# Subject Index

#### A

Absorption refining technique, 90 Acenaphthene, effect on sediment formation, 79 Acid effects on deposit formation, 83-84 interaction with nitrogen and sulfur compounds, 84 Acid treating, 90 Additives (See also specific additive) combinations, 124-125 effects on deposition in deoxygenated fuels, 106-107 for high-temperature applications, 140 reviews and surveys of, 122–123 summary of effects, 127 Advanced aircraft fuel system simulator, 23 - 25comparison of steady-state deposit rates in. 53 deoxygnation studies, 100-101 deposit composition studies, 86-87 schematic of, 24 temperature effects in, 51-52 Advanced Fuel Research mini-reactor, 48 Advanced kinetic unit, 35-36 Arrhenius plot for fuel deposition in, 57 composition effects on deposition in deoxygenated fuels, 104-107 deoxygnation studies in, 102-103 metallic exposure effects on deposition, 116 pressure effects in, 60 schematic of, 36 temperature effects in, 54, 57 AFDTA (See Aircraft fuel deposit test apparatus) Afterburners, spraybar tests, 27 A-1 fuel acid-doped, deposition behavior, 83 copper contaminated, breakpoint of, 113 mild hydrotreatment vs. noble metal processing, 90-91 Aging effects, on thermal stability, 89–90 Aircraft commercial, fuel temperature, 133–136

military, fuel temperature, 136-137 Aircraft fuel deposit test apparatus, 35, 37 global reactions for chemical processes in, 68–69 pressure effects on JP-5 fuel, 60 schematic of, 37 Air-saturated fuels, pressure effects, 58-59 *n*-Alkanes, deposit formation, 75–76 Aluminum deposit thickness on JFTOT tubes, 118 effects on deposition, 116-118 heater tube deposits, 116 in MEC deposits, 5 Anti-icing additives effects on deposition in deoxygenated fuels, 106-107 effects on thermal stability, 151 Antioxidants cautions for, 151 effects on deposition in deoxygenated fuels, 106 - 107JP-4 shale-derived fuel, 125 thermal stability, 123 Antistatic inhibitors, 124 Apparent energy of activation, 59 Aromatics in *n*-dodecane, temperature oxidation data, 77 removal, 90-91 ASTM standards Adjunct No. 12-416600-00: 15 D 1655: 6, 15, 20, 42 D 1660: 5, 15, 148 D 1665: 5 D 3241: 14, 17, 144, 148 D 3241-88a: 118 Auger electron spectroscopy elemental composition of deposits, 86 magnesium on heater tubes, 117–118 Autoxidation, 72–75 flask oxidation studies, 74-75 n-dodecane, 75 paraffinic hydrocarbons, 73-74 AVTUR (See Kerosene-type aviation

turbine fuels)

#### В

Bender process deposit formation after, 85 fuel characterization, 5
Benzothiophene, effect on metal compound deposition, 84
Beryllium, effects on breakpoints, 116
Biomass-derived fuels, 144
Bureau of Mines, thermal stability review (1962), 1–2
Bypass recirculation, environment at flight idle, 10

#### С

Cadmium plating, effects on deposition, 116 Carbon deposition, test duration effects, 117 Cartridge brass, heater tube deposits, 116 CF6-50E engines, deposits on MEC, 4-5 CF6-80E engines, deposits on MEC, 4-5 Clay absorption, 90 Clay filtration and high-temperature applications, 140 metals removal by, 115 Coal-derived fuels vs. petroleum-derived JP-5, copper pickup, 113 as petroleum replacements, 143 Coking rate, deoxygenation and, 103 Color standards (for deposits) ASTM D 2276, 20 CRC/ASTM coker, 15 JFTOT, 17 Commercial aircraft, fuel temperatures, 133 - 136Computerized fluid dynamics and chemistry, thermal stability modeling, 68 Concorde aircraft, fuel temperatures, 133 Coordinating Research Council, thermal stability review (1979), 2-3 Copper catalytic activity, 119-120 compounds, effects on deposition, 113 deposit thickness on JFTOT tubes, 118 dissolved in JP-4 fuels, 114 dissolved in JP-5 fuels, 114-115 effects on breakpoints, 116 deposition in deoxygenated fuels, 106 - 107JP-7 breakpoint, 113-114 kerosene oxidation rate, 114

thermal stability coker tests, 113 JFTOT tests, 112–113 rig tests, 112 effects on spray patterns, 111 in MEC deposits, 5 mechanisms of action, 118-119 solubility, 115 in USSR static tests, 21 Copper contamination JP-5 fuel, effects on heat exchangers, 8 nozzles, 7-8, 111 JT3D/MC-6 and MC-7 engines, 2 summary of effects, 150 Copper/nickel, effect on deposition in deoxygenated fuels, 106 Corrosion inhibitors effects on deposition in deoxygenated fuels, 106-107 effects on thermal stability, 124 CRC/ASTM coker comparisons with JFTOT, 17 with STHTR, 16 description, 14-16 development, 3 dissolved metal effects on thermal stability, 113-114 drawbacks, 16 flight test results, 4 gas driven, 44 high-temperature research coker, 43-44 for metal effects, 45 metallic exposure effects on deposition, 116 micro fuel coker, 45 modifications to, 43-45 modified fuel coker, 44 rating criteria, 15 research coker development and use, 19 - 20as research tool, 16, 19-20 schematic of, 15 CRC/NAA simulator, temperature effects in, 51 Cycloalkanes, inhibition of decane deposit formation, 76

#### D

Decalin, as endothermic fuel, 141 Density, of thermal stability deposits, 67 Deoxygenated fuels applications for, 108

deposits additive effects, 107 characterization, 107 hydrocarbon effects, 104 interactions between added compounds, 107 metal effects, 106-107 nitrogen compound effects, 105-106 oxygen compound effects, 106 sulfur compound effects, 104-105 precautions for, 108 pressure effects, 58-59 Deoxygenation effects Aero Propulsion studies, 100-101 Exxon studies, 101–103 high-temperature applications and, 140 NASA studies, 100 Shell Development studies, 99–100 summary of, 150 UTRC studies, 103 Deposit formation in advanced kinetic unit, rate measurement, 35-36 n-alkanes, 75-76 and Bender process, 5, 85 carbon, test duration effects, 117 chemical mechanisms in, 91-94 deoxygenated fuel additive effects, 107 hydrocarbon effects, 104 interactions between added compounds, 107, 150 metal effects, 106-107 nitrogen compound effects, 105-106 oxygen compound effects, 106 sulfur compound effects, 104-105 dodecoxy free-radical intermediates, 78 dropoff at higher temperatures, 57-58 effects of acids, 83-84 exposure to metallic materials, 116 - 118oxygen compounds, 83-84 polar fractions, 83-84 temperature, 51-58, 89-90, 149 on flow divider values, 6-7hetero atom-containing compounds in, 79-85 in JFTOT, pressure effects, 59 JP-5 fuel during extended duration tests, 63 mechanisms, 100 nitrogen compounds in, 81 pressure effects, 59 radioactively tagged compounds, 78-79

sulfur compounds in, 79-81 Deposition rate in advanced kinetic unit, pressure effects, 60 flow velocity effects, 60-61 in fuel deposit test apparatus, flow rate effects, 62 heat transfer-related, 64-66 at higher temperatures, 57-58 JP-5 in AFDTA, pressure effects, 60 JP-5 in single tube heat exchanger (UTRC), 61 modeling, 68-69 prediction, 68 surface finish effects, 67-68 test duration effects, 63-64 two-step global kinetic mechanism for, 68 Deposits (See also specific deposit) ASTM D1655 codes, 15 chemical structure, 87-89 color standards CRC/ASTM coker, 15 JFTOT, 17 from contaminated MECs, 5 density measurements, 67 from deoxygenated fuels, characterization, 108 effects on fuel metering system, 3 heat exchangers, 3 nozzles, 3 elemental composition of, 85-87 in fuel system filters, 4 light reflectance meters for, 19 magnesium, 116-118 Miceller theory of, 66 morphology, 66-67 nitrogen concentration in, 88 sulfur concentration in, 88 thermal conductivity measurements, 67 thickness in fuel tank simulator, 30 optical interference techniques, 19 Dielectric strength, of metal deposits, 118 Diolefins, effect on *n*-decane deposit formation, 75 N, N'-Disalicylidine-1,2–ethanediamine, 123 N, N'-Disalicylidine-1,2-propanediamine effectiveness, 123 effects on fuel properties, 125-127 Dispersants cautions for, 151 effects on thermal stability, 124

Disulfides, effect on metal compound deposition, 84 *n*-Dodecane autoxidation, 75 dodecoxy free-radical intermediates, 78 temperature oxidation data for aromatics in, 77 Dodecoxy free-radical intermediates, 78 DTS-1 unit, 39 Duration of tests and carbon deposition, 117 and deposition rate, 63-64 Dynamic testers (*See* specific tester)

#### E

Endothermic fuels, for high-temperature applications, 140-141 Energies of activation, 55-57, 59, 149 Engine component rigs afterburner spraybar tests, 27 nozzle testers, 25-27 single tube heat exchanger, 29-30 Engine gear pump, environment at flight idle, 10 Engine oil cooler, environment at flight idle, 10 Extraction methods, 90

Exxon wing tank testers (See Wing tank testers (Exxon))

#### F

Fatty acids, high-molecular-weight, 124 F100C aircraft, TOS flight tests, 3 F101 fuel nozzle, deposit formation, 6 F404 fuel nozzle fouling test results, 54 Field ionization mass spectrometry, chemical structure of deposits, 89 Filters color standard ASTM D 2276, 20 CRC/ASTM coker, 15 deposits in, 4 environment at flight idle, 10 JFTOT, 18-19 sediment composition, 89 FIMS (See Field ionization mass spectrometry) Flask oxidation studies, 74-75 antioxidant effects. 125 effects of dissolved metals on kerosenes, 114 Flask oxidation test description of, 46-47 schematic of, 47

Flight idle, fuel environment at commercial aircraft, 10 Flight tests, 3–4 Flow divider values, deposit formation on, 6 - 7Flow velocity effect on deposition rate, 60-61 heat transfer, 60-61 summary of, 149 UTRC studies, 61–62 Fluorene, effects on deposit formation, 76-77 Fluorocarbon lubricity additives, 124 Free-radical inhibitors natural, 73 synthetic, 73 Free radicals dodecoxy, intermediates in deposit formation, 78 initiation, metals effects, 119 Fuel breakpoints dissolved metal effects, 116-118 jet fuel thermal oxidation tester, 19, 42, 112 - 113Fuel coking apparatus, 39 chemical structure of deposits, 87-88 flow rate effects, 61 Fuel deposit test apparatus copper effects on carbon deposition, 112 design and use, 41-42 flow rate effects studies, 61-62 test duration effects on deposition rates, 63 Fuel environment, at flight idle (commercial aircraft), 10 Fuel flow, at flight idle (commercial aircraft), 10 Fuel injector nozzles (See Nozzles) Fuel metering systems, effects of deposits, 3 Fuel oil additive 310, effects on fuel properties, 125-127 Fuel oil stabilizer 3, effects on fuel properties, 125-127 Fuel quality, and engine performance, 3-4 Fuel systems commercial airplanes, thermal environment of, 9-10 filters (See Filters) generic subsonic airplane, 9 simulators advanced aircraft fuel system simulator, 23-25 GE4 fuel system simulator, 22-23

half-engine-scale fuel system rig, 25 temperatures for supersonic aircraft, 134 - 136Fuel tanks environment at flight idle, 10 Exxon wing tank testers, 46-48 simulator, 30 Fuel temperatures (See also Temperature effects) at combustor nozzle, 137 in commercial aircraft, 133-136 for Concorde aircraft, 133 at flight idle (commercial aircraft), 10 vs. flight time for heat exchangers, 5 in military aircraft, 136-137 for supersonic aircraft, 134-136

#### G

Gas driven fuel coker, 44 GE4 fuel system simulator, design and use, 22 - 23**GE-NZ** apparatus design and use, 25-27 F404 nozzle fouling results, 54 summary of nozzle-fouling regression results, 55 tests in, 52-53 Gold, deposit thickness on JFTOT tubes, 118 Gost Method 9144-79 description, 21 limits, 20 operational principle, 14 Gost Method 11802-66 description, 21 limits, 20 operational principle, 14 Gost Test 17751-79 for Specification RT Kerosene, N. 16564-71, 20

## H

Half-engine-scale fuel system rig description, 25 schematic of, 26 Heater tubes additive tests, 125–126 deposits chemical composition, 89 FIMS and HR/MS, 89 Hastelly C, 99 JFTOT, 18 Nichrome V, 100 surface effects summary, 150 surface finish effects, 67–68 Heat exchange effectiveness factor, 65 Heat exchangers CF6-50E and CF6-80E engines, 5 deposition effects on heat transfer, 3 fuel temperature vs. flight time, 5 heat transfer deterioration, 8 Naval Air Propulsion Center, 65 single tube test rig, 29-30 testing, 8 Heat load, at flight idle (commercial aircraft), 10 Heat transfer effects of copper, 112 copper-doped JP-5 fuel, 8 flow velocity, 60-61 pressure, 59 sulfur compounds, 80 single tube heat exchanger rig, 29-30 Heat transfer unit (Esso) design and use, 39-41 flow diagram of, 40 heat transfer reference data for RAF-179-64.56 heat transfer-related deposition, 64 temperature effects in, 53, 56 Heavy oil-derived fuels, 144 n-Hexadecane, decomposition, 141 Hexanoic acid, effect on nitrogen compound deposition, 84 High-resolution mass spectrometry, JFTOT heater tube deposits, 89 High-temperature requirements in commercial aircraft, 133-136 in military aircraft, 136-137 High-temperature research fuel coker, 43 - 44HR/MS (See High-resolution mass spectrometry) Hydrocarbons alicyclic, as endothermic fuel, 141 effects on deposition in deoxygenated fuels, 104 paraffinic, autoxidation, 73-74 pure, noncatalytic decomposition, 141 structure and deposition, 75-79 Hydrogenation, and JFTOT breakpoint, 91 Hydroperoxides and copper presence, 119 decomposition, 73 effect on deposition in deoxygenated fuels, 106 formation during storage, 109 product breakdown, 77-78 summary of effects, 150

Hydrotreatment refining technique, 90–91, 151 for high-temperature applications, 140

#### I

Icing inhibitors, 124 Inconel 600, effect on deposition in deoxygenated fuels, 106 Indene, effect on n-decane deposit formation, 76 Injector feed-arm rig (Shell Thorton) design and use, 41 flow diagram of, 41 flow velocity effects in, 61 heat transfer-related deposition, 66 time-dependence of deposition in, 63-64 Injector nozzles (See Nozzles) Ion-exchange cleanup, for metal removal, 115 IONOL, effects on fuel properties, 125 - 127Iron dissolved in JP-4 fuels, 114 effects on deposition in deoxygenated fuels, 106 - 107JP-7 breakpoint, 113-114 kerosene oxidation rate, 114 mechanism of action, 119 solubility, 115 summary of effects, 150

# J

J-57 engine in F100C aircraft, 3 in fighter aircraft, 4 instability behavior, 2 TOS flight tests, 3–4 Jet fuel thermal oxidation tester acid studies in, 83 additives to JP-4 fuel, evaluation, 124-125 breakpoints hydrogenation and, 91 and metal contamination tests, 112 - 113bulk heating step ahead of, 43 carbon burnoff in SS tubes, 43 coal-derived fuels, 143 comparison with CRC/ASTM coker, 17 copper mechanism of action, 119 deoxygenation studies, 100-101 diagram of, 18

elemental composition of deposits, 86 fiber optic modified, test duration effects. 64 flow velocity effects in, 61 fuel breakpoints, 19, 42 heater tube additive tests, 125-126 heater tube deposits, FIMS and HR/MS, 89 high temperature for, 42 for JP-7 fuels, 20 metal deactivator studies, 128-130 metallic exposure effects on deposition, 116 - 118Millipore filters, 43 modifications to, 42-43 nitrogen compound studies in, 81 127-mm heater tubes for, 43 optical techniques, 19 polar fraction studies, 83 pressure effects on JP-4 breakpoints, 59 problems with, 19 rating criteria, 17 rating relationships with JFTOT, 17 shale-derived fuels, 142-143 sulfur compound studies in, 80-81 tar sand and heavy oil-derived fuels, 144 test duration effects on deposition rates, 64 test parameters, 17 use of, 5 JFA-5 dispersant, 124 JFTOT (See Jet fuel thermal oxidation tester) JP-4 fuels high-temperature applications, 140 shale-derived additives evaluation, 124-125 antioxidants evaluation, 124-127 shale-derived, antioxidant evaluation, 124 - 127sources of dissolved metals in, 114 JP-5 fuels in AFDTA, pressure effects, 60 vs. coal-derived fuels, copper pickup, 113 copper-contaminated heat exchanger tests with, 8 nozzle tests with, 7-8, 111 deoxygenation effects, 102-103 deposit formation during extended tests, 63 hydroperoxide effects, 106 nitrogen compound effects, 105-106 peroxide effects, 106 sulfur compound effects, 104-106

high-temperature applications, 140 pressure effects, 59 sources of dissolved metals in, 114 JP-7 fuels breakpoint, dissolved metal effects, 113 - 114deoxygenation effects, 103 fouling rates, 8 high-temperature applications, 140 JFTOT conditions for, 17 metals removal from, 115 research coker use for, 20 static testers for, 20-21 thermal stability, 8, 20 JT3D/MC-6 engine, instability problems, 2 JT3D/MC-7 engines, instability problems, 2

#### K

Kerosene fuels CRC coker specification for, 16 dynamic tests for Peoples Republic of China, 20 **USSR**, 20 high-temperature applications, 151 for high-temperature applications, 140 metallic exposure effects, 116 oxidation rate copper effects, 114 iron effects, 114 pressure effects, 59 static tests in USSR, 20 thermal precipitation rating, 20 Kerosene-type aviation turbine fuels (AVTUR) effect of nitrogen compounds, 82 heat transfer coefficient, test duration effects, 64-65 tests for nitrogen/sulfur compound effects, 46

#### L

L-605 (Haynes 25), heater tube deposits, 116 Large-scale thermal stability testers advanced aircraft fuel system simulator, 23-25 GE4 fuel system simulators, 22-23 half-engine-scale fuel system rig, 25 priority list for, 23 Laser ionization mass analysis, metal deactivators, 129 Lead dissolved in JP-4 fuels, 114 effects on breakpoints, 116 JP-7 breakpoint, 113–114 Light reflectance meters, deposit rating with, 19 Light scattering, phenyl sulfide role in particulate matter formation, 80 Lubricity additives, effects on thermal stability, 124

## M

Mach number, and fuel stresses, 133-137 Magnesium compounds, effects on deposition, 113 Magnesium deposition deposit thickness on JFTOT tubes, 118 migration, 116-118, 148 Main engine control CF6-50E and CF6-80E engines, deposits on, 4-5 deposits analysis, 5 environment at flight idle, 10 Manifolds fouling, 3 redesign, J-57 engine, 2 surface finish effects, 67-68 MEC (See Main engine control) Mercaptans, conversion to disulfides, 5, 85 Metal concentrations effects on thermal stability, 112 sources of dissolved metals in JP-4 fuels, 114 in JP-5 fuels, 114-115 Metal deactivators, 123 cautions for, 151 N, N'-disalicylidine-1,2-propanediamine effects, 128-130 laser ionization mass analysis, 129 mechanism of action, 127-128 secondary ion mass spectrometry, 130 X-ray photoelectron spectroscopy, 129 - 130Metal effects ASTM coker modification for, 45 coker tests, 113-114 on deposition in deoxygenated fuels, 106 - 107engine component tests, 111-112 flask oxidation studies, 114 JFTOT tests, 112-113 rig tests, 112 summary of, 150 Metal passivators, 123, 151

Metals dissolved, sources of, 114–115 mechanisms of action, 118-120 solubility, 115 Methylcyclohexane catalytic decomposition studies, 141 dehydrogenation catalysts, 141 as endothermic fuel, 141, 151 Miceller theory, of deposits, 66 Microbiocides, 124 Micro fuel coker description, 45 radioactively tagged compounds for deposition studies, 79 Military aircraft, fuel temperatures, 136 - 137Minex heat transfer rig additives study, 123 calculation methods, 33-34 decay rates of heat transfer coefficients, 34 description, 33-35 flow diagram of, 33 revised version of, 34-35 Modeling, of thermal stability processes, 68-69 Modified fuel coker, 44 Monel 400, heater tube deposits, 116 Multiple tube testers fuel deposit test apparatus, 41-42 heat transfer unit, 39-41 injector-feed-arm rig, 41

# N

Naphthalenes in heater tubes, 89 release of, 89 NASA Lewis Research Center single tube rigs deoxygenation studies in, 100 description, 38-39 heat transfer studies, 64 Naval Air Propulsion Center heat exchanger, heat exchange effectiveness factor, 65 Nickel aluminized, heater tube deposits, 116 dissolved in JP-5 fuels, 115 Nickel 200, heater tube deposits, 116 Nitrogen compounds effects on deposit formation, 81 deposition in deoxygenated fuels, 105 - 106

interaction with acids and sulfur compounds, 84 summary of effects, 150 tests in static devices, 82-83 Noble metal catalysts, refining with, 90-91 Nozzle fouling by copper-contaminated JP-5 fuel, 7-8 by copper-generated solids, 111 flow-divider valve depositions, 3 F404 test results, 54 by high aromatic fuel blend, 7-8test facility, 26-28 tests in GE-NZ apparatus, 52-53 Nozzles combustor, fuel temperature at, 137 environment at flight idle, 10 T700 engine, 7 weighted temperature parameter, 6-7 Nozzle testers, 6–7, 25–27 F404/T700 test rig schematic, 28 GE-NZ, temperature effects in, 52-53

## 0

Oil cooler, environment at flight idle, 10 Olefins effect on n-decane deposit formation, 75 removal, 90-91 Optical interference techniques, for deposit thickness, 19 Oxidation, kerosenes, dissolved copper and zinc effects, 114 Oxygen compounds effects on deposit formation, 83-84 deposition in deoxygenated fuels, 106 summary of effects, 150 Oxygen contents, reduced Aero Propulsion studies, 100-101 Exxon studies, 101-103 NASA studies, 100 Shell Development studies, 99-100 UTRC studies, 103

## Р

Paraffin oxidation, 73–74 Peroxides, effect on deposition in deoxygenated fuels, 106 Petroleum replacements, 151 biomass-derived, 144 coal-derived fuels, 143–144 from heavy oils, 144 shale-derived fuels, 142–143 tar sand-derived fuels, 144 Phenols, in heater tubes, 89 Phenyl disulfide, effect on nitrogen compound deposition, 84 para-Phenylenediamine antioxidants, 123 Phillips Petroleum Co. 5-mL bomb technique, 45-46 Phosphorus-containing corrosion inhibitors, 124 Pipeline drag reducer additives, 124 Polar compounds removal processes, 90 summary of effects, 151 Polar fractions, effect on deposit formation, 83-84 Prediction, deposition rates, 68 Preheater tubes CRC/ASTM coker, 14 metal composition effects, 111 research coker, 19 Pressure, at flight idle (commercial aircraft), 10 Pressure effects in advanced kinetic unit, 60 on air-saturated and deoxygenated fuels, 58-59 on deposit buildup, 59 general observations and recommendations, 60 on heat transfer, 59 in JFTOT, 59 on JP-5 fuel in AFDTA, 60 summary of, 149 on USAF special jet fuel with high thermal stability, 60

## R

Radioactively tagged compounds, for deposition studies, 78–79 Rating criteria CRC/ASTM coker, 15 jet fuel thermal oxidation tester, 17 summary of, 149 Rectangular flow tester (UTRC) deoxygenation studies, 103 design and use, 48 flow rate effects, 61 Refining techniques, 90–91 Residence time, at flight idle, 10

# S

Scanning electron microscopy, for deposit morphology, 66–67 Secondary ion mass spectrometry, metal deactivators, 130 Shale-derived fuels IP-4 additives evaluation, 124-125 antioxidant evaluation, 124-127 as petroleum replacement, 142-143 Shell Development Company single tube rigs, 38 Silver, effects on breakpoints, 116 Simulators (See also specific simulator) summary of, 148-149 Single tube heat exchanger (UTRC), flow rate effects, 61 Single tube heat transfer rig (Shell Thornton) applications, 38 copper effects on heat transfer, 112 development, 35, 38 heat transfer coefficient deterioration in, 58 metal deactivator studies, 128-129 sulfur compound studies in, 80 temperature effects in, 55, 58 Single tube testers advanced kinetic unit, 35-36 AFDTA, 35, 37 deposit composition studies, 86 description, 32-33 DTS-1 unit, 39 fuel coking apparatus, 39 heat exchanger test rig, 29-30 heat transfer rig (Shell Thornton), 16, 35, 38 comparison with CRC/ASTM coker, 16 heat transfer studies, 64-66 Minex heat transfer rig, 33-35 NASA Lewis Research Center apparatus, 38–39, 64 Shell Development Company apparatuses, 38 **USSR**. 39 Solubility, of metals, 115 Specification methods (See also specific method) summary of, 148 table of, 14 types of tests, 13 Spraybar tests, for afterburners, 27 Spray patterns, copper contamination effects, 111 SR-71 reconnaissance aircraft, fuel stresses, 137 Stability definition, 1 storage, 1

Stability—*Continued* thermal oxidation (See Thermal oxidation stability) Stainless steels type 304 deposit thickness on JFTOT tubes, 118 heater tube deposits, 116 type 316 deposit thickness on JFTOT tubes, 118 heater tube deposits, 116 type 446, heater tube deposits, 116 Static testers color standards for filters, 20 deposits for Auger electron spectroscopy, 46 flask oxidation test, 46-47 Gost Method 9144-79, 14, 21 Gost Method 11802-66, 14, 21 for JP-7 fuels, 20 nitrogen effects on AVTUR, 46 Phillips 5-mL bomb technique, 45-46 sulfur effects on AVTUR, 46 thermal precipitation rating, 20 Steels, type 1015, heater tube deposits, 116 STHTR (See Single tube heat transfer rig (Shell Thornton)) Storage effects hydroperoxide formation, 109 at low temperatures, 89-90 Storage stability, 1 Stress conditions, in aviation turbine engines, 8-11 Sulfides, effect on metal compound deposition, 84 Sulfur, in MEC deposits, 5 Sulfur compounds effects on deposition in deoxygenated fuels, 104-106 interaction with nitrogen compounds and acids, 84 role in deposit formation, 79-81 summary of effects, 150 Sulfur dioxide, extraction, 90 Supersonic aircraft fuel temperatures, 133-136 possible fuel system for, 136 Surface finish, deposition rate and, 67-68 Surface temperature, at flight idle, 10 SY2226 (China), 20

#### Т

Tar sand-derived fuels, 144 Temperature effects (*See also* Fuel temperature)

in advanced aircraft fuel system simulator (USAF), 51-52 in advanced kinetic unit, 54, 57 in CRC/NAA simulator, 51 deposition rate dropoff, 57-58 fuel storage at low temperatures, 89-90 in GE-nozzle apparatus, 52-53 in heat transfer unit (Esso), 53, 56 at high velocities, 133 in single tube heat transfer rig (Shell Thornton), 55, 58 summary of, 149 Temperatures exterior surface (aircraft), 133 radiation equilibrium surface, 134 T700 engine copper effects on nozzle flow rate, 111 nozzle flow characteristics, 7 nozzle fouling, 7-8 Test duration effects on carbon deposition, 117 on deposition rate, 63-64 Tetralin, effect on sediment formation, 79 TF30 engines, fuel and wall temperatures, Thermal conductivity, of deposits, 67 Thermally stable kerosene (U.S. MIL-T-25524c) CRC coker specification for, 16 JFA-5 dispersant additive, 124 JFTOT conditions for, 17 Thermal precipitation rating, for JP-7 fuels, 20 Thermal stability deposition (See Deposit formation) Thermal stability processes aging, 89-90 chemical, summary of, 150-151 modeling, 68-69 physical, summary of, 149-150 Titanium, effect on deposition in deoxygenated fuels, 106 TOS (See Thermal oxidation stability) Tungsten, effects on breakpoints, 116 Two-step global kinetic mechanism, for deposition rate prediction, 68

#### U

U.S. Military specifications U.S. MIL-T-25524c: 17

U.S. MIL-T-25524c: Amemdment 2, 16

USAF special jet fuel with high thermal stability

metals removal from, 115 pressure effects, 60

#### V

Vanadium, effects on deposition in deoxygenated fuels, 106-107

## W

Weighted temperature parameter, 6-7, 52 Wing tank testers, 46-48 Wing tank testers (Exxon) deoxygenation studies in, 101-102 description of, 46-48 nitrogen compound studies in, 81 sulfur compound studies in, 79-80

#### Х

XB-70A aircraft, fuel stresses, 137 X-ray photoelectron spectroscopy, metal deactivators, 129–130

# Z

Zinc dissolved in JP-4 fuels, 114 dissolved in JP-5 fuels, 115 effects on breakpoints, 116 JP-7 breakpoint, 113–114 thermal stability, coker tests, 113 mechanism of action, 119 solubility, 115