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DETAIL SPECIFICATION

PROPELLANT, HIGH DENSITY SYNTHETIC HYDROCARBON TYPE, GRADE JP-10

Comments, suggestions, or questions on this document should be addressed to AFPA/PTPT, 2430 C Street, Bldg 70, Area B, Wright-Patterson AFB OH 45433-7632 or e-mailed to AFPET.AFTT@wpafb.af.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.daps.dla.mil.

AMSC N/A FSC 9135

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers one grade of high density synthetic hydrocarbon type propellant.

1.2 Classification.

Grade	Description
JP-10	High density hydrocarbon fuel, composed solely of exo-tetrahydrodicyclopentadiene

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

FEDERAL STANDARDS

FED-STD-313	Material Safety Data, Transportation Data and Disposal Data for Hazardous Materials Furnished to Government Activities

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-DTL-85470	Inhibitor, Icing, Fuel System, High Flash NATO Code Number S-1745

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-290	Packing of Petroleum and Related Products

(Copies of these documents are available online at https://assist.daps.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Bldg 4D, Philadelphia PA 19111-5094.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASTM International

ASTM D56	Standard Test Method for Flash Point by Tag Closed Cup Tester (DoD Adopted)
ASTM D93	Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester (DoD Adopted)
ASTM D156	Standard Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method) (DoD Adopted)

ASTM D240	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (DoD Adopted)
ASTM D381	Standard Test Method for Gum Content in Fuels by Jet Evaporation (DoD Adopted)
ASTM D445	Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity) (DoD Adopted)
ASTM D976	Standard Test Method for Calculated Cetane Index of Distillate Fuels (DoD Adopted)
ASTM D1298	Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method (DoD Adopted)
ASTM D2276	Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling (DoD Adopted)
ASTM D3241	Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels (DoD Adopted)
ASTM D3828	Standard Test Methods for Flash Point by Small Scale Closed Cup Tester (DoD Adopted)
ASTM D4052	Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter (DoD Adopted)
ASTM D4057	Standard Practice for Manual Sampling of Petroleum and Petroleum Products (DoD Adopted)
ASTM D4176	Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures) (DoD Adopted)
ASTM D4809	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method) (DoD Adopted)
ASTM D5006	Standard Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels (DoD Adopted)
ASTM D5452	Standard Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration (DoD Adopted)
ASTM D6045	Standard Test Method for Color of Petroleum Products by the Automatic Tristimulus Method
ASTM E29	Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications (DoD Adopted)

(Copies of these documents are available online at http://www.astm.org or from ASTM International, 100 Barr Harbor Drive, West Conshohocken PA 19428-2959)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the 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.

3. REQUIREMENTS

3.1 Materials. Except as otherwise specified herein, Grade JP-10 shall consist solely of exo-tetrahydrodicyclopentadiene.

3.1.1 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible, provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

3.2 Chemical and physical requirements. The chemical and physical requirements of the finished fuel shall conform to those listed in Table I. Requirements contained herein are not subject to correction for test tolerances. If multiple determinations are made, results falling within any specified repeatability and reproducibility tolerances may be averaged. For rounding off of significant figures, ASTM E29 shall apply to all tests required by this specification.

3.3 Additives. The additives listed shall be used in combination in amounts not to exceed those specified. The type and amount of each additive used shall be reported.

3.3.1 Antioxidants. The following active inhibitors shall be blended separately or in combination into the fuel in total concentration of 90 parts per million (minimum) to 110 parts per million (maximum), by weight, not including weight of solvent, in order to prevent the formation of polymeric oxidation products:

a. 2,6-di-tert-butyl-4-methylphenol

b. 6-tert-butyl-2,4-dimethylphenol

c. 2,6-di-tert-butylphenol

3.3.2 Fuel system icing inhibitor. Fuel system icing inhibitor (FSII) shall only be used at the request of the user. When requested by the user, the FSII shall conform to MIL-DTL-85470.

3.4 Workmanship. The finished fuel blend shall be visually free from undissolved water, sediment or suspended matter and shall be clear and bright at the ambient temperature or at 21°C (70°F), whichever is higher. ASTM D4176 describes a suitable test method for determining if the fuel is clear and bright.

4. VERIFICATION

4.1 Classification of inspection. The inspection requirements specified herein are classified as quality conformance inspection (4.2).

4.2 Conformance inspections. For acceptance purposes, individual lots shall be examined as specified herein and subject to tests for all requirements cited in section 3.

4.2.1 Inspection lot.

4.2.1.1 Bulk lot. A bulk lot shall consist of an indefinite quantity of a homogenous mixture of material offered for acceptance in a single isolated container.

4.2.1.2 Packaged lot. A packaged lot shall consist of an indefinite number of 55-gallon drums or smaller unit packages of identical size and shape offered for acceptance and filled from the isolated tank containing a homogenous mixture of material.

4.2.2.1 Sampling for verification of product quality. Each bulk or packaged lot of material shall be sampled for verification of product quality in accordance with ASTM D4057 except where individual test procedures contain specific sampling instructions.

4.2.2.2 Sampling for examination of filled containers for delivery. A random sample of filled containers shall be selected from each lot. The samples shall be examined in accordance with 4.4.3.

4.3 Inspection. Inspection shall be in accordance with 4.4.3 of this specification.

4.4 Examinations.

4.4.1 Examination of products. Samples selected in accordance with 4.2.2.1 shall be visually examined for compliance with 3.4.

4.4.2 Examination of empty containers. Prior to filling, each empty unit container shall be visually inspected for cleanliness and suitability.

TABLE I. Chemical and physical requirements and test methods.

Property	Min	Max	ASTM Standards
Color, Saybolt	+25		D156 [1] or D6045
Chemical Analysis, wt percent exo-tetrahydrodicyclopentadiene other hydrocarbons [2]	98.5	100.0 1.5	
Flash point, °C (°F)	54.4 (130)		D56, D93 [1], or D3828
Density, 15 °C, kg/L (API Gravity)	0.934 (20.0)	0.943 (18.5)	D1298 or D4052 [1]
Viscosity, mm^2/s at °C (°F) -54 (-65) -18 (0)		 40 10	D445
Net heat of combustion MJ/kg (Btu/lb) MJ/m (Btu/gal)	 42.1 (18,100) 39,400 (141,500)		D240 or D4809
Thermal stability change in pressure drop, mm Hg heater tube deposit visual rating		 10 less than code 3	D3241 [4]
Existent gum, mg/100 mL		5.0	D381 [5]
Particulate matter, mg/L		1.0	D2276 or D5452
FSII, vol. percent [6]	0.10	0.15	D5006

Notes
1. Referee test method.
2. Test procedure and required equipment outlined in Appendix A.
3. This is for reference only, not a requirement.
4. See 4.5.1.1 for ASTM D3241 test conditions and test limits.
5. If air is used instead of steam while performing ASTM D381, it must be reported. In the case of a failure with air, the sample must be retested using steam.
6. As required by user, see 3.3.2.

4.4.3 Examination of filled containers. Samples taken as specified in 4.2.2.2 shall be examined for conformance to MIL-STD-290 with regard to fill, closure, sealing, leakage, packaging, packing, and markings. Any container having one or more defects under the required fill shall be rejected.

4.5 Test methods. Tests to determine conformance to chemical and physical requirements shall be conducted in accordance with the applicable ASTM standards, or in the case of unique requirements, the test procedures as outlined in Table I and described in the attached Appendix.

4.5.1 Thermal stability.

4.5.1.1 ASTM D3241. The thermal stability test shall be conducted and the tube shall be rated using ASTM D 3241 (JFTOT).

4.5.1.1.1 ASTM D3241 test conditions.

a. Heater tube temperature at maximum point: 300°C (572°F).
b. Fuel system pressure: 3.43 MPa (500 psig).
c. Fuel flow rate: 3.0 ml/minute.
d. Test duration: 150 minutes.

4.5.1.1.2 Results. The fuel sample is acceptable if all the following criteria are met:

a. The maximum visual rating of the heated tube deposits is less than a code 3.
b. The visual rating of the heater tube show neither peacock type deposit (code P) nor abnormal type deposits (code A).
c. The maximum differential pressure across the test filter does not exceed 10 millimeters of mercury (mm Hg).

4.5.1.1.3 ASTM D3241 reported data. The following data shall be reported:

a. Differential pressure in mm Hg at 150 minutes, or time to differential pressure of 10 mm Hg, whichever occurs first.
b. Heater tube deposit visual rating code at the end of the test.

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The fuel covered by this specification is intended for use in military gas turbine engines or military ramjet engines for missile application.

6.2 Acquisition requirements. Acquisition documents must specify the following:

a. Title, number, and date of the specification.

b. Quantity required and size containers required.

c. Level of packaging and packing required.

d. When blocking and bracing is specified.

6.2.1 Additive. Type and amount of additive (3.3).

6.3 Precaution of mixing additives. To prevent any possible reaction between the concentrated forms of the different additives (3.3) the fuel contractor is cautioned not to commingle additives prior to their addition to the fuels.

6.4 Subject term (key word) listing.

exo-Tetrahydrodicyclopentadiene
Missile Fuel
Ramjet

6.5 Material Safety Data Sheets. Contracting officers will identify those activities that require copies of completed Material Safety Data Sheets (MSDS) prepared in accordance with FED-STD-313. The pertinent Government mailing addresses for submission of data are listed in FED-STD-313.

6.6 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

APPENDIX A

METHOD OF TEST FOR ANALYSIS OF GRADE JP-10 FUEL BY GAS CHROMATOGRAPHY

A.1 SCOPE

A.1.1 Scope. This method provides for the quantitative determination of the purity of exo-tetrahydrodicyclopentadiene, the single chemical structure of JP-10. This Appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

A.2 SUMMARY

A.2.1 Summary of methods. The sample is introduced into a gas chromatograph column, which has been calibrated with a pure sample of exo- tetrahydrodicyclopentadiene, (4.5). The detector signal is monitored continuously and the areas of individual peaks are used for computing the quantities of the JP-10 and other hydrocarbon impurities. The detailed composition of the JP-10 component is computed from the individual peak areas in the subgroup.

A.3 APPARATUS

A.3.1 Chromatograph. Any conventional gas chromatograph, having at least the following features, is acceptable.

A.3.1.1 Detector. A thermal conductivity (TCD), flame ionization (FID), or mass spectrometer (MS) detector may be used. The detector shall be operated in such a manner that its linear dynamic range is not exceeded, and its linearity should be checked periodically. The detector shall be capable of continuous operation, and must be connected to the column in a manner that eliminates cold spots.

A.3.1.2 Temperature Programmer. The instrument must be capable of reproducible temperature programming over the range of 50ºC to 300°C. The programming rate must be sufficiently reproducible so that individual retention times do not vary by more than 2 percent. Any temperature program, including multilinear modes and intermediate periods of isothermal operation, is acceptable, provided that the column resolution, as defined in section A.5.2, is not compromised. If capillary-type columns are used for the analysis, it may not be necessary to program the oven above 200°C.

A.3.1.3 Sample inlet system. Either flash vaporization or on-column injection may be used. For flash vaporization, the sample inlet port must be maintained between 250° and 300°C, and well-conditioned septa must be used. If on-column injection is employed, provision must be made for programming the temperature of the full length of the column. A sample inlet splitter may be used in conjunction with capillary columns, if care is taken to ensure that a representative sample is delivered to the column. New septa should be allowed to condition overnight after being installed in order to minimize spurious peaks, and several blank runs should be made to purge the column of materials bleeding from the septum. Overnight conditioning can be eliminated by the practice of storing a supply of septa in the column oven. However, at least one blank run should still be made following each septum change.

A.3.1.4 Column. Either packed or open-tubular (capillary-type) columns may be used, provided the minimum resolution, specified in A.5.2, is maintained. The column should be designed for maximum thermal stability and minimum bleed, since the temperature program is likely to run as high as 275°C for packed columns and 200°C for capillary columns. Dual-column compensation is required if column bleed results in excessive baseline drift at high temperature.

A.3.1.5 Data Acquisition. Computer controlled data acquisition and integration is the preferred method of data collection and analysis. The computer system must be designed and calibrated for gas chromatograph operation. An electric data recorder / integrator may be used if necessary.

A.3.1.6 Microsyringe. A microsyringe, capable of delivering sample volumes from 0.5 to 5.0 microliters, is required for FID and TCD detectors. The widely used 0 – 10 microliter syringe, Hamilton Model 701N or its equivalent, is recommended. A microsyringe, capable of delivering sample volumes

from 0.1 to 0.5 microliters, is required for MS detectors. These syringes are routinely available from most instrument manufacturers and chromatography supply houses.

A.4 REAGENTS AND MATERIALS

A.4.1 Stationary phase. The stationary phase should be one of the familiar non-polar polysiloxanes, or equivalent. The following columns have been used successfully:

100% Dimethylpolysiloxane

(5%-Phenyl)-methylpolysiloxane

Either of the listed phases is satisfactory, provided baseline drift at high temperatures is maintained by conditioning or by dual-column compensation.

A.4.2 Carrier gas. Either helium or nitrogen is suitable for FID detectors, although nitrogen is known to give somewhat higher column efficiencies at lower flow rates, and is more economical. Helium must be used with thermal conductivity detectors. Either helium or hydrogen may be used with a mass spectrometer detector. The flow must be maintained constant to within one percent throughout the entire range of operating temperatures by means of constant flow controllers.

A.4.3 Hydrogen. High purity, for flame ionization detectors.

A.4.4 Air. Dry, filtered, and oil-free, for flame ionization detectors.

A.4.5 Exo-tetrahydrodicyclopentadiene. Minimum ninety-nine weight percent purity, hereafter referred to as C-10.

A.4.6 N-pentane, n-hexane, or petroleum ether. Chromatographic purity.

A.4.7 Qualitative calibration mixtures. A series of known hydrocarbons is used for calculating column resolution. Prepare a mixture containing about one percent (by volume) each, in pentane or hexane, of at least eight normal alkanes from highly pure (minimum 99 percent) samples which have boiling points in the 70°C to 250°C range. The mixture must contain n-dodecane and n-tetradecane.

A.5 PREPARATION OF APPARATUS

A.5.1 Column. Any conventional method of conditioning and installing the column is satisfactory, provided the system is free of gas leaks and the column resolution meets the minimum requirement specified in A.5.2.

A.5.2 Column resolution. Run a sample of the qualitative calibration mixture and measure the retention times and widths of the n-dodecane and n-tetradecane peaks as shown on Figure A1. Resolution is defined as the difference in retention times for n-C_{12} and n-C_{14} divided by their average width:

$$R = \frac{2\left(RT_{14} - RT_{12}\right)}{W_{14} + W_{12}}$$

Resolution determined in this way must be at least 5.0 and can be optimized by varying the temperature program and the carrier flow rate. If resolution cannot be increased to at least 5.0 by optimizing these parameters, it is necessary to use a difference column.

A.5.3 Chromatograph. Place in service according to the manufacturer's specifications paying particular attention to flow rates through the detector.

A.6 PROCEDURE

A.6.1 Suitable sample. Establish a suitable sample volume by making several trial runs with the qualitative calibration mixture. For FID instruments, the volume may be between 0.5 and 1.0 µL. For TCD instruments, volumes from 1.0 to 5.0 µL have been found satisfactory. For MS instruments, volumes from 0.1 to 0.25 µL have been found satisfactory.

A.6.2 Acceptance sample. Dilute an aliquot of the JP-10 acceptance sample at least 1:10 (preferably 1:20) with pentane, hexane, or petroleum ether. Mix thoroughly and inject a measured volume into the chromatograph, simultaneously activating the temperature program, the integrator, and the recorder.

A.6.3 Integration. Integrate the area under the chromatogram continuously until the final peak has been eluted. C-10 extra peaks which are within plus or minus ten percent of the retention time for C-10 shall be considered part of the C-10 peak if they do not contribute more than 20 percent to the total C-10 peak areas. A typical GC/MS chromatogram is included as Figure A2.

A.7 CALCULATIONS

A.7.1 Weight percent. For each JP-10 acceptance sample, calculate the weight percent of C-10 as follows:

$$\%\ \mathrm{C\text{-}10} = \frac{A_{\mathrm{C\text{-}10}}}{A_{\mathrm{C\text{-}10}} + A_{\mathrm{impurties}}} \times 100$$

In the above equation, all hydrocarbons other than those contained in the C-10 subgroup are considered impurities. A response factor of 1.000 is used for the impurities.

A.8 PRECISION

A.8.1 Studies. Detailed precision studies have not been performed for this method. However, limited results indicate that the method is capable of the following precision.

A.8.1.1 Repeatability. Replicate analyses, performed under identical conditions in the same laboratory, should yield results that do not vary more than 1 percent (absolute) from the mean value for each component.

A.8.1.2 Reproducibility. When the same sample is analyzed in different laboratories according to this method, the results for any component should not differ by more than 1.5 percent (absolute).

A.8.1.3 Accuracy. Back-analysis of a calibration standard should give results that agree with the known values to within 0.5 percent (absolute).

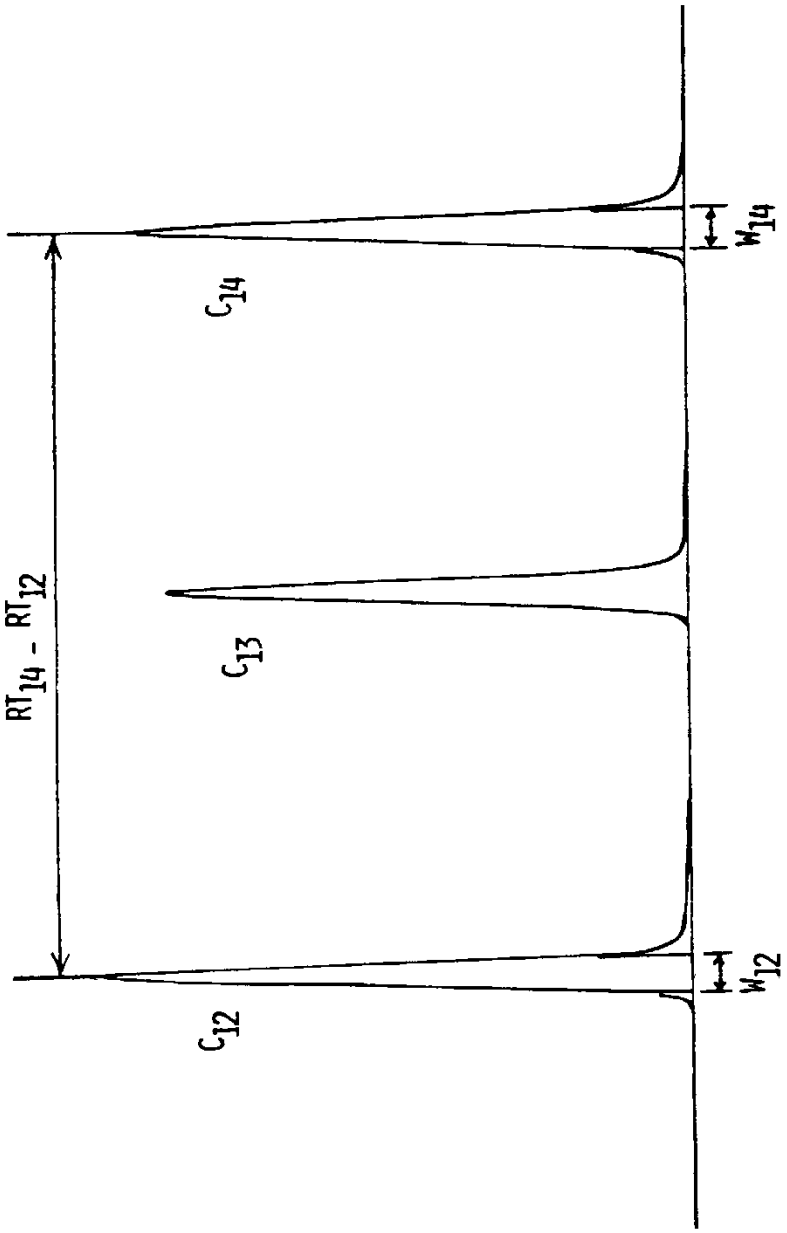
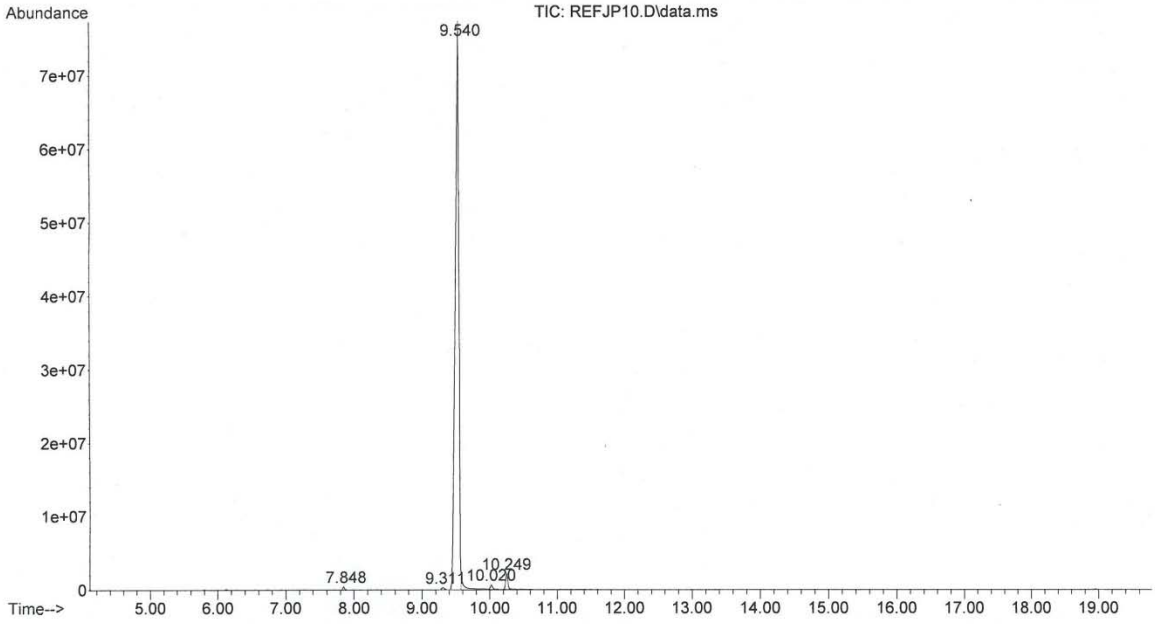


FIGURE A1. Calculation of column resolution.

Area Percent Report

```
Data Path : D:\MSdata\afpet\
Data File : REFJP10.D
Acq On    : 17 Nov 2011  11:51
Operator  : ASV
Sample    : 1:10   JP10:Petroleum Ether
Misc      : 0.2 uL, 100:1 Split, JP10nv Program
ALS Vial  : 1   Sample Multiplier: 1

Integration Parameters: rteint.p
Integrator: RTE
Smoothing : OFF                          Filtering: 5
Sampling  : 1                             Min Area: 0.1 % of largest Peak
Start Thrs: 0.2                          Max Peaks: 100
Stop Thrs : 0                          Peak Location: TOP

If leading or trailing edge < 100 prefer < Baseline drop else tangent >
Peak separation: 5

Method    : C:\MSDCHEM\1\METHODS\JP10nv.M
Title     :

Signal     : TIC: REFJP10.D\data.ms

                    Sum of corrected areas:   292178338

JP10nv.M Thu Nov 17 13:52:13 2011
```



Peak #	R.T. min	First scan	Max scan	Last scan	PK TY	Peak height	Corr. area	Corr. % max	% of total	ID
1	7.848	325	329	336	rVB	453320	835514	0.29%	0.286%	Decane
2	9.311	450	457	465	rBV	322544	898907	0.32%	0.308%	Decalin
3	9.540	465	477	480	rBV2	77337584	284484692	100.00%	97.367%	exo-tetrahydrodicyclopentadiene
4	10.020	515	519	534	rVB	628174	1446234	0.51%	0.495%	Adamantane
5	10.249	535	539	547	rBV	2133160	4512991	1.59%	1.545%	endo-tetrahydrodicyclopentadiene

Figure A2 - Typical GC/MS Chromatogram of JP-10.

CONCLUDING MATERIAL

Custodians:
Navy – AS
Air Force – 68
DLA - PS

Preparing activity:
Air Force – 68
(Project 9135-2012-001)

Review activity:
Air Force – 11

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