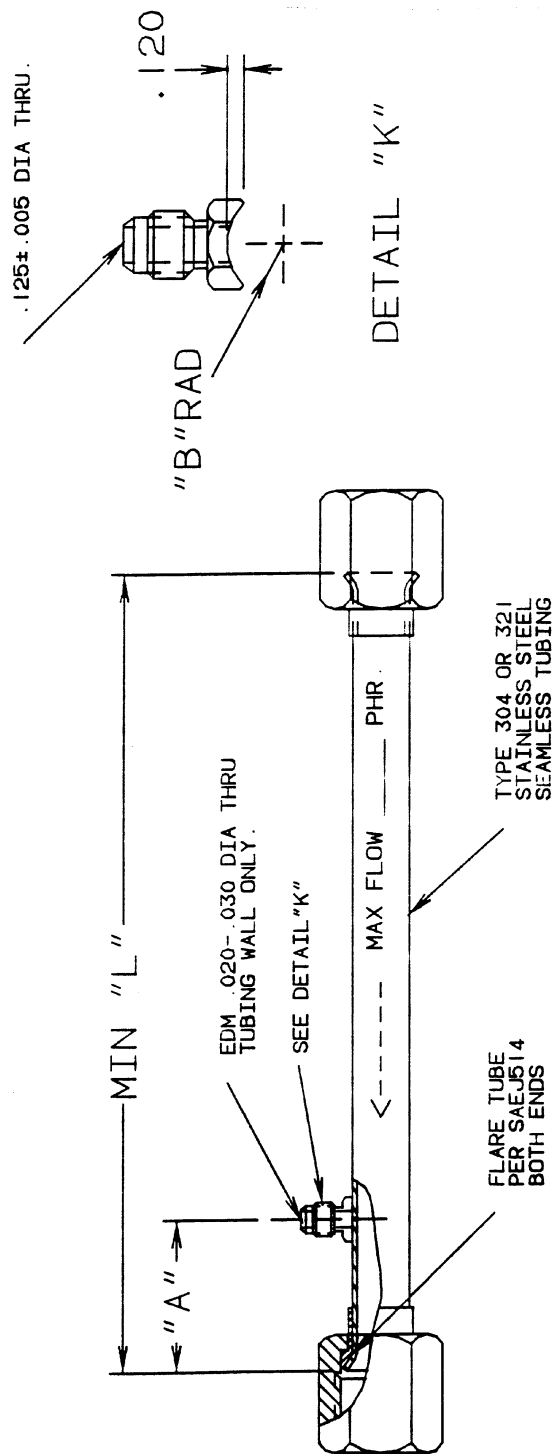
4.1 Pressure Measurement:

The pressure measurement equipment shall be accurate to within $\pm 0.5\%$ OF READING for the UUT (See Appendix C).

4.2 Pressure Sensing:

The pressure measuring taps shall indicate true static pressure at a point as close as practical to the UUT inlet in a tube having a minimum internal diameter equal to the fitting to which it is attached. The pressure tap should be located within 6 in of parallel height from the pressure gauge reference plane. Establish the spray chamber height, with the UUT installed in the fixture. If this is not possible a calibration must be performed to allow for positive or negative head pressure.

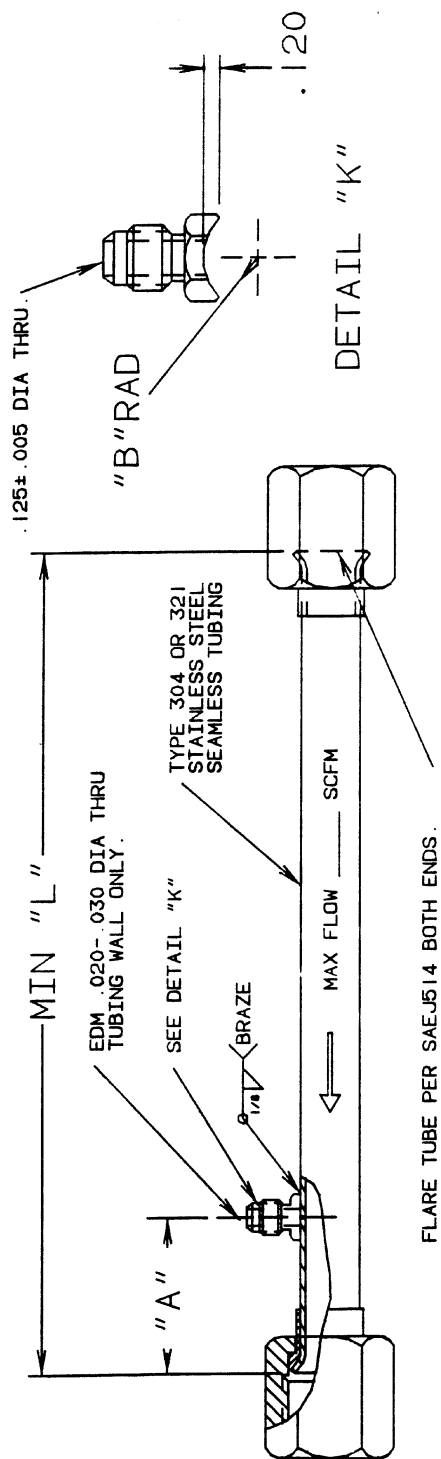
- 4.2.1 Measuring Sections: Static pressure can be measured with a pressure measuring section designed such that the pressure sensing passage is small relative to the diameter of the flow passage and the pressure is sensed in the boundary layer of the fluid during normal operation. The internal diameter must be large enough to assure a maximum velocity of no more than 20 ft/s (6.096 m/s) at the flow condition for fuel or Mach 0.2 for air such that the dynamic pressure component is minimized. The pressure tap is placed a minimum of 10 diameters downstream from the supply fitting connection and 2 diameters upstream from the exit. See Figure 1 for fuel flow and Figure 2 for airflow.
- 4.2.2 Quick Disconnects (QD): If a QD is used during performance testing, the center check valve should be removed. The inlet adapter must have at least the same internal diameter as the UUT fitting. Periodic leakage checks should be performed on the inlet adapter and QD.
- 4.2.3 Calibration of QDs: If the test setup does not allow removal of the center check valve, then a calibration must be performed to establish a correlation between pressure drop and flow rate.



1. ALL PRESSURE MEASURING SECTIONS SHALL BE PRESSURE TESTED FOR A PERIOD OF ONE MINUTE AT HYDROSTATIC TEST PRESSURE LISTED (UNDER TEST AND WORKING PRESSURE) WITH NUTS TORQUED TO VALUES SHOWN. THERE SHALL BE NO EVIDENCE OF LEAKAGE OR PERMANENT SET.
2. REFERENCE FLOWS ARE FOR MAX TEST PRESSURES GREATER THAN 90 PSIG. USING MIL-C-7024 TYPE II TEST FLUID.

PART DESCRIPTION				DETAIL "K"				TEST AND WORKING PRESSURES			
TUBE OD	NOM WALL THK	MIN LENGTH "L"	DIM "A"	SLEEVE SAE	NUT SAE	"B" RADIUS	HYDROSTATIC TEST PRESSURE	TORQUE (FT-LB)	MAX ALLOWABLE PRESSURE 0. F TO 1000. F	MAX ALLOWABLE FLOW (PHR)	
1.875	.049	4.500	2.000	3-070115	3-070115	.089-.099	2000	8	2000	150	
2.500	.049	4.500	2.000	4-070115	4-070115	.120-.130		10		435	
3.125	.049	4.500	2.000	5-070115	5-070115	.151-.161		15		860	
3.750	.049	4.750	2.000	6-070115	6-070115	.183-.193		20		1435	
5.000	.049	6.000	2.000	8-070115	8-070115	.245-.255		25		3022	
6.250	.049	7.750	2.500	10-070115	10-070115	.297-.307		30		5200	

FIGURE 1 - Typical Fuel Flow Measuring Section



1. LENGTH TO DIA RATIOS FOR LARGER DIA SECTION SHOULD BE : 10/1 UPSTREAM, 2/1 DOWNSTREAM.
2. ALL PRESSURE MEASURING SECTIONS SHALL BE PRESSURE TESTED FOR A PERIOD OF ONE MINUTE AT HYDROSTATIC TEST PRESSURES LISTED UNDER (TEST AND WORKING PRESSURE) WITH NUTS TORQUED TO VALUES SHOWN THERE SHALL BE NO EVIDENCE OF LEAKAGE OR PERMANENT SET
3. REFERENCE FLOWS ARE FOR CLEAN DRY AIR.

PART DESCRIPTION					DETAIL "K"				TEST AND WORKING PRESSURES		
TUBE OD	NOM WALL THK	MTN LENGTH "L"	DIM "A"	SLEEVE SAE	NUT SAE	"B" RADIUS	HYDROSTATIC TEST PRESSURE	TORQUE (FT-LB)	MAX ALLOWABLE PRESSURE (PSIG) 0°F TO 1000°F	MAX ALLOWABLE AIR FLOW (SCFM)	
1.000	.083	12.500	2.500	16-070115	16-070110	.495-.505	1500	75	1000	50	
1.250	.095	15.500	3.000	20-070115	20-070110	.620-.630		75		85	
1.500	.095	18.500	3.500	24-070115	24-070110	.745-.755		75		125	
2.000	.095	24.500	4.500	32-070115	32-070110	.995-1.005		75		250	

FIGURE 2 - Typical Airflow Measuring Section

- 4.2.4 Plenum Measurement (AIR): Static pressure can be measured in a Plenum chamber which provides the working fluid to the test article. This is done with a small pressure sensing passage at the periphery of the chamber. The internal volume must be large enough to assure a Plenum feed of the test fluid to the test article. The maximum velocity at the inlet of the Plenum should be no more than Mach 0.2 at the flow condition and no portion of the Plenum cross section shall be smaller than the inlet. See Figure 3. The general shape of the air box is not critical if these requirements are met.

4.3 Pressure or Flow Setting:

Pressure setting shall be within $\pm 1\%$ OF READING at all test points of the UUT. When applicable, flow setting shall be within $\pm 2.0\%$ OF READING.

4.4 Fuel Flow Measurement:

The flow measurement shall be accurate to within $\pm 0.5\%$ OF READING at all test points of the UUT.

4.5 Airflow Measurement:

The flow measurement equipment shall be accurate to within $\pm 1.0\%$ OF READING at all test points.

4.6 Spray Angle Measurements:

The angle measuring device shall be accurate to within $\pm 1^\circ$ OF READING for overall angle and/or $\pm 1\%$ OF READING for linear width. The majority of sprays are conical in nature as they exit the orifice of the UUT. The spray angle is measured at a point specified by the engine and nozzle manufacturer. The spray cone is viewed as a two dimensional plane using simple fixturing and measuring devices. The measured data can be either an angle and skew or linear dimensions from centerline.

- 4.6.1 Spray Angle Test Fixturing: Test fixturing is normally mounted on or integral to spray chambers which collect the spray dispensed, evacuate the fumes, and return the test fluid to the test stand. The spray chamber and fixturing allow the spray to exit downward in a vertical plane and is viewed by the operator through a transparent, nondistorting viewing aperture. Where spray angle measurement or patterning is required, the UUT shall be mounted in a suitable fixture such that, when installed in the measuring device, the UUT tip center-line is held within ± 0.025 in (0.635 mm) of the angle device or patternator centerline. See Figures 4 and 5. The theoretical spray cone apex, as defined by the appropriate control document, shall also be placed at the measurement device reference plane, as defined by the device assembly drawing, within ± 0.025 in (0.635 mm). It is essential to establish the theoretical spray cone apex and ensure the fixture dimensions are correct when installed in the spray angle device being used.

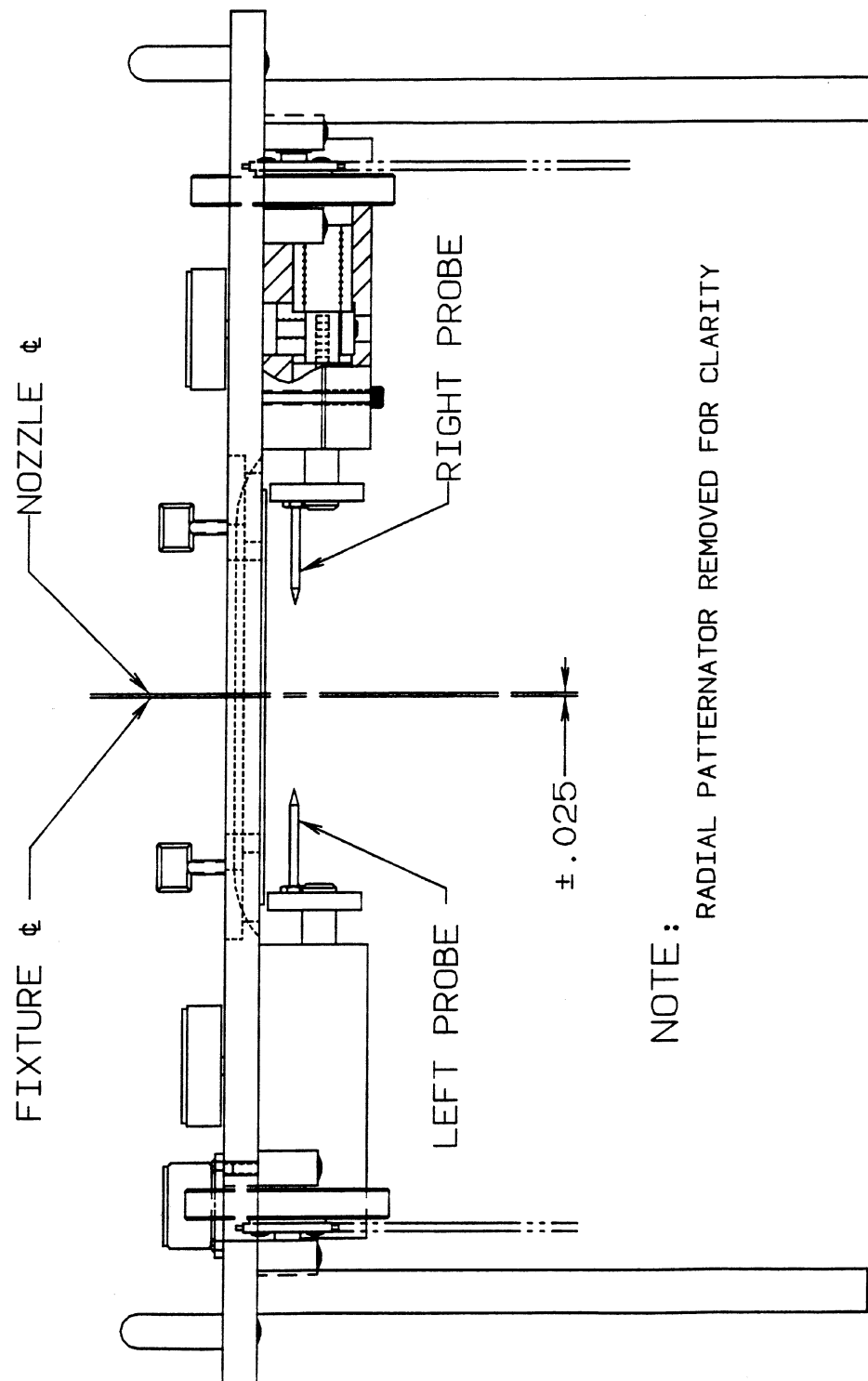


FIGURE 4 - Typical Spray Angle Device Front View