

Technologies for Near-Zero-Emission Gasoline-Powered Vehicles

List of Chapters

Chapter 1 Transient Engine Startup and Shutdown Processes

By Wai K. Cheng

- 1.1 Introduction
- 1.2 The Engine Shutdown Process for Port Fuel Injected Engines
 - 1.2.1 General Behavior During the Shutdown Process
 - 1.2.2 Impact of the Shutdown Process on Hydrocarbon Emissions
- 1.3 The Engine Startup Process for Port Fuel Injected Engines
 - 1.3.1 Initial Conditions for Engine Startup
 - 1.3.2 General Behavior During the Startup Process
 - 1.3.3 Mixture Preparation in the Startup Transient
 - 1.3.4 Combustion in the Startup Transient
 - 1.3.5 Hydrocarbon Emissions in the Startup Transient
- 1.4 The Engine Startup Process for Direct Injection Spark Ignition Engines
- 1.5 Summary
- 1.6 References

Chapter 2 Mixture Formation Processes

By Ron Matthews and Matt Hall

- 2.1 Introduction
- 2.2 Liquid Fuel as a Source of Hydrocarbon Emissions
- 2.3 Fuel Injection Hardware and Controls
 - 2.3.1 Injector Types
 - 2.3.2 Injection Timing
 - 2.3.3 Other Injection Parameters
- 2.4 Flow Field Effects
- 2.5 Strategies to Improve Fuel Preparation and Reduce Liquid Fuel Effects During Cold Start and Warm-Up
- 2.6 Summary
- 2.7 References

Chapter 3 Cold-Start Hydrocarbon Emissions Mechanisms

By James A. Eng

- 3.1 Introduction
- 3.2 Global Engine Behavior During a Cold Start
 - 3.2.1 Required Fueling Levels
 - 3.2.2 Fuel Accounting
- 3.3 Hydrocarbon Storage Mechanisms
 - 3.3.1 Storage in Crevices
 - 3.3.2 Absorption in Oil Layers and Deposits

- 3.3.3 Liquid Fuel
- 3.3.4 Quench Layers
- 3.3.5 Partial Burns
- 3.3.6 Rich Air/Fuel Operation
- 3.4 Hydrocarbon Transport Mechanisms
 - 3.4.1 Transport Mechanisms at Warm Conditions
 - 3.4.2 Transport Mechanisms at Cold Conditions
- 3.5 Hydrocarbon Oxidation
 - 3.5.1 Hydrocarbon Oxidation Mechanisms
 - 3.5.2 Hydrocarbon Consumption Rates
 - 3.5.3 Post-Flame Hydrocarbon Consumption in Engines
- 3.6 Summary
- 3.7 References

Chapter 4 Characterization of Cold Engine Processes

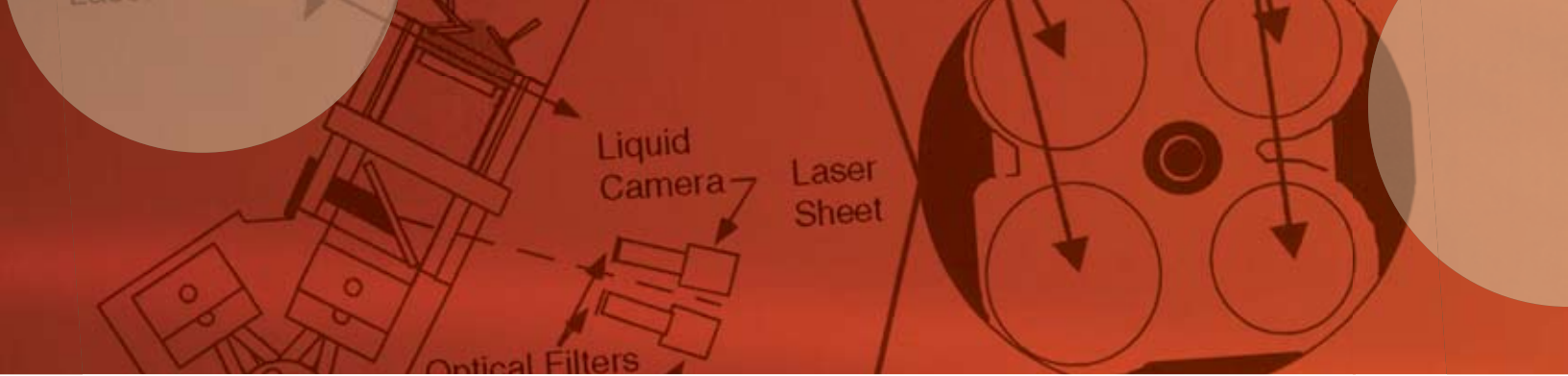
By Choongsik Bae

- 4.1 Introduction
- 4.2 Fuel Injection Characteristics and Fuel Delivery into the Engine Cylinder
 - 4.2.1 Fuel Sprays
 - 4.2.2 Wall Wetting
 - 4.2.3 Fuel Delivery into the Engine Cylinder
- 4.3 Mixture Distribution and Its Interaction with Flow
- 4.4 Combustion Processes and Pollutant Formation
- 4.5 Summary
- 4.6 References

Chapter 5 Spark Retardation for Improving Catalyst Light-Off Performance

By Stephen Russ

- 5.1 Introduction
- 5.2 Calibration Actions for Improving Catalyst Light-Off
- 5.3 Engine Operation with Retarded Ignition
- 5.4 Approaches for More Robust Operation with Ignition Retard
 - 5.4.1 Enhanced Charge Motion
 - 5.4.2 Dual Spark Ignition
- 5.5 Summary
- 5.6 References



Chapter 6 Secondary Air Injection for Improving Catalyst Light-Off Performance

By Fuquan (Frank) Zhao and Mark Borland

- 6.1 Introduction
- 6.2 Principle and System Layout of Secondary Air Injection
- 6.3 Thermal Oxidation Versus Catalytic Oxidation
- 6.4 Role of Temperature and Mixing in Enhancing the Thermal Oxidation Process
- 6.5 Requirements on Engine Enrichment and Secondary Air Injection Quantity
- 6.6 Secondary Air Injection Control and Onboard Diagnostics
 - 6.6.1 Open-Loop Control
 - 6.6.2 Closed-Loop Control
 - 6.6.3 Sensors for Feedback Control
- 6.7 Other Application Considerations for Secondary Air Injection
 - 6.7.1 Application of Secondary Air Injection to Vee Engines
 - 6.7.2 Application of Secondary Air Injection to Turbocharged Engines
 - 6.7.3 Other Application Issues
- 6.8 Summary
- 6.9 References

Chapter 7 Effects of Fuel Properties and Fuel Reforming on Cold-Start Hydrocarbon Emissions and Catalyst Light-Off

By James A. Eng

- 7.1 Introduction
- 7.2 Gasoline Properties
 - 7.2.1 Composition
 - 7.2.2 Volatility
 - 7.2.3 Driveability
 - 7.2.4 Reformulated Gasoline
- 7.3 Fuel Effects on Hydrocarbon Emissions
- 7.4 Onboard Fuel Reformers
 - 7.4.1 Steam Reforming
 - 7.4.2 Partial Oxidation Reforming
 - 7.4.3 Autothermal Reforming
 - 7.4.4 Cold-Start Performance Improvements
 - 7.4.5 Improved Catalyst Light-Off
 - 7.4.6 Cold-Starting Alcohol-Fueled Vehicles
- 7.5 Onboard Fuel Distillation
- 7.6 Summary
- 7.7 References

Chapter 8 Advanced Catalyst Design

By Paul J. Andersen, Todd H. Ballinger, and David S. Lafyatis

- 8.1 Introduction
- 8.2 Advanced Three-Way Catalyst Concepts and Design
- 8.3 Catalyst System Design Principles for Meeting Partial Zero Emissions Vehicle Emissions Standards
- 8.4 Summary
- 8.5 References

Chapter 9 The Hydrocarbon Trap

By Kimiyoshi Nishizawa

- 9.1 Introduction
- 9.2 Functions of the Hydrocarbon Trap
 - 9.2.1 Hydrocarbon Trap System
 - 9.2.2 Materials
- 9.3 Factors to Control Efficiency
 - 9.3.1 Selecting and Developing Trapping Material
 - 9.3.2 Selecting and Developing the Catalyst Coating
 - 9.3.3 Selecting the Shape of the Catalyst Substrate
- 9.4 Measures for Improving System Efficiency
 - 9.4.1 Actively Controlled Systems
 - 9.4.2 Improved Passive Systems
- 9.5 Summary
- 9.6 References

Chapter 10 Three-Way Catalytic Converter System Modeling

By Tariq Shamim

- 10.1 Introduction
- 10.2 Modeling Approaches
 - 10.2.1 Single-Channel-Based One-Dimensional Modeling
 - 10.2.2 Multidimensional Modeling
- 10.3 Chemical Reaction Mechanisms
 - 10.3.1 Three-Step Chemical Reaction Mechanism
 - 10.3.2 Four-Step Chemical Reaction Mechanism
 - 10.3.3 Modified Four-Step Chemical Reaction Mechanism
 - 10.3.4 Five-Step Chemical Reaction Mechanism
 - 10.3.5 Six-Step Chemical Reaction Mechanism
 - 10.3.6 Thirteen-Step Chemical Reaction Mechanism
 - 10.3.7 Multistep Chemical Reaction Mechanism with Elementary Reaction
 - 10.3.8 Influence of Catalyst Deactivation on Reaction Mechanism
- 10.4 Oxygen Storage Mechanism
 - 10.4.1 Simple Single-Step Oxygen Storage Capacity Mechanism

- 10.4.2 Detailed Nine-Step Oxygen Storage Capacity Mechanism
- 10.5 Heat and Mass Transfer Phenomena
- 10.6 Inlet Flow Distribution
 - 10.6.1 Flow Distribution Index
 - 10.6.2 Improvement of Flow Uniformity
- 10.7 Modeling of Catalyst Dynamic Behavior
- 10.8 Summary
- 10.9 Mathematical Nomenclature
- 10.10 References
- 10.11 Appendix

Chapter 11 Evaporative Emissions Reduction

By Jenny Spravsow and Christopher Hadre

- 11.1 Introduction
 - 11.1.1 Overview of Evaporative Emissions Standards
 - 11.1.2 Types of Evaporative Emissions
 - 11.1.3 Evaporative Emissions Test Procedures
- 11.2 Types of Evaporative Emissions Control Systems
- 11.3 Reducing Evaporative Emissions
 - 11.3.1 Seals
 - 11.3.2 Connectors
 - 11.3.3 Materials
 - 11.3.4 Canister and Engine Control Technology
- 11.4 Summary
- 11.5 References

Chapter 12 Onboard Diagnostics

By Glenn Zimlich, Kathleen Grant, and Timothy Gernant

- 12.1 Introduction
 - 12.1.1 Emissions Failure Thresholds for Diagnostic Monitors
 - 12.1.2 Proper Identification of Diagnostic Failures
- 12.2 Catalyst System Monitor
 - 12.2.1 Theory, Application, and Regulatory Implications
 - 12.2.2 Catalyst Monitor Operation
- 12.3 Comprehensive Component Monitor
- 12.4 Cold-Start Emissions Reduction Control Strategy Monitor
- 12.5 Engine Misfire Monitor
 - 12.5.1 Theory, Application, and Regulatory Implications
 - 12.5.2 Misfire Monitor Operation
- 12.6 Evaporative System Monitor
 - 12.6.1 Theory, Application, and Regulatory Implications
 - 12.6.2 Initial Vacuum Decay-Based Method for Leak Detection
 - 12.6.3 Positive Pressure Decay Leak Detection
 - 12.6.4 Natural Vacuum-Based Leak Detection
- 12.7 Exhaust Gas Recirculation System Monitor
- 12.8 Fuel System Monitor

- 12.8.1 Theory, Application, and Regulatory Implications
- 12.8.2 Fuel System Monitor Operation
- 12.9 Oxygen Sensor Monitor
 - 12.9.1 Theory, Application, and Regulatory Implications
 - 12.9.2 Oxygen Sensor Monitor Operation
- 12.10 Secondary Air System Monitor
- 12.11 Variable Valve Timing/Control System Monitor
- 12.12 In-Use Performance Tracking
- 12.13 Summary
- 12.14 References

Chapter 13 Emissions Measurements

By Michael Akard

- 13.1 Introduction
- 13.2 Exhaust Emissions
- 13.3 Constant Volume Sampler
 - 13.3.1 Dilution Air
 - 13.3.2 Exhaust Dilution
 - 13.3.3 Dilution Ratio Optimization
 - 13.3.4 Bag Sampling
 - 13.3.5 Bag Materials
 - 13.3.6 Flow Rate Measurement and Control
 - 13.3.7 Sample Transfer from Bags to Analyzers
- 13.4 Bag Mini-Diluter
 - 13.4.1 Bag Mini-Diluter Dilution Gas
 - 13.4.2 Oxygen Interference
 - 13.4.3 Modeled Performance for Sampling Systems
 - 13.4.4 Differences Among Bag Mini-Diluters
 - 13.4.5 System Verification
- 13.5 Analyzer Accuracy
 - 13.5.1 Calibration Gas Requirements
 - 13.5.2 Utilities and System Components
- 13.6 Summary
- 13.7 References

Chapter 14 Near-Zero-Emission Gasoline-Powered Vehicle Systems

By Fuquan (Frank) Zhao

- 14.1 Introduction
- 14.2 System Requirements for a Near-Zero-Emissions Gasoline-Powered Vehicle
- 14.3 BMW Partial Zero Emissions Vehicle System
- 14.4 Ford Partial Zero Emissions Vehicle System
- 14.5 Honda Ultra-Clean Gasoline-Powered Vehicle System
- 14.6 Nissan Partial Zero Emissions Vehicle System
- 14.7 Toyota Partial Zero Emissions Vehicle System
- 14.8 Toyota Ultra-Clean Hybrid Vehicle System
- 14.9 Summary
- 14.10 References