

Thermal
Oxidation
Stability of

Aviation
Turbine Fuels

Robert N. Hazlett



Monograph 1

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Dedication

I dedicate this book to my wife, Margaret, who patiently encouraged me throughout and accepted my long hours at the word processor. I also recognize those who have been positive influences in my professional career: Max Barber, my high school science teacher; Dr. Ruth Thompson, my college chemistry professor; Dr. William McEwen, my thesis advisor for my Ph.D. research; and Dr. Homer Carhart, my long-time mentor and friend at the Naval Research Laboratory.

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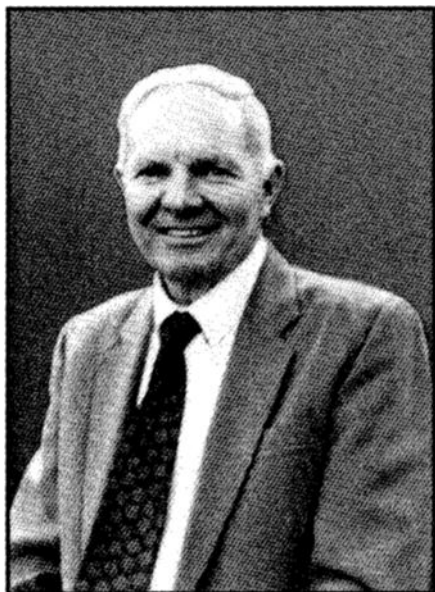
Glossary of Terms, Acronyms, Symbols, and Standards

A	area
AAFSS	advanced aircraft fuel system simulator (United States Air Force)
AFAPL	Air Force Aero Propulsion Laboratory (U.S.)
AFDTA	aircraft fuel deposit test apparatus (single tube rig built by United Technologies Research Center)
AFFB	USAF fuel bank sample
AF-SIM	see AAFSS
AKU	advanced kinetic unit (single tube rig built by Esso Research and Development Co.)
AN-2	hindered phenol antioxidant (Ethyl Corp.)
AO	antioxidant
ARCO	Atlantic-Richfield Co.
ASTM D 1655	Specification for Aviation Turbine Fuels (U.S.)
ASTM D 1660	Test Method for Thermal Stability of Aviation Turbine Fuels (uses ASTM-CRC fuel coker)
ASTM D 2276	Test Methods for Particulate Contaminant in Aviation Turbine Fuels
ASTM D 3241	Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels (JFTOT Procedure)
at%	Atomic percent
AVTUR	kerosene-type <i>aviation turbine fuel</i> (U.K.)
B-52	U.S. Air Force jet bomber
BP	British Petroleum, Ltd.
BuMines	Bureau of Mines (U.S.)
C	carbon (chemical element)
CFDC	computational fluid dynamics and chemistry (physicochemical model for predicting flow and deposit phenomena)
CFR	Cooperative Fuel Research (organization that became the CRC)
CI	corrosion inhibitor (also used as lubricity improvers)
COED	char oil energy development: a coal liquefaction process developed by FMC Corp., Princeton, NJ
Coker	ASTM coker used in specification testing for thermal stability
CRC	Coordinating Research Council (U.S.)
DFM	diesel fuel marine (U.S. Navy fuel for ships)
DMD	deposit measuring device (dielectric method developed by Southwest Research Institute)
DOD	Department of Defense (U.S.)
DOE	Department of Energy (U.S.)
DTS-1	USSR flow rig for thermal stability studies
E_{act}	energy of activation for chemical or physical process
EDS	Exxon donor solvent coal liquefaction process
F-14	U.S. Navy fighter aircraft
FCA	fuel coking apparatus (UTRC)

FDTA	fuel deposit test apparatus (UTRC multitube rig)
FIMS	field ionization mass spectrometry
FOA-3	fuel oil additive No. 3 (duPont)
FOA-310	fuel oil additive No. 310 (duPont)
FSII	fuel system icing inhibitor
GE	General Electric Co.
GE-4-SIM	General Electric fuel system simulator
GE-NZ	General Electric fuel nozzle test facility
GOST-9144	thermal stability test methods used in USSR
GOST-11802	aviation turbine fuel specifications
GOST-17751	
H	hydrogen (chemical element)
<i>h</i>	heat transfer coefficient
H-COAL	a coal liquefaction process developed by Hydrocarbon Research, Inc.
Hitec 515	corrosion inhibitor (Ethyl Corporation)
HR/MS	high resolution mass spectrometry
HTU	heat transfer unit (built by Esso Research and Development for CRC SST program)
HX	heat exchanger
ID	inside diameter
IFAR	injector feed-arm rig (Shell Thornton)
in. Hg	inches of mercury (measure of pressure)
IONOL	hindered phenol antioxidant (Shell Chemical Co.)
IP 323	Institute of Petroleum (U.K.) designation for Thermal Stability Test Method by JFTOT
IR	chemical analysis by infrared
Jet A	designation for commercial aviation turbine fuel refined to ASTM D 1655 specification (kerosene type)
Jet A-1	designation for low freeze point commercial aviation turbine fuel refined to ASTM D 1655 specification (kerosene type)
Jet B	designation for commercial aviation turbine fuel refined to ASTM D 1655 specification (wide-cut type)
JFA-5	thermal stability additive composed of polymers, organic amines, and amides (duPont)
JFTOT	jet fuel thermal oxidation tester (manufactured by Alcor, Inc. and used in many jet fuel specifications)
JP-4	U.S. military jet fuel (wide-cut type); specification MIL-T-5624M
JP-5	U.S. military jet fuel (high flash point kerosene type); specification MIL-T-5624M
JP-7	USAF special jet fuel for high-speed aircraft (low volatility); specification MIL-T-38219B
JP-8	U.S. military jet fuel (kerosene type); specification MIL-T-83133B
JPTS	USAF special jet fuel with high thermal stability; specification MIL-T-25524C
kCal/mol	kilocalories/mole (measure of energy in a chemical or physical process)
kJ/mol	kilojoules/mole (measure of energy in a chemical or physical process)
Lube	lubricant
MDA	metal deactivator additive
MEC	main engine fuel control
MHR	mini heated reservoir (used as a preheat device with JFTOT)

MINEX	miniature heat exchanger rig developed by General Electric Co.
MS	mass spectrometry
N	nitrogen (chemical element)
NAA	North American Aviation Co.
NASA	National Aeronautics and Space Administration (U.S.)
NAPC	Naval Air Propulsion Center (U.S.)
NIPER	National Institute for Petroleum and Energy Research (U.S.)
NRL	Naval Research Laboratory (U.S.)
O	oxygen (chemical element)
OD	outside diameter
PDA	phenylene diamine antioxidant
ppb	parts per billion
ppm	parts per million
PRC	Petroleum Research Centre, Baghdad, Iraq
psia	pounds per square inch absolute (measure of pressure)
psig	pounds per square inch gauge (measure of pressure)
q	quantity of heat
RAF	reference aviation fuel from CRC fuel bank
RFT	rectangular flow tester (UTRC)
RP-1, RP-2, and RP-3	grades of aviation turbine fuel (Peoples Republic of China)
S	sulfur (chemical element)
SIMS	secondary ion mass spectrometry
SR-71	high-speed reconnaissance aircraft (USAF)
SS	stainless steel
SST	supersonic transport
STHTR	single tube heat transfer rig (Shell Thornton)
SY2226	thermal stability test method used in People's Republic of China
T-1, TS-1, T-2 and RT	grades of aviation turbine fuel (USSR)
TDR	tube deposit rater (used by some organizations to rate deposits on JFTOT heater tubes)
TOSCO	company active in developing oil shale as a source of hydrocarbon fuels
TOPANOL	hindered phenol antioxidant (ICI, Ltd.)
USAF	United States Air Force
UTRC	United Technologies Research Center
XPS	X-ray photoelectron spectroscopy (used to analyze surfaces and deposits)

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About the Author

Currently retired from the Naval Research Laboratory, Dr. Robert N. Hazlett served there for 36 years. Most of Dr. Hazlett's career was spent in research on liquid fuels—rocket, jet, and diesel. His research on hydrocarbon fuels has dealt with properties, composition, availability, and stability of jet and diesel fuels. Hazlett's work in these areas has been widely published and referenced by others in the field.

The author holds a B.S. degree in chemistry from Sterling College, Kansas and a Ph.D. in organic chemistry from the University of

Kansas. Three Naval Research Laboratory publication awards, the Applied Science Award from the NRL Chapter of Sigma Xi, an Honorary D.Sc. from Sterling College, and the Black Bear Award to an outstanding alumnus of Sterling High School have been bestowed on this distinguished author.

Dr. Hazlett is an active member of ASTM's Committee D-2 on Petroleum Products and Lubricants, the American Chemical Society, the Coordinating Research Council, Sigma Xi, and the International Association for Stability and Handling of Liquid Fuels. The author spent one year (1984-1985) as an exchange scientist at the Materials Research Laboratory, Melbourne, Australia.

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