CRC Report No. AV-32-22

Investigate JP-5 Vapor Pressure values in Figure 2-12 of CRC Fuel Handbook

Final Report

April 2025

COORDINATING RESEARCH COUNCIL, INC.
1 CONCOURSE PARKWAY • SUITE 800 • ATLANTA, GA 30328

The Coordinating Research Council, Inc. (CRC) is a non-profit corporation supported by the petroleum and automotive equipment industries with participation from other industries, companies, and governmental bodies on research programs of mutual interest. CRC operates through the committees made up of technical experts from industry and government who voluntarily participate. The five main areas of research within CRC are: air pollution (atmospheric and engineering studies); aviation fuels, lubricants, and equipment performance; heavy-duty vehicle fuels, lubricants, and equipment performance (e.g., diesel trucks); light-duty vehicle fuels, lubricants, and equipment performance (e.g., passenger cars); and sustainable mobility (e.g., decarbonization). CRC's function is to provide the mechanism for joint research conducted by industries that will help in determining the optimum combination of products. CRC's work is limited to research that is mutually beneficial to the industries involved. The final results of the research conducted by, or under the auspices of, CRC are available to the public.

LEGAL NOTICE

This report was prepared by the University of Dayton Research Institute (UDRI) as an account of work sponsored by the Coordinating Research Council (CRC). Neither the CRC, members of the CRC, University of Dayton Research Institute (UDRI), nor any person acting on their behalf: (1) makes any warranty, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this report, or (2) assumes any liabilities with respect to use of, inability to use, or damages resulting from the use or inability to use, any information, apparatus, method, or process disclosed in this report. In formulating and approving reports, the appropriate committee of the Coordinating Research Council, Inc. has not investigated or considered patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against liability for infringement of patents.

CRC Project AV-32-22: Investigate JP-5 Vapor Pressure values in Figure 2-12 of CRC Fuel Handbook

Final Technical Report

Submitted To:
CRC Aviation Committee

Submitted By:
Zachary West & Willie Steinecker
University of Dayton Research Institute

4-April-2025

Fuels & Combustion Division

300 College Park, Dayton OH 45469-8211 | udri.udayton.edu

Background

Starting with the 2nd edition (1983) and continuing through the current 4th edition (2014) the CRC *Handbook of Aviation Fuel Properties* reports vapor pressure data for JP-5 and JP-7 as coincident, i.e., the same curve of vapor pressure with respect to temperature. The likelihood of this overlap is being questioned by CRC technical committee members due to known chemical differences between these two grades of fuel. Therefore, the CRC is requesting an investigation into both the source of the originally published JP-5 and JP-7 vapor pressure data along with a review of current/contemporary vapor pressure data for JP-5 fuels. Findings that result from this review may initiate corrections/modifications to future versions of the CRC Handbook.

Results and Discussion

Source Data

A literature review was conducted to identify potential original source(s) of CRC Handbook (4th edition) vapor pressure data, specifically for grade JP-5 jet fuel. Several reports were examined from a variety of US government agencies, e.g., US Navy, US Air Force, and US Bureau of Mines. Many of the reports were dated between the 1950's through to the 1970's. Much of the information this reviewer found regarding vapor pressure seemed to be repeated, in some form, amongst the many references, i.e., true vapor pressure was often derived from Reid vapor pressure and distillation information (especially for more volatile fuels such as AVGAS and JP-4). Since vapor pressure is not a specification property for JP-5 grade fuel, there is a notable absence of measured vapor pressures reported in the historical record. There is less information is available for JP-7 grade fuel in the open literature, which this reviewer speculates is due to the military development and use of this fuel.

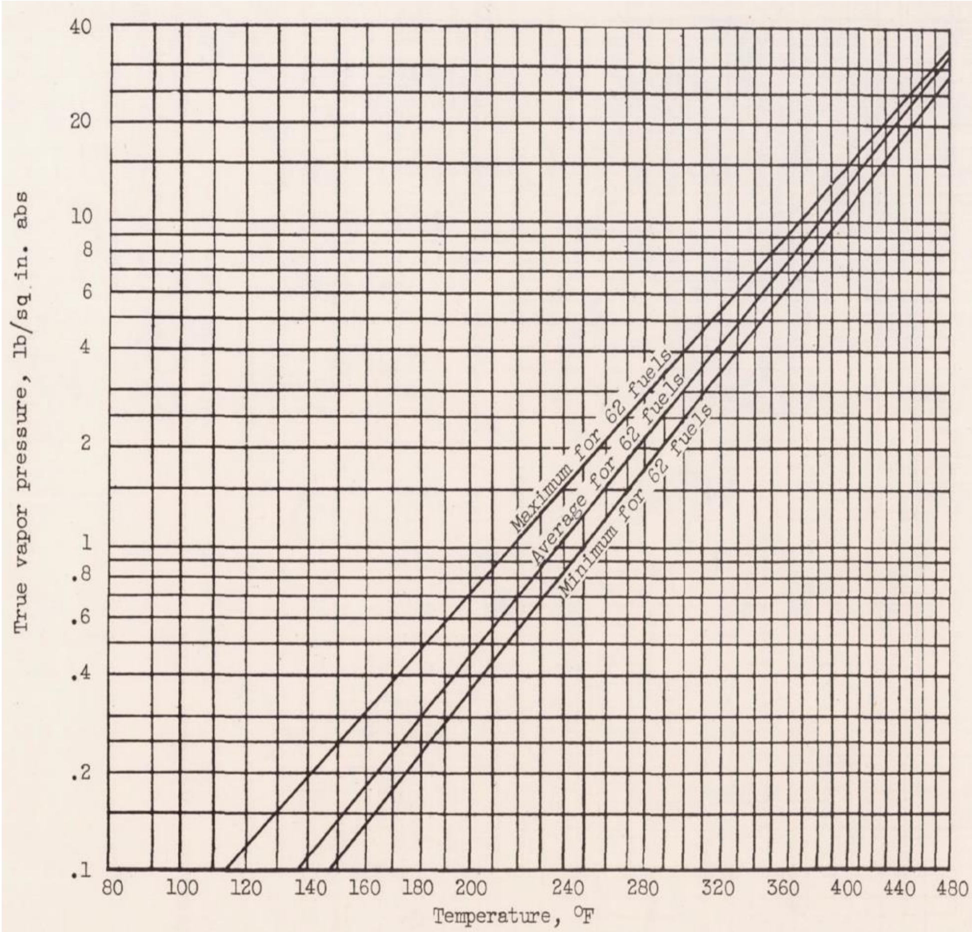
The most promising original work found for JP-5 vapor pressure correlation to temperature is[1]:

Barnett, H.C., Hibbard, R.R. "Properties of Aircraft Fuels," Technical Note 3276, National Advisory Committee for Aeronautics (NACA), August 1956.

Figure 1 shows true vapor pressure (TVP) versus temperature for JP-5 fuels from Barnett & Hibbard, 1956. The average, maximum, and minimum TVP are reported for a data set of 62 fuel samples, however, it appears that TVP was calculated from other measured quantities, i.e., flash point and 10% distillation slope. We were unable to obtain the original source data used to build Figure 1; however, it is possible that the following reference may contain additional relevant data and/or information: Bridgeman, Oscar C.; Aldrich, Elizabeth W.

[1] The original CRC Aviation Handbook (NAVAIR Report 06-5-504, p 45-117, 1967) has an extensive discussion on fuel volatility with an additional 27 references. The discussion includes numerous correlation methods and applications of volatility data.

"Vapor Pressure Data on Distillate Fuel Oils." Report 879-52R, Res. Div., Phillips Petroleum Co. (ASTIA No. 89943)



(b) MIL-F-5624C (JP-5) fuel.

Figure 7. - Continued. Variation of vapor pressure with temperature for different fuels.

Figure 1. True vapor pressure chart from Barnett & Hibbard, 1956.

It appears that both flash point and 10% distillation slope were the likely measured quantities used to estimate TVP for low volatility fuels such as JP-5. Barnett & Hibbard (1956, pages 16–19) outline three methods for calculating TVP as a function of temperature depending on the fuel test data available: 1) using normal boiling point (or estimated normal boiling point) and 10% distillation slope, 2) using normal boiling point (or estimated) and flash point, or 3) using 10% distillation slope and flash point.

Regardless, data were manually read from Figure 1 (Barnett & Hibbard, 1956 also referred to as NACA TN 3276) and compared to data taken from the 4th edition of the CRC Handbook of

Aviation Fuel Properties (CRC Report 663, 2014). Pressures and temperatures were converted to kPa and degrees Celsius, respectively, for uniform comparison of values. The comparison of JP-5 vapor pressure data is shown in Figure 2 as a parity plot. It can be seen in this figure that the CRC Report 663 values fall in between the average and minimum vapor pressure values reported by Barnett & Hibbard (1956). Figure 3 shows the calculated percent differences between vapor pressure values as a function of temperature; percent difference was calculated by the following: %Diff = $(TVP_{CRC} – TVP_{NACA}) / TVP_{CRC} \times 100\%$. It can be seen in Figure 3 that the percent difference range for the MIN TVP data is about 2 to -10% over the full temperature range. This range of percent difference seems to indicate a good correlation between the historic Barnett & Hibbard data to those shown in the 4^{th} edition CRC Handbook chart. **While not a perfect match, it seems highly probable that the Barnett & Hibbard correlation is closely linked to the origin of the vapor pressure chart shown in the CRC Handbook for JP-5.**

No reference for JP-7 vapor pressure data was identified in this study[2].

Overlapping Data

Regarding the question about why the JP-5 and JP-7 vapor pressure data are reported as the same curve in the 4^{th} edition of the CRC Handbook the following hypothesis is offered. Both JP-5 (MIL-DTL-5624) and JP-7 (MIL-DTL-38219) grades of fuel specify a minimum flash point of 60°C. This flash point is significantly higher than the current Jet A/A-1 (ASTM D1655) minimum limit of 38°C, which means these JP-5 and JP-7 are much less volatile than other kerosene grades. Affens (1966) asserts that the flash point occurs when the vapor pressure of a fuel equals the fuel concentration at the lower flammability limit, that is, there appears to be a direct correlation between flash point and vapor pressure. Therefore, in the absence of direct vapor pressure measurements[3], it stands to reason that since both grades of fuel share a flash point, they might also share (similar) vapor pressures near the lower temperature portions of their respective distillation range.

[2] While no published citation could be obtained for JP-7 vapor pressure measurements, Melanie Thom (Baere Aerospace) was able to provide an Engineering Reference Data "addendum", ca. 1981. However, the provenance of these data is unknown. The chart is included in the Appendix to this report.

[3] JP-5 does not specify vapor pressure; however, JP-7 does. JP-7 specifies maximum vapor pressures of 20.7 and 331 kPa at 149 and 260°C, respectively, and the vapor pressures for JP-7 require specialized methods of measurement that are identified in the specification (MIL-DTL-38219). Regardless, test data for both grades are difficult to find in the open literature.

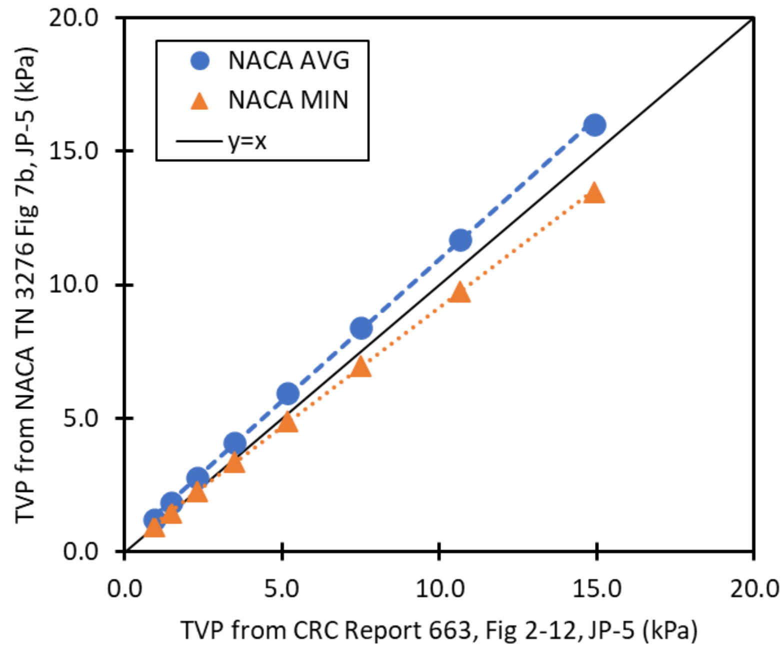


Figure 2. Parity plot of JP-5 vapor pressure data from NACA TN 3276 (Barnett & Hibbard, 1956) and the 4th edition of the CRC Handbook; comparisons shown for both the average (AVG) and minimum (MIN) vapor pressure curves from NACA TN 3276.

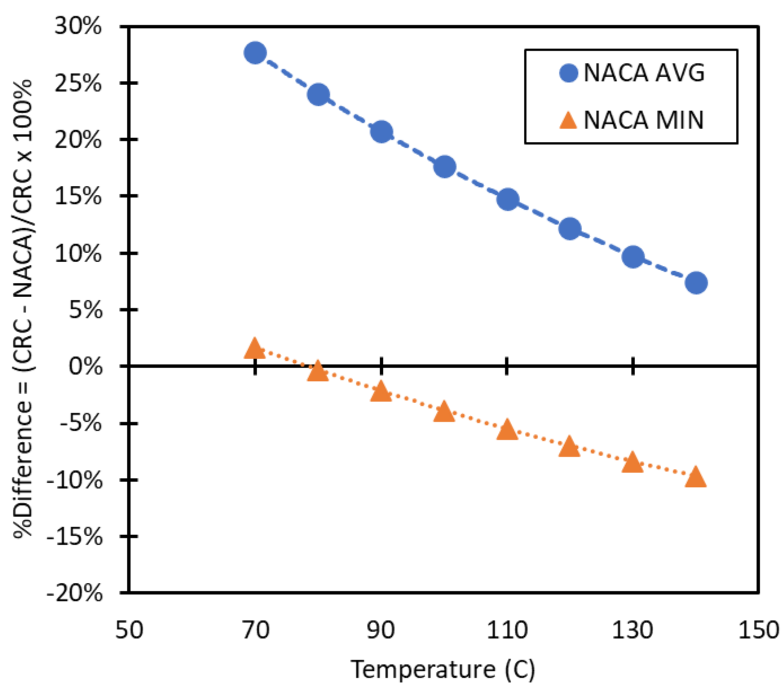


Figure 3. Percent difference of vapor pressure values between CRC Handbook (Report 663) and NACA TN 3276 (Barnett & Hibbard, 1956).

Contemporary Data/Measurement

Contemporary, direct measurement of vapor pressure for JP-5 is very limited since vapor pressure is not a specification requirement in MIL-DTL-5624. Only one study was found to report both JP-5 and JP-7 vapor pressure (Anderson et al., 2022); however, only single batches of both fuels were measured and reported (with the sample of JP-7 being decades old). Inquiry with the Defense Logistics Agency Energy (DLA-E)—the agency that procures fuels for the US Department of Defense—found no record of JP-7 procurements over the past ca. 20 years. It seems that JP-7 is no longer an active jet fuel specification, or at least not one that parties are buying/selling.

Methods of Determination

True vapor pressure (TVP) can be measured directly using methods such as ASTM D2879 (the isoteniscope method) or indirectly with a variety of other methods, e.g., ASTM D6378 (triple expansion method) and distillation/reflux techniques. Care must be taken to properly degas a sample prior to D2879 to determine TVP using that method. While sample degassing is not required for D6378, correlations are required to back out the TVP from the measured data, i.e., TVP is an indirect measurement. The JP-7 specification (MIL-DTL-38219D) outlines the following methods to determine TVP at elevated temperatures using distillation, reflux, or estimation:

- Method A – Distillation (Appendix A, §A3): estimation technique using a lookup chart (of unknown origin) which is valid if ASTM D86 20% distillation point falls between 182.2 °C – 215.6 °C and the difference between initial boiling point (IBP) and 20% distillation is <27.8 °C
- Method B – Vapor Reflux (Appendix A, §A4): measurement technique using specified distillation apparatus
- Method C – Reflux Vapor Pressure Test (Appendix C): measurement technique using specified distillation apparatus which is valid for pure compounds and narrow boiling range hydrocarbons, i.e., the difference between D86 IBP and final boiling point (FBP) must be no greater than 70°C.

Methods B and C both require degassing of the sample prior to determination. Additionally, the estimation technique, Method A, is applicable to fuels with Reid vapor pressure (RVP) <0.1 psi and having a 5 to 95% D86 distillation range of less than 93.3°C. TVP is not equivalent to RVP, although some relations are known to approximate each from the other.

Conclusions

It seems highly probable that the JP-5 true vapor pressure (TVP) reported in the CRC Handbook of Aviation Fuel Properties (editions 2 through 4) stems from Barnett & Hibbard, 1956. Furthermore, it appears that flash point and 10% distillation slope were the measured quantities used to estimate TVP for JP-5; the original measurements/data could not be confirmed. Since both JP-5 and JP-7 grades of fuel share a flash point, it is hypothesized that they might also share similar vapor pressures near the lower temperature portions of their respective distillation range; therefore, the decision to represent both grades as the same curve in the CRC Handbook of Aviation Fuel Properties. *Regardless, due to the apparent lack of use of the JP-7 specification it is recommended that JP-7 be considered for removal from future editions of the CRC Handbook.*

Bibliography

Affens, W. A. Flammability Properties of Hydrocarbon Fuels: Interrelations of Flammability Properties of n-Alkanes in Air. *J. Chem. Eng. Data.* **1966,** *11*(2), 197—202.

Affens, W. A.; McLaren, G. W. Flammability Properties of Hydrocarbon Solutions in Air. *J. Chem. Eng. Data*. **1972,** *17*(4), 482—488, 1972.

Anderson, C.; Arts, A. M.; Cook, R.; Mueller, S. S.; West, Z. J. *Measurement of Aviation Fuel Properties Relevant for the Estimation of V/L Ratio Parameter Calculation;* CRC Report No. AV-27-18 (UDRI Report No. UDR-TR-2021-90); Coordinating Research Council (CRC): Alpharetta, GA, 2022.

Barnett, H.C.; Hibbard, R.R. *Properties of Aircraft Fuels*; Technical Note 3276; National Advisory Committee for Aeronautics (NACA): Cleveland, OH, August 1956.

Bridgeman, Oscar C.; Aldrich, Elizabeth W. *Vapor Pressure Data on Distillate Fuel Oils;* Report 879-52R, Res. Div., Phillips Petroleum Co. (ASTIA No. 89943)

Coordinating Research Council (CRC) Aviation Handbook: Fuels and Fuel Systems; NAVAIR Report 06-5-504; Naval Air Systems Command, 1967.

Detail Specification: Turbine Fuel, Aviation, Grade JP-5 (NATO F-44); MIL-DTL-5624X; NAVAIR: Joint Base MDL, NJ, 2024.

Detail Specification: Turbine Fuel, Low Volatility, JP-7; MIL-DTL-38219D(USAF); ASC/ENSI: Wright-Patterson AFB, OH, 1998.

Handbook of Aviation Fuel Properties; CRC Report No. 530; Coordinating Research Council, Inc. (CRC): Atlanta, GA, 1983.

Handbook of Aviation Fuel Properties, 3rd ed.; CRC Report no. 635; Coordinating Research Council, Inc. (CRC): Alpharetta, GA, 2004.

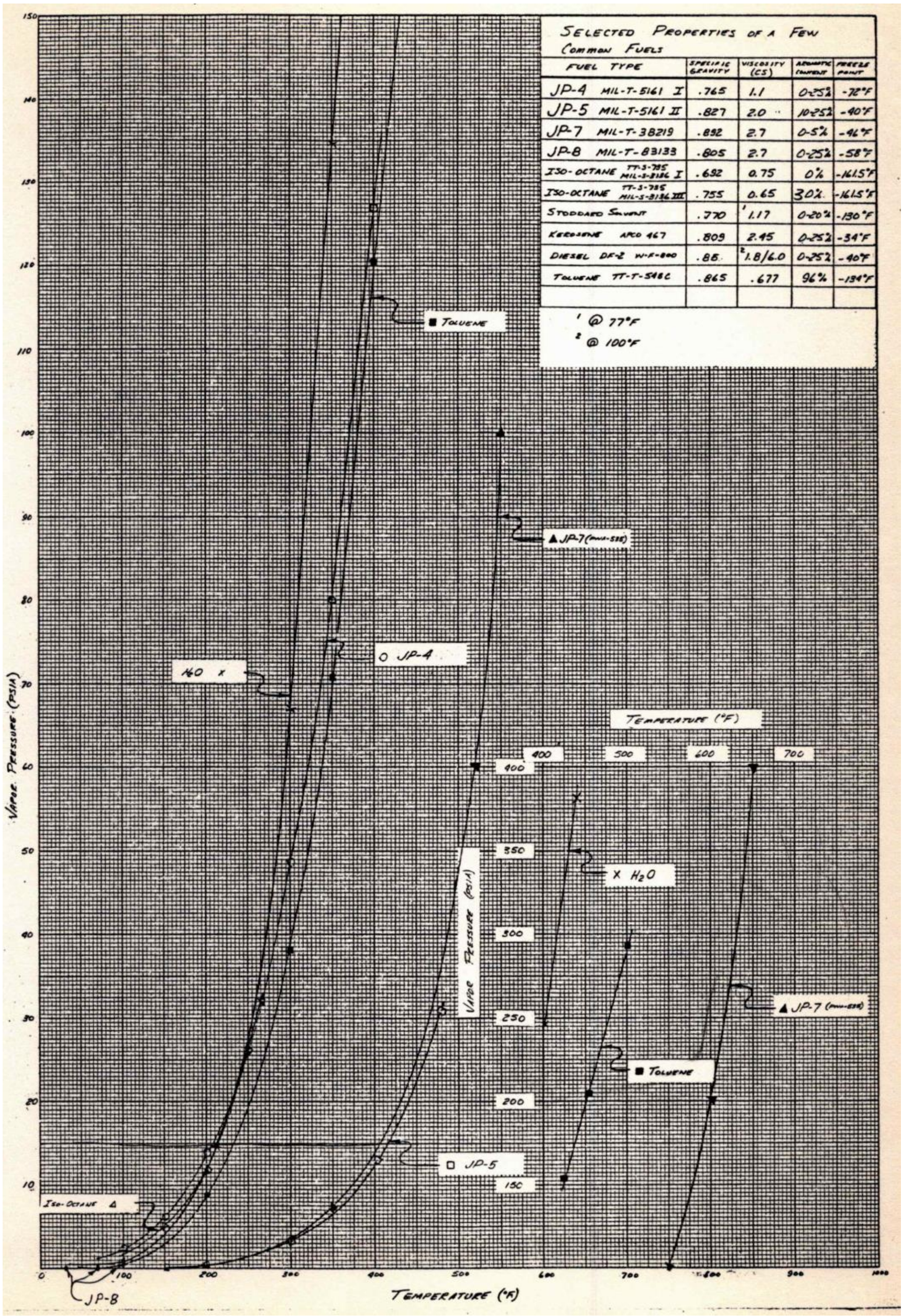
Handbook of Aviation Fuel Properties, 4th ed.; CRC Report no. 663; Coordinating Research Council, Inc. (CRC): Alpharetta, GA, 201~~3~~4.

Kuchta, J. M. *Fire and Explosion Manual for Aircraft Accident Investigators;* Technical Report AFAPL-TR-73-74 (Bureau of Mines Report No. 4193); Air Force Aero Propulsion Laboratory: Wright-Patterson AFB, OH, 1973.

Shelton, E. M. *Aviation Turbine Fuels, 1980;* DOE/DETC/PPS-81/2; US Department of Energy: Bartlesville, OK, 1981.

Welty, J. R. Physical Properties of JP-5 Fuel at Elevated Temperatures. M.S. Thesis, Oregon State College, 1959.

Appendix I: JP-5 and JP-7 Vapor Pressure Data ca. 1981 (source unknown)



Courtesy of Melanie Thom, Baere Aerospace. Data was included as an “addendum” to engineering reference data manual, circa 1981.