AEROSPACE RECOMMENDED PRACTICE

ARP4865	REV. A
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Gas Turbine Engine Fuel Nozzle Test Procedures

RATIONALE

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

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE EG-1E Gas Turbine Test Facilities and Equipment Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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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 ±0.5% OF READING for the UUT (See Appendix C).

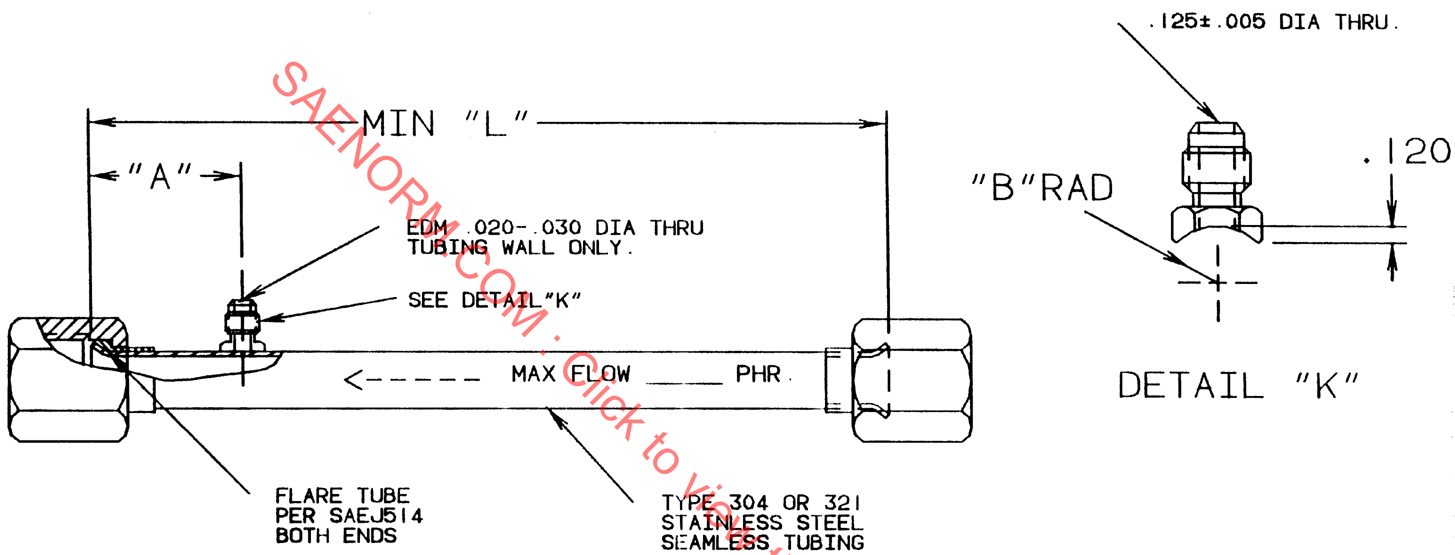
4.2 Pressure Sensing:

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.

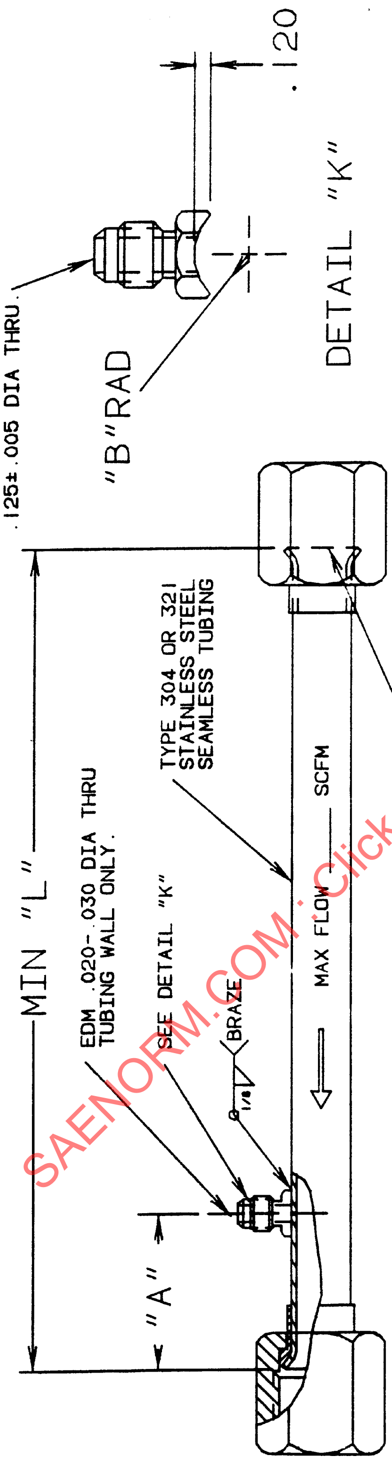


1. ALL PRESSURE MEASURING SECTIONS SHALL BE PRESSURE TESTED FOR A PERIOD OF ONE MINUTE AT HYDROSTATIC TEST PRESSURE LISTED (UNDER TEST AND WORKING PRESSURE) WITH NUTS TORQUED TO VALUES SHOWN, THERE SHALL BE NO EVIDENCE OF LEAKAGE OR PERMANENT SET.

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 (PSIG) 0 °F TO 1000 °F	MAX ALLOWABLE FLOW (PHR)
.1875	.049	4.500	2.000	3-070115	3-070115	.089-.099	2000	8	2000	150
.250	.049	4.500	2.000	4-070115	4-070115	.120-.130	↓	10	↓	435
.3125	.049	4.500	2.000	5-070115	5-070115	.151-.161	↓	15	↓	860
.375	.049	4.750	2.000	6-070115	6-070115	.183-.193	↓	20	↓	1435
.500	.049	6.000	2.000	8-070115	8-070115	.245-.255	↓	25	↓	3022
.625	.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	MIN 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 ±1% OF READING at all test points of the UUT. When applicable, flow setting shall be within ±2.0% OF READING.

4.4 Fuel Flow Measurement:

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

4.5 Airflow Measurement:

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

4.6 Spray Angle Measurements:

The angle measuring device shall be accurate to within ±1° OF READING for overall angle and/or ±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 patternation 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.

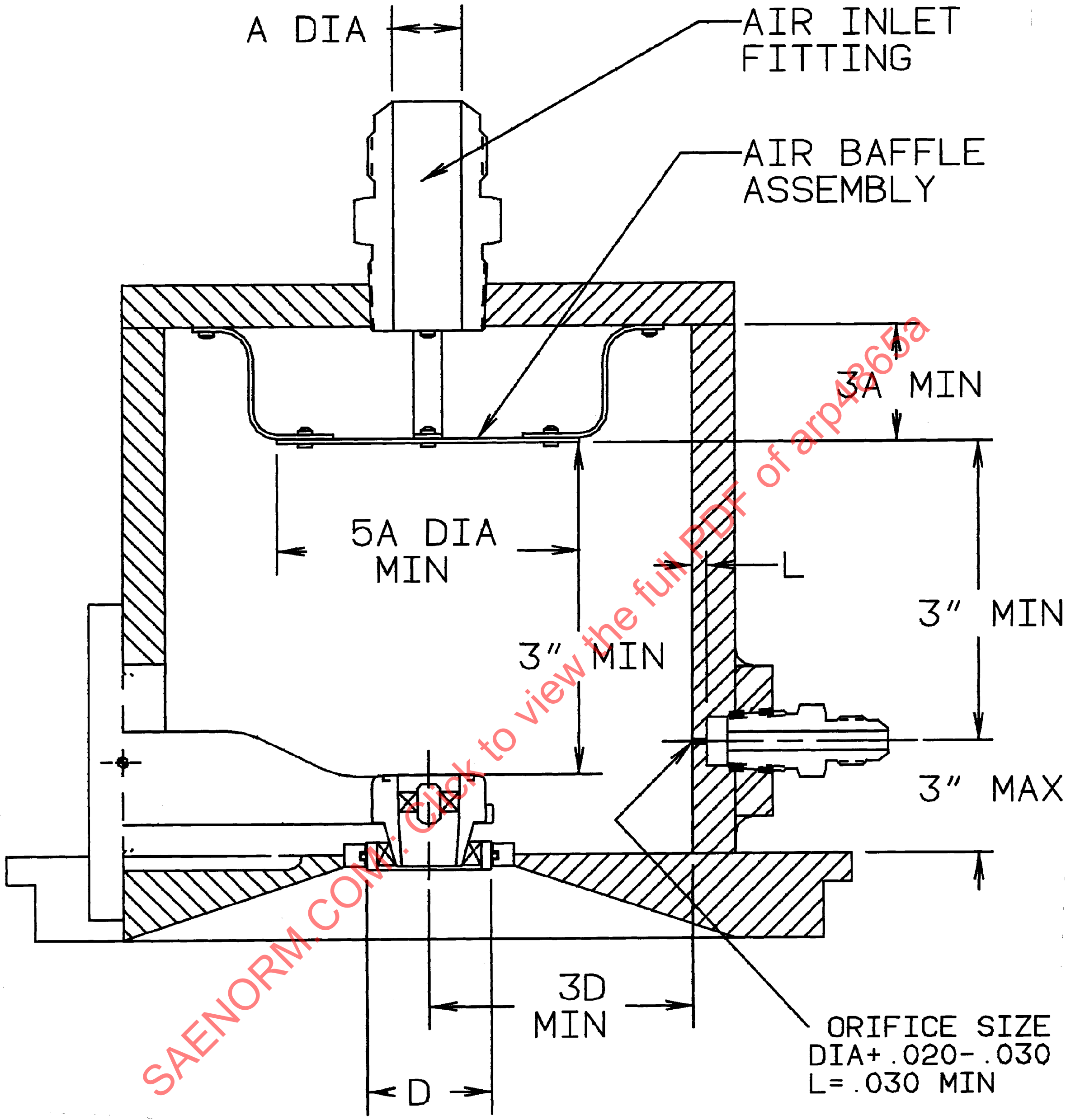


FIGURE 3 - Typical Air Box

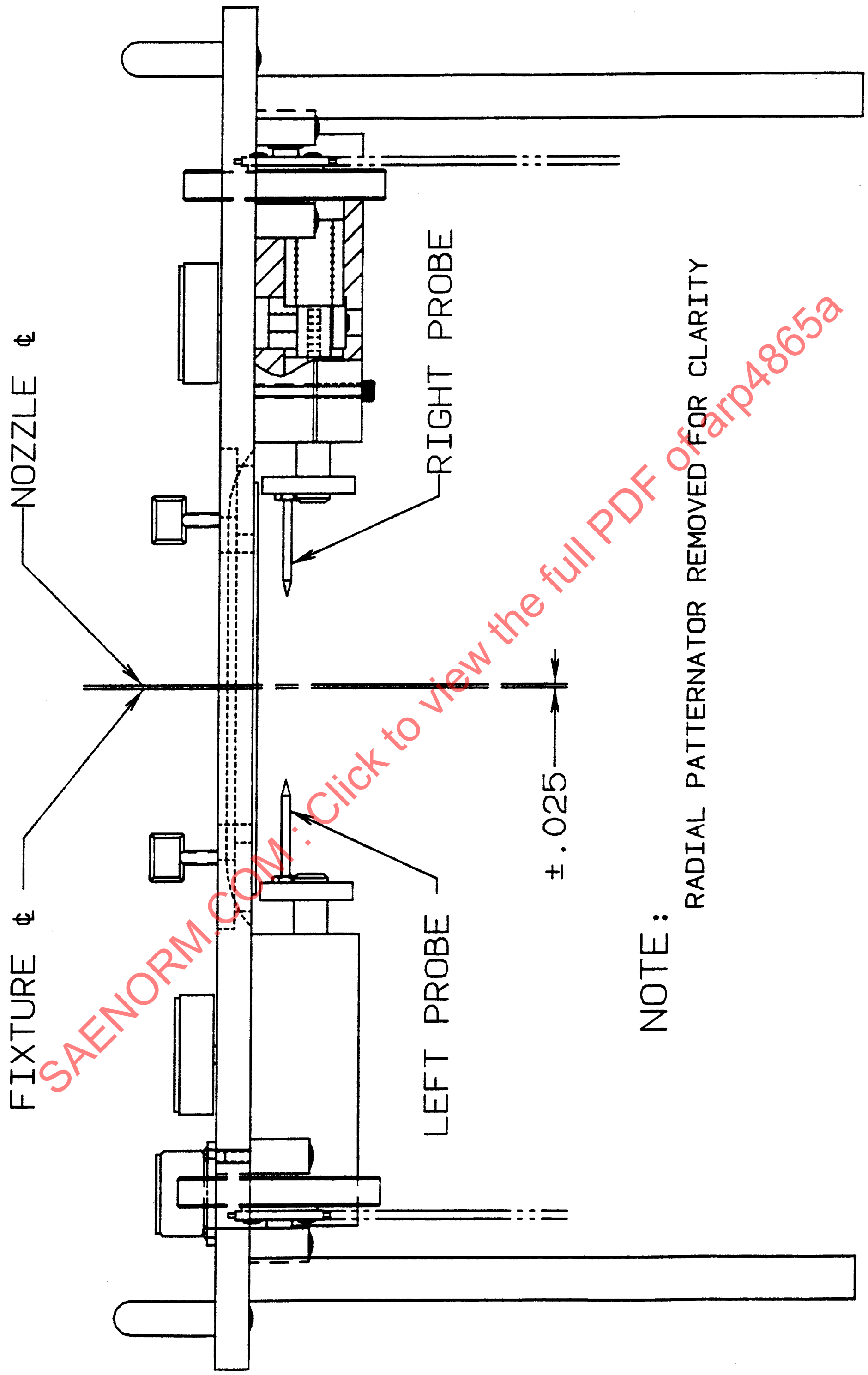


FIGURE 4 - Typical Spray Angle Device Front View

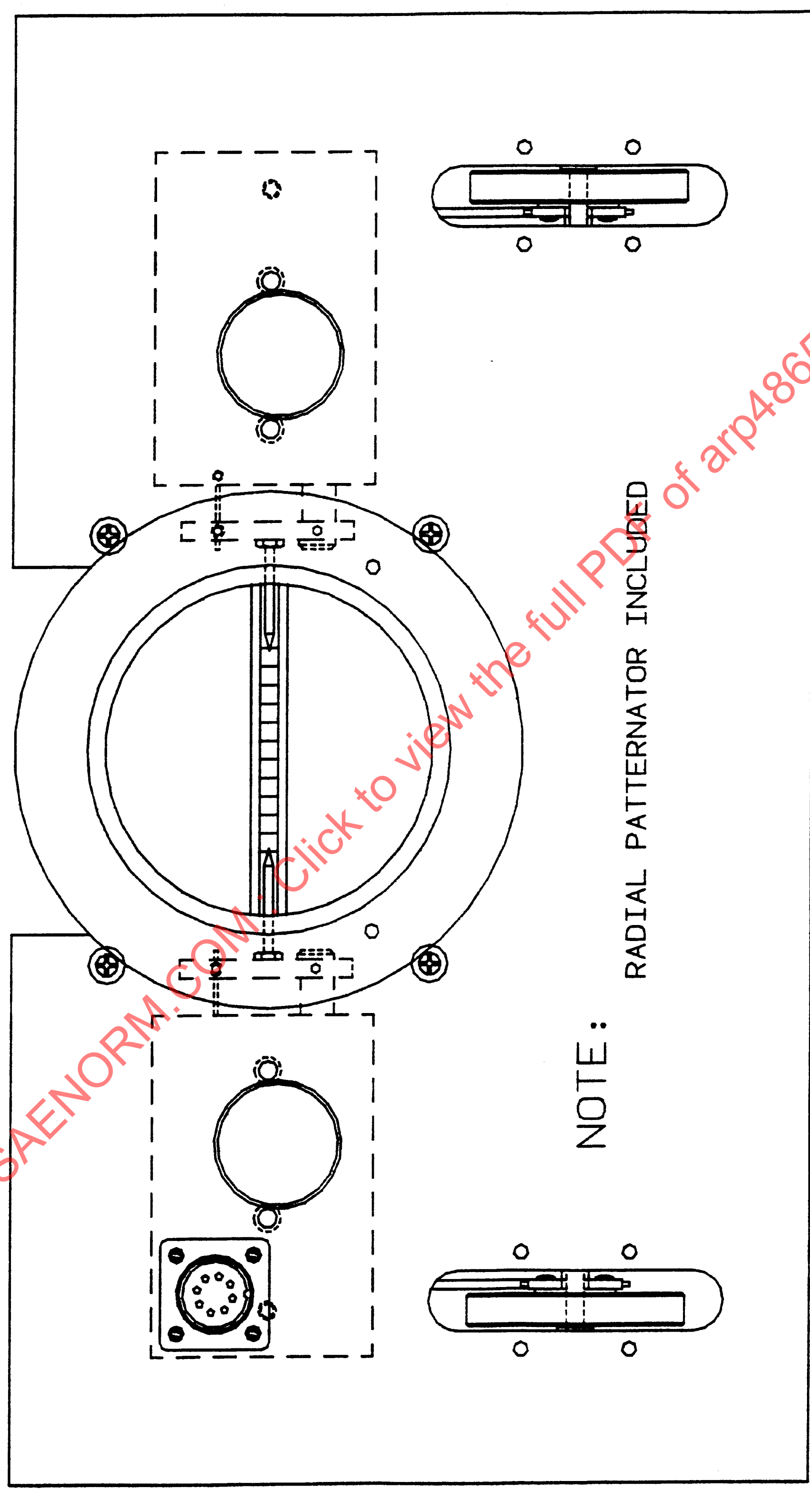


FIGURE 5 - Typical Spray Angle Device Top View

4.6.2 Plane -TS- For Test Fixtures: It is recommended that a reference plane called plane "-TS-" be defined which is directly related to the UUT flange mounting holes. Thus, the measurement plane is located relative to the flange datum on every UUT. The distance from "-TS-" to the measurement plane is the nominal tip location plus the nominal defined location for measurement of the spray angle and symmetry. Test tooling used to evaluate the spray must be designed so the combination of the air box or UUT mounting fixture places the measurement plane within 0.025 in (0.635 mm) of true position. Plane -TS- also becomes a standard reference plane that should be added to the UUT envelope drawing. The tolerance specified for -TS- to patternation devices should be ±0.050 in (1.270 mm). See Figures 6 and 7.

4.6.3 Visual Method: This method is very subjective and a procedure should be defined such that repeatable results can be achieved. Normally there are two measurement indicators spaced 180° apart. The spray angle device indicators are moved slowly toward the conical spray. The recommended practice is to read the position of these indicators when fluid droplets are observed dripping at a constant rate. There are two types of indicator movement. The first mechanism has the indicators in the horizontal plane located a known distance vertically from the apex of the spray cone. These indicators move linearly towards the centerline of the spray. See Figure 8. In the second mechanism, rotating indicators use the apex of the spray as the axis of rotation. See Figure 9.

4.6.4 Calculation of Angle: The calculation of angle in the linear version is determined by trigonometry. The fixture establishes the center axis of the spray and the required height from the cone apex to the measurement plane. When the position of each indicator from the center line is known, the two half angles of the spray are measured. Adding the two half angles yields the total spray angle, sometimes referred to as combined angle. Subtracting the two half angles and dividing by two, yields the skew angle which is a measure of the deviation from centerline of the spray cone.

4.7 Circumferential Patternation:

The circumferential patternator is used to determine the variance of flow splits between a number of defined segments of the spray. It is not considered a flow device and is used only to determine deviation between the segments. See a typical device in Figure 7.

4.7.1 Collection of Fluid: The UUT is mounted directly above and centered on the collection device. The device collects fluid when the UUT is spraying and guides it to individual measurement segments.

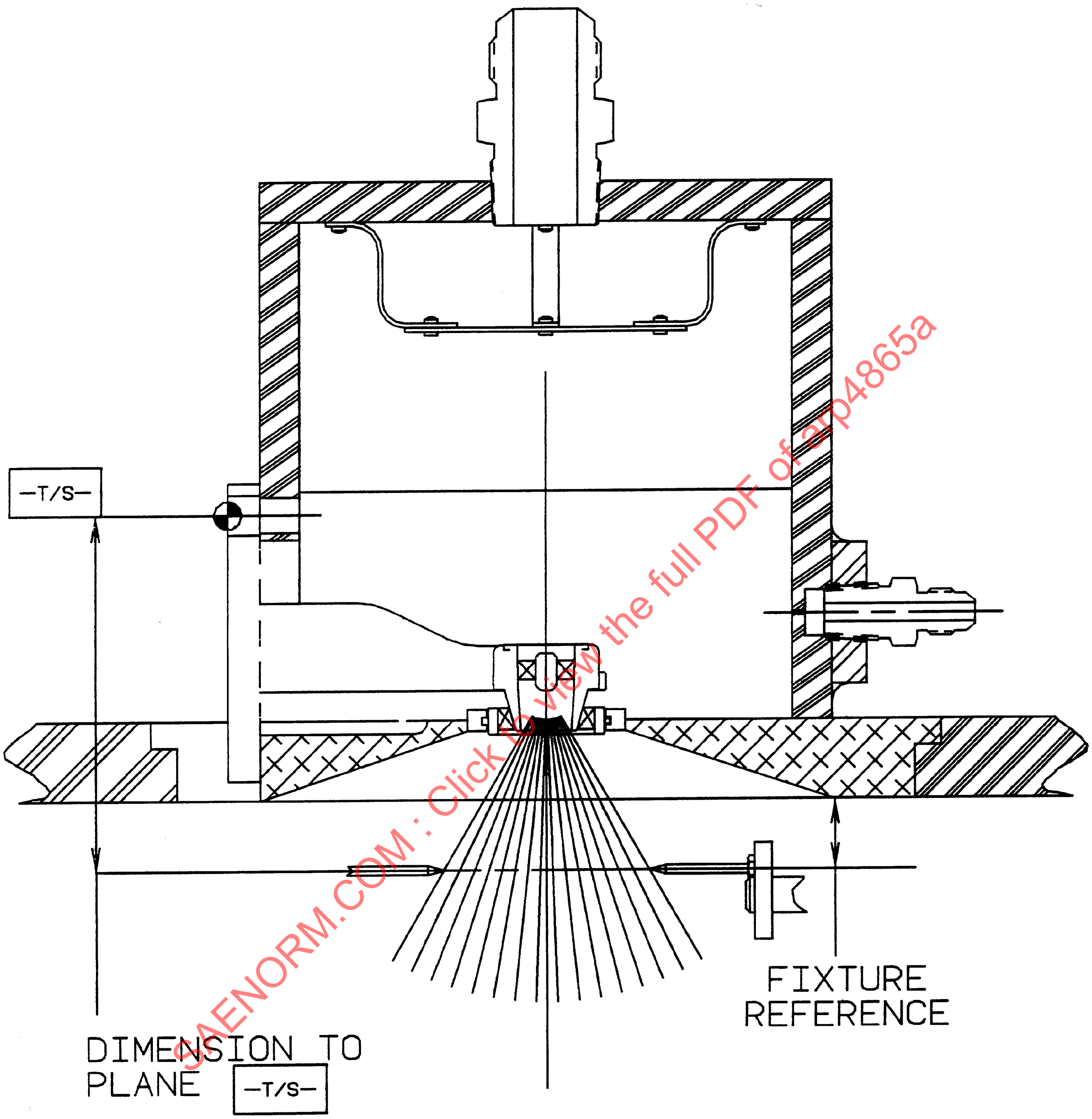


FIGURE 6 - Typical Plane

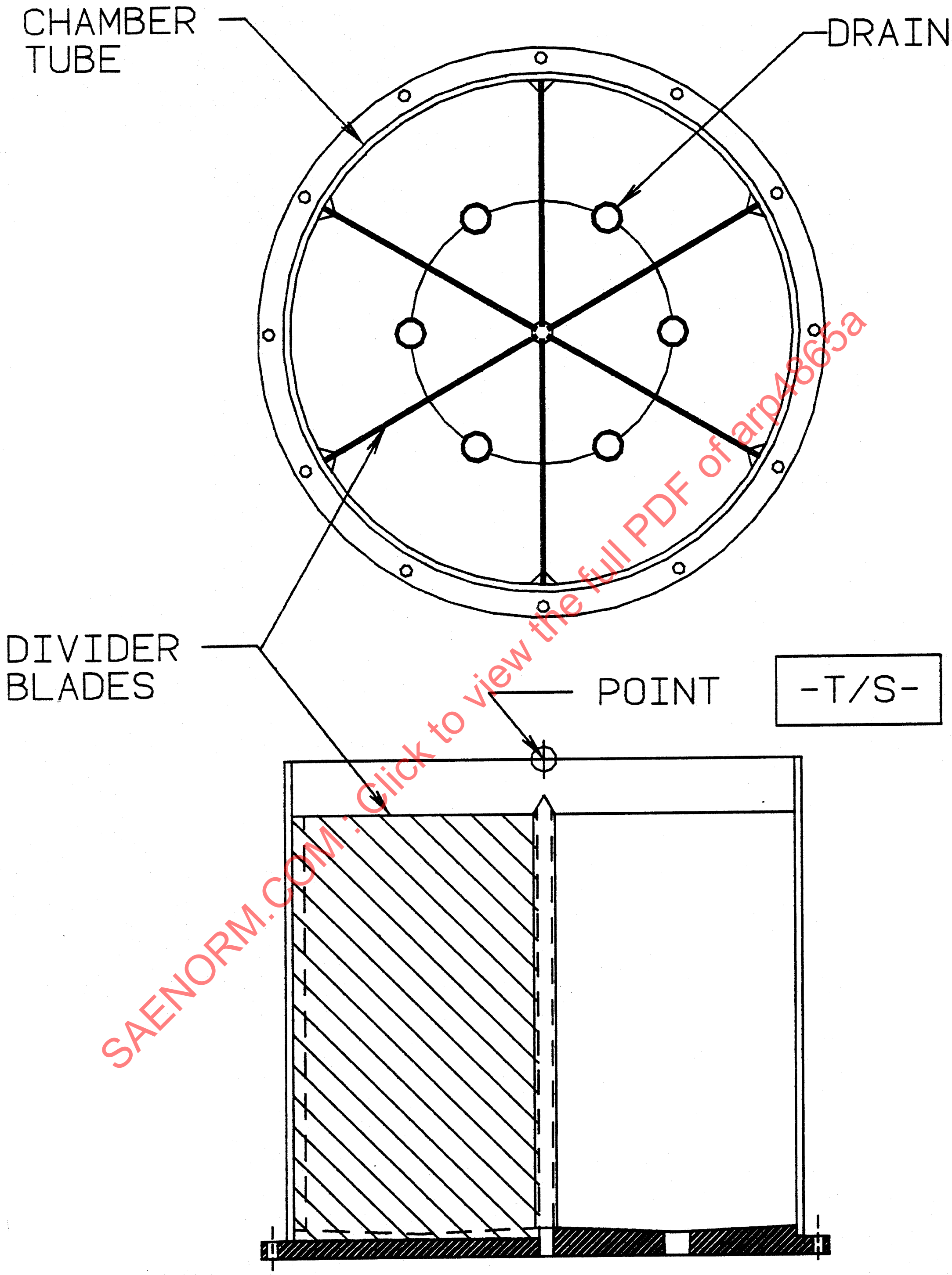


FIGURE 7 - Typical Circumferential Patternator

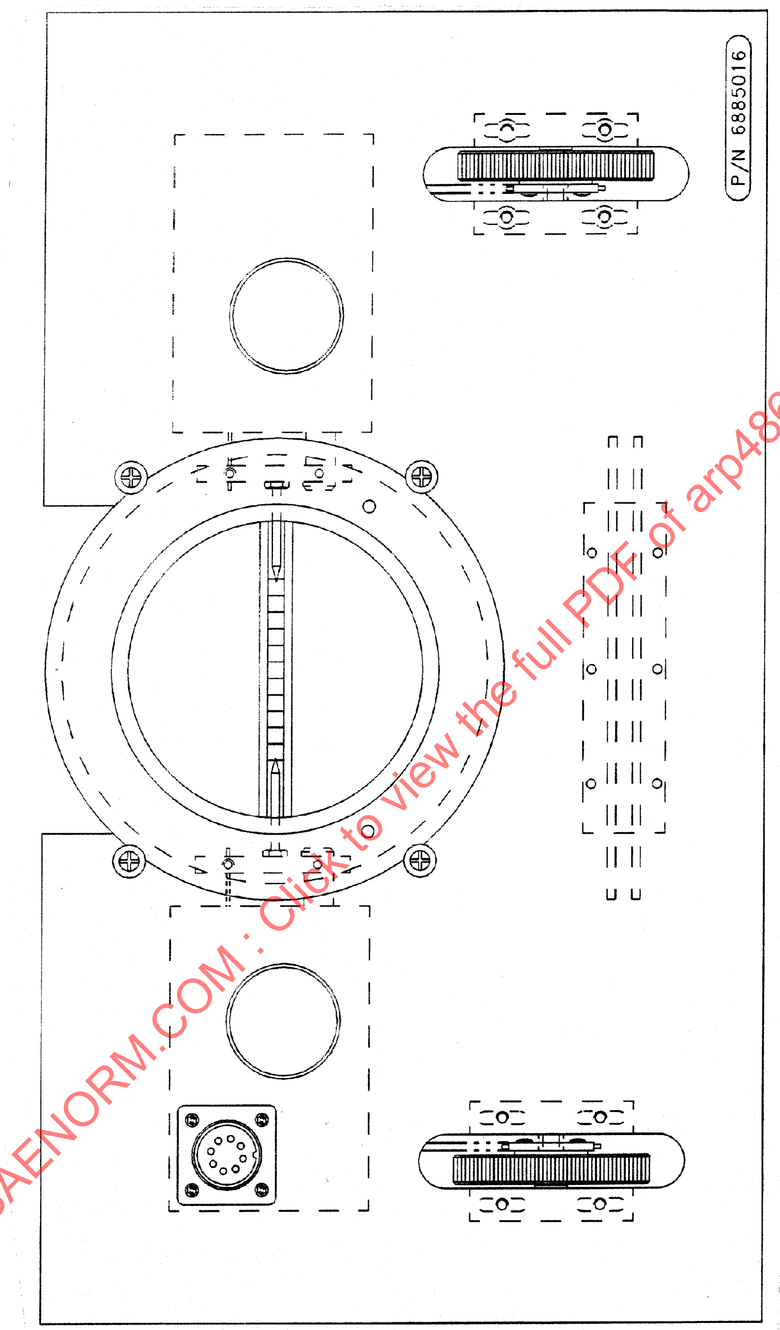


FIGURE 8 - Typical Spray Angle Device Top View

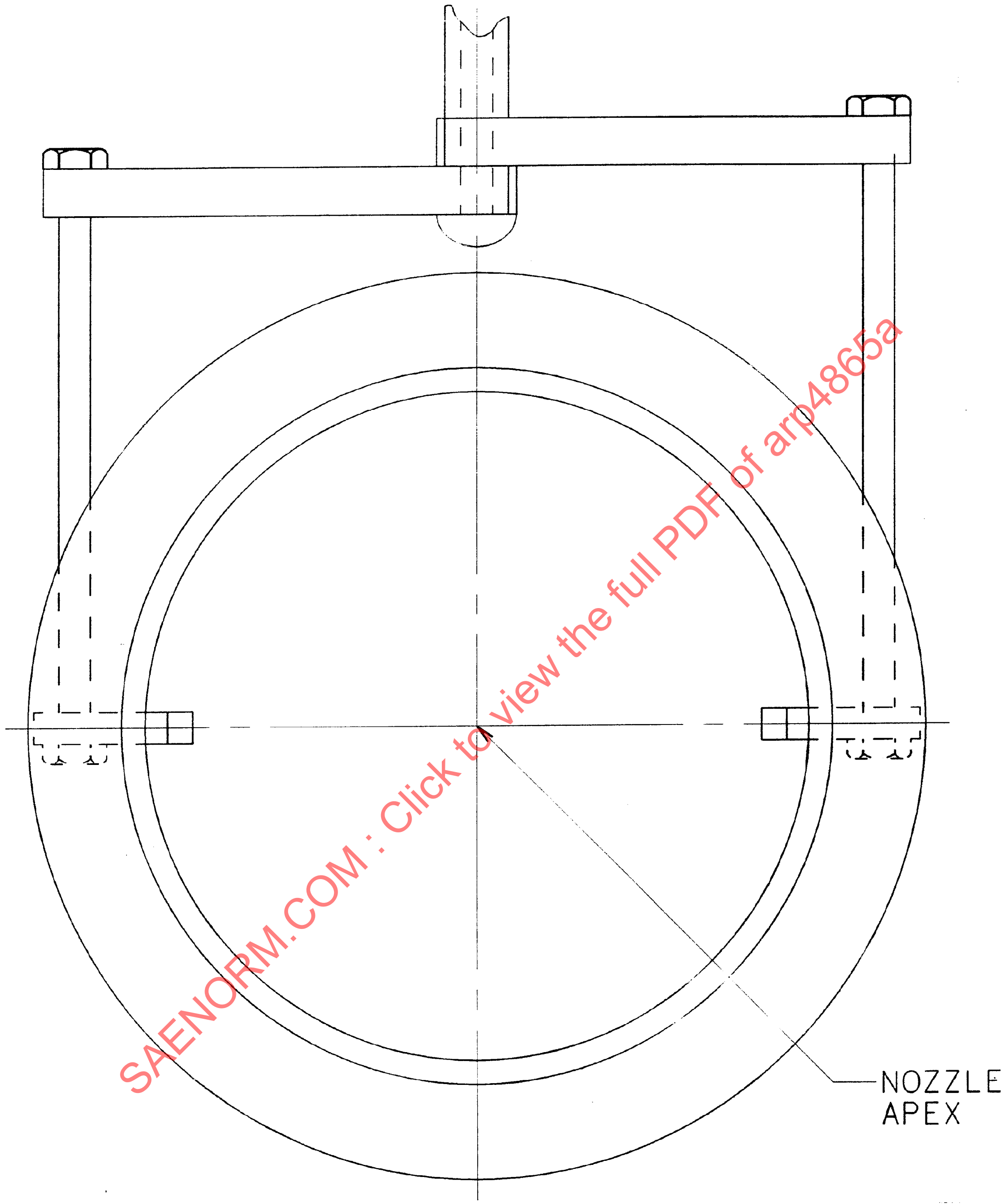


FIGURE 9 - Typical Protractor Angle Device Top View

4.7.2 Calculation of Patternation: Two methods are used to determine and display patternation data, percent deviation from nominal and percent fuel per zone. Percent deviation from nominal is obtained by adding the normalized collected volumes and dividing by the number of collection segments to obtain a nominal value for each collection segment. Each individual collected segment volume is subtracted from and divided by the nominal to give the segment's deviation from nominal. This value is multiplied by 100 to give percent deviation from nominal. The total spread percentage will be the difference between the minimum and maximum % deviations. Percent fuel per zone is the collected volume, in percent, for each segment.

4.7.3 Spray Dissipation: A typical spray dissipation method for circumferential segmented patternators uses randomly placed lock-wire in the individual segments. When the spray strikes the lock-wire the droplets entrained in the air stream will coalesce on the lock-wire and drain or drip to the bottom. Supporting the lock-wire with a large perforation mesh screen will continue to coalesce the drain-off. Each segment should vent near the mesh screen at the outside diameter of the patternator. Normal aspiration will suffice if the venting hole is large enough. Use a forced evacuation system if a nonlaminar air stream or a nonrepeatable result is evident. Measure the pressure in the chamber, referenced to atmosphere, and control the exhaust air volume.

4.8 Radial Patternation:

The radial patternator is used to measure variances in flow collection segments arranged radially from the spray cone apex of the UUT. The resulting data that is collected will provide a method for determining spray angle and distribution of the spray. A typical collection device is shown in Figure 10 and is described below. This device would normally be mounted directly below the UUT spray centerline. The positioning can be seen in the top view of the device in Figure 5. This description is not considered a recommended standard and is presented here only as a guide for understanding. Similar radial patternators may have more or less segments and different markings, but the general purpose is the same. The OEM nozzle manufacturers can provide the exact information needed for each nozzle program.

An UUT is mounted directly above and centered on the centerline of the radial patternator collector. A total of 14 segments on each side of centerline are lettered between A - P (I and O are excluded). The center of the collection device is not lettered. The size of each collection column or segment is 2.0 in high x 0.25 in wide x .25 in deep (50.8 mm high x 6.35 mm wide x 6.35 mm deep). The upper edge of the collector is located at a radius of 4 in (101.6 mm) from the UUT apex. Each segment column is spaced 4.5° from each other. This will allow a measurement of spray angle up to 126°. The transparent face of the collector has inscribed lines that subdivide each segment column into eight units. These data are read when the meniscus of the fluid passes the inscribed line. The collector utilizes a deflector shield that covers the segments before measurement is started so that the proper flow and pressure can be set before filling each segment. The shield is removed to begin filling the collector. The testing procedure will specify either removing the shield for a specific time or until the last scribed line is reached in the fastest filling segment. The shield is then returned to the deflecting position.

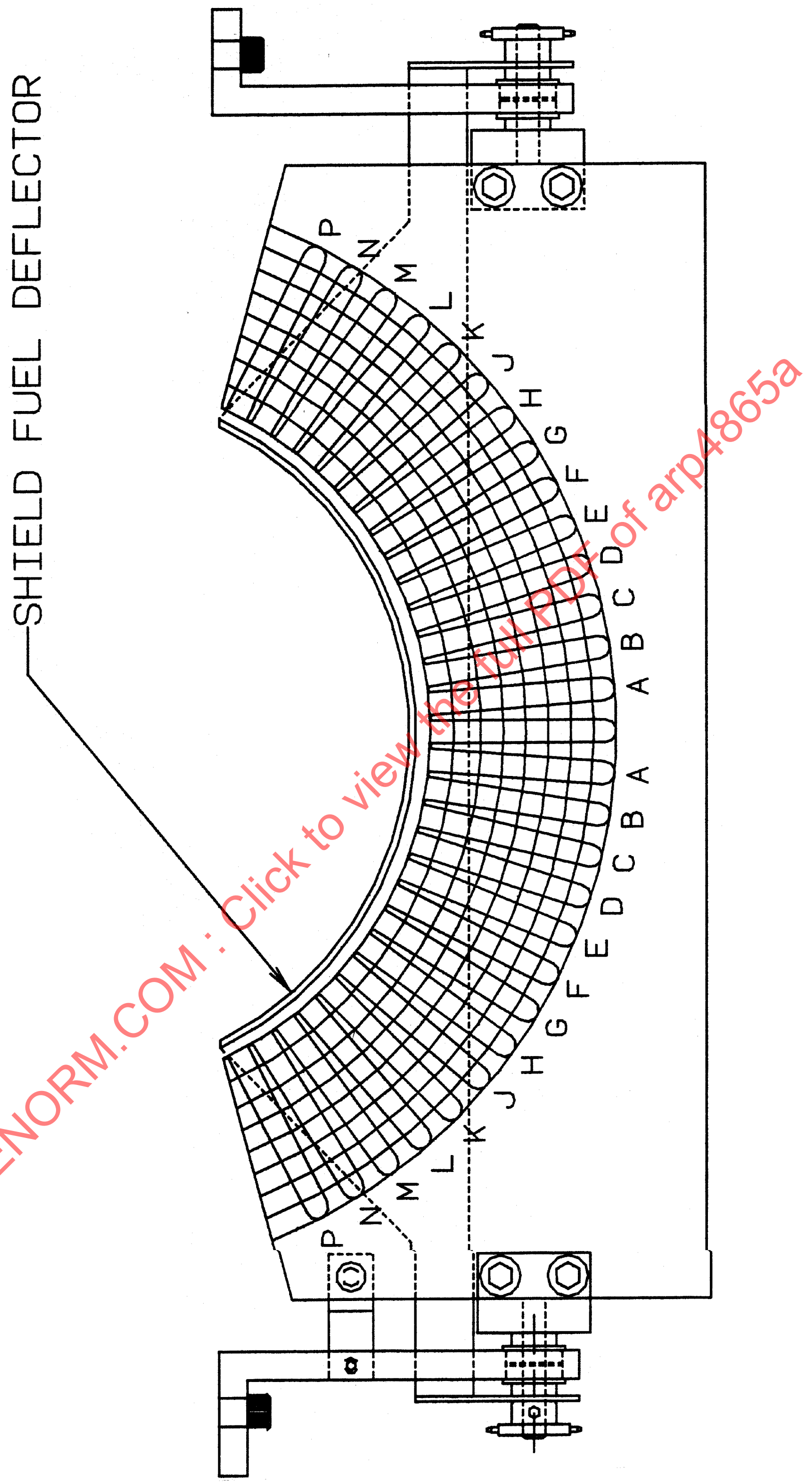


FIGURE 10 - Typical Radial Patternator

4.9 Spray Chamber:

The test chamber lighting and venting must be adequate to allow a clear view of the spray by the operator. There shall be no obstructions that would distort the UUT spray within the measurement plane.

4.9.1 Venting: The test chamber must provide for the safe venting of the UUT spray. The venting flow rate must be adequate to keep the test chamber free from vapor that obscures the operator's view of the UUT spray cone. The chamber pressure shall be within ±0.1 in of water column when referenced to atmosphere. Location of the venting system shall not skew the UUT spray which would cause inaccurate readings.

4.9.2 Lighting: A minimum of a 75 W collimated under-lighting and/or 300 W external indirect lighting source should be used. Fiber-optic transmission of the light can be used to meet most safety considerations. The under lighting apparatus shall not cause distortions to the spray.

4.9.3 Heat Transfer: Adequate safety precautions should be used to minimize the heat transfer from the lighting source to the test fluid. A maximum surface temperature of 95 °F (35 °C) is recommended for all surfaces that contact the test fluid.

4.9.4 Size: A minimum dimension of 9 in (228.6 mm) from the UUT centerline to the containment wall is recommended. The format can be cylindrical or cubical. A minimum depth of 15 in (381 mm) downstream from the UUT is recommended. Chamber sizing smaller than this can cause distortions even at lower UUT flow conditions because of venting problems. Contact the OEM to define what is allowable.

4.9.5 Spray Dissipation: One typical method for dissipating the spray is using fuel-cell foam (SCOTFOAM-Orange) utilized in aircraft wings to prevent sloshing. Place a thickness of about 3 in (76 mm) at the bottom of the spray chamber. It can eliminate the splash back of the test fluid and provide better visibility. Some systems provide an exhaust or evacuation system below this fuel-cell foam layer. This will provide a laminar of air in a constant downward direction and a stable system for reading spray angles. Another method for high velocity drops is using lock-wire bent in a random pattern.

5. NOZZLE TESTING:

The testing of UUTs must be consistent with the same methods employed in a field service facility as are performed at the OEM facility. The most important function of testing is performing tasks in a consistent, repeatable manner. There may always be some amount of variance related to the use of different testing systems, however, the differences between facilities can be more readily evaluated and corrected with consistent test procedures.

5.1 Operator Checklist:

The operator should have a checklist to run through before starting the test stand, allowing for safety considerations and proper functioning. The test equipment shall state these requirements in the operator's manual. The most important elements of operation can be outlined and available near the operator's station. Also included in the checklist shall be a verification of the calibration to the required standards.

5.2 Installing the UUT:

When installing the UUT into a fixture, ensure that the UUT is located correctly, particularly for spray angle and patternation measurements. The fixturing should be adequately designed such that it does not rely solely on the operator's expertise to correctly align the UUT. Most UUT test systems use inlet adapters to protect the UUT fitting from damage. The inlet adapters are typically designed to allow for a quick exchange of UUTs.

5.3 Setting the Pressure:

The pressure gauge is normally the most accurate measurement instrument, therefore, the testing should be performed by setting a specific pressure whenever possible. The test operator must increase the pressure to the test point without overshooting the test point. If a manually operated test stand is used, the test operator must carefully increase or decrease pressure over the last 10% of the test point to avoid the overshoot. Test articles with integral valves have test points for Hysteresis values. The overshoot must be minimized such that valid Hysteresis values can be obtained. Automated test equipment must provide accurate and repeatable control of the pressure setting functions to limit overshoot to the required pressure setting tolerance.

5.4 Flow Reading:

The test operator or automated test procedure must allow a settling time for the flow instrumentation. Most flow transducers require substantial settling time before accurate and repeatable readings can be obtained. Not all test systems are the same and repeatability studies should be performed to determine the correct settling time.

5.5 Data Record:

The data record must minimally include the following:

a. Test equipment used
b. Date
c. Test fluid
d. Pressure
e. Fluid flow
f. UUT part number
g. UUT serial number
h. Test operator identification

5.6 Testing Procedure:

The testing procedure shall be documented and shall follow the original equipment manufacturers test or overhaul procedures.

See Appendix D for an example of a general UUT test procedure.

5.7 Test Stand Noise:

The influences of the test stand noise to valve flow hysteresis must be considered. Some studies indicate that excessive mechanical vibration near the nozzle will reduce hysteresis. It is imperative that the amount of vibration be kept at a minimum repeatable hysteresis value. Integral spray chambers attached directly to the test stand can receive this mechanical vibration from the test stand and transmit it to the test fixture that holds the UUT. Engine companies may require a specified amount of vibration to simulate the engine vibration. Suppliers must establish what level of mechanical vibration is acceptable to the engine company.

APPENDIX A
FILTRATION

The filtration process itself is poorly understood. This causes terminology, concepts, and test methods to improperly define or evaluate filters, filtration requirements, and filter performance. Filtration is the separation of particles from a carrier fluid. This can be a mechanical separation at the surface or depth filtration. Mechanical separation of particles occurs when a barrier, with openings smaller than the particles being filtered, prevent the passage of such particles while allowing the passage of the carrier fluid through the openings. Coarse strainers, fine wire mesh and membranes use this type of separation which can be called "sifting" or "straining". Depth filtration, usually with lower micron ratings, require separation throughout the depth of a filter by capturing the particles in a convoluted pathway.

A.1 RATING SYSTEMS:

The filter system shall perform as follows:

a. β_6 = 2 (50.0% efficient @ 6 µm)
b. β_{11} = 20 (95.0% efficient @ 11 µm)
c. β_{15} = 75 (98.66% efficient @ 15 µm)

There are three rating systems in common use in the aerospace industry.

a. ABSOLUTE RATING: Defined as the size of the largest spherical glass particle which will pass under laboratory conditions, this rating is often misunderstood and misused in the filter industry and its customers. This rating means this is the largest size glass bead particle that will be downstream of the element under very low pressure differentials and non-pulsating flow conditions. This term should not be used in any test specification.

b. NOMINAL RATING: This value has no pertinent meaning. It does not signify any characteristic of the filter which can be determined or measured against an accepted standard. Nominal filter ratings have many limitations. First, they do not present a clear indication of the largest size particle that can pass through a filter. Second, it is a nonstandard system that lacks consistency; effectively an arbitrary value assigned to the filter by the manufacturer. This term should be discouraged for use in any liquid test specification. Due to these factors, nominal ratings have lost favor to the more sophisticated Beta filtration rating systems.

c. DYNAMIC EFFICIENCY: Filter performance determined on the basis of simultaneously counting particles in a number of preselected size ranges upstream and downstream of the test filter.

A.1 (Continued):

The preferred system for rating filters is dynamic efficiency. The ratio is determined by dividing the number of particles entering by the number of particles leaving the test filter. This is usually done by using an electronic automatic particle counting technique. The actual operating conditions of the filters are used for this rating. The term for the resulting values is the Beta ratio as defined in Equation A1:

$$\beta_x = Nu_x / Nd_x \quad \text{(Eq.A1)}$$

where:

x = the preselected particle size
Nu = number of particles of size x and greater upstream
Nd = number of particles of size x and greater downstream

The relationship between the Beta ratio and filter efficiency is shown in Equation A2:

$$\%\ \text{efficiency} = 100 - 100/\beta \quad \text{(Eq.A2)}$$

Example:

Beta ratio: β_{10} = 50
Expressed as efficiency: 100 - 100/50 = 98
Therefore: 98% of all particles greater than 10 μm are removed.

It would be impractical to compare beta rating's above 75, because you would be dealing with the last 1% of efficiencies. We have adopted the 2/20/75 method which presents data as shown in Equation A3:

$$\beta_{6/11/15} = 2/20/75 \quad \text{(Eq.A3)}$$

The filter element performs as follows:

a. β_6 = 2 (50.0% efficient @ 6 μm)
b. β_{11} = 20 (95.0% efficient @ 11 μm)
c. β_{15} = 75 (98.66% efficient @ 15 μm)

NOTE: The filter industry is generally defining the particle size (x) at which β_x = 2 as the nominal rating and the particle size (x) where β_x = 75 as the absolute rating of an element.

APPENDIX B
FUEL CONTAMINATION TESTING

Contamination level measurement has historically used two basic methods. The first method (ARP598) manually counts the particles in a given sample of fluid and classifies them as to the number of counts in a given micron size range. The fluid sample size is 100 mL. The second method (ARP785) weighs the particles collected in a given sample of fluid. This method (Gravimetric) is used by the producer of the MIL-C-7024 Type II calibrating fluid. The acceptance level conforms to the requirement of MIL-C-7024 Type II fluid.

A more recent testing method is the International Standards Organization Solid Contaminant Code (ISOSCC) which is assigned on the basis of the number of particles per unit volume. This rating system uses two numbers separated by a solidus. All particles greater than 5 µm are identified with the first number and all particles greater than 15 µm are identified with the second number.

APPENDIX C
CALIBRATION

There are two methods of determining accuracy of equipment. The first is full scale accuracy (%FS) and the second is percent of reading (%R). The two methods can be defined as follows:

a. %FS: Full scale of the device used. The upper limit of the device is multiplied by the percentage given (±) to specify the amount of uncertainty at any point on the scale.

b. %R: Percentage of reading. The nominal number value is multiplied by the percentage given (±). This value is added and subtracted to the nominal value to determine the accuracy.

For a measurement device that is defined in %FS accuracy, the crossover point, where the %FS and %R intersect, provides the lower limit for use of the device. This crossover point is the method for determining the point to overlap %FS devices to comply with %R requirements. It is recommended that pressure gauges have a minimum %FS of 0.11 and a %R of 0.5%. An easy method for finding the crossover point is dividing the %FS by the %R to find the ratio, then times the upper limit to find the intersect.

Example:

A pressure gauge with a 1000 psig range and %FS of 0.11% will divide the %FS (0.11) by the recommended %R (0.5) to obtain a ratio of 0.22.

0.11 %FS / 0.50 %R = 0.22 ratio

Multiply the resultant ratio times the Full Scale range to find the crossover and the recommended lower limit of the gauge.

0.22 ratio * 1000 psig = 220 psig

The next overlapping gauge with a range of 250 psig and %FS of 0.11% will extend %R to 55 psig to maintain a recommended %R of 0.5.

0.22 ratio * 250 psig = 55 psig

This gauge would be usable down to 55 psig while maintaining %R.

C.1 CALIBRATION PROCEDURES:

All instrumentation will have calibration traceable to National Institute of Standards and Technology (NIST) or appropriate national standard. The methods used for calibration of specific instruments must be developed internally. Most government authorities (Military, FAA) and engine companies require established written detailed procedures.