

contents

CHAPTER 1

The Use of Electric Batteries on Civil Aircraft	1
Introduction	1
The Need for Electric Power	1
Evolution of the Airway Navigation System	2
Airframe and System Advances	3
Popularity and Growth of Air Transport	3
The World War II Era	5
Modern-Day Aircraft and Advanced Systems	5
New Technologies, New Challenges	8
Looking Forward	9
References	9

CHAPTER 2

Commercial Aircraft Batteries	11
Introduction	12
Battery Selection	13
Conclusion	14
Contact	14

CHAPTER 3

Bipolar Nickel-Metal Hydride Batteries for Aircraft Applications	15
Introduction	16
Aircraft Applications	17
Battery Design	17
Cell and Battery Testing	18
Future Testing and Plans	19
Conclusion	20
Acknowledgements	20

CHAPTER 4**Implementation of New Aircraft Battery
Technology in the Army 21****Introduction 21****Main Section 22**

Background 22

First Step Forward 22

New Era Begins 23

Conclusion 24**Contact 24****CHAPTER 5****Review of Capabilities and Performance
of Sintered Plate NiCd Batteries 25****Introduction 26****Sintered Electrodes 26**

Slurry Versus Dry Sinter 26

Sintered Plate NiCd Products 27

Flight Programs 27**Considerations for Flight 28**

Maintenance 28

Weight 28

Volume 29

Rate 29

Charger Requirements 29

Cost 30

Summary 30**Contact 31****CHAPTER 6****Aircraft Battery Design Concept
for Improved Ultralow Temperature
Performance 33****Introduction 33****Parallel-Series Design Concept 34**

Practical Example 34

Experimental Program 35

Literature Search 35

Test Plan 35

Test Assets	36
Half Battery Test Configurations	37
Increased Capacity Effect	37
Discussion	38
Acknowledgments	38
References	38
Contact	38
Definitions, Acronyms, Abbreviations	39

CHAPTER 7

Development and Test of Safe, High Power Lithium-Ion Main Batteries for General Aviation Aircraft	41
Introduction	41
Baseline Requirements	43
Critical Battery Load Scenarios	43
Most Demanding Load Profile for a Baseline Battery	43
Ground and Flight Environment	44
Pressure Altitude	45
Ground Temperature	45
Flight Temperature	46
Battery Environment	46
Airspeed and OAT	46
Flight Test Data	47
Lithium-Ion Technology	49
Safe, High Power Chemistry	49
Aircraft Battery Concept	50
Initial Cell Feasibility Tests	50
Cell Capacity, 1°C Rate (+23°C)	51
Capacity at 1°C Discharge Vs. Temperature	51
Rapid Discharge Vs. Temperature	51
Aircraft Load Verification Tests	54
Engine Start Tests Using Load Bank Simulation of Ni-Cd Start Profiles	54
Engine Start Tests on Aircraft with Ambient Temperature Engines	56
Engine Start Tests on Aircraft With Cold-Soaked Engines	58
Safety Tests	59
Abusive High Temperature, High Current Charge from 0% SOC	59
Induced Destructive Overcharge	60
Burn Testing	61
Direct Flame on Electrodes	61
Direct Flame on Cell Case	61

Ground and Flight Environment Compatibility Tests	62
Battery Cooldown During Flight Simulation	62
Other Environmental Tests	63
Conclusion	64
Acknowledgments	64
References	65
Definitions, Acronyms, Abbreviations	69

CHAPTER 8

System Integration of a Safe, High Power, Lithium-Ion Main Battery into a Civil Aviation Aircraft	71
Introduction	72
Battery Design	72
Modules	74
Central Monitoring System (CMS)	74
Operating System and Application Software	74
Awake and Sleep Modes	75
Software Certification	75
Heater	76
Temperature Monitoring	76
No Battery Vent Ports	76
Aircraft Architecture Design	77
Electrical Bus	77
Battery Bus	77
Battery Enable	77
Heater Enable	77
Battery Charging	78
Overvoltage and Short Circuit Protection	78
Avionics Suite	79
Strap to Indicate Installed Battery's Chemistry	79
Battery System Display on EICAS	79
Annunciation/CAS Message Changes	79
<i>Baseline CAS Message for Ni-Cd Batteries</i>	79
<i>New Battery Fault CAS Message for Li-Ion Battery</i>	80
<i>New Battery Fail CAS Message for Li-Ion Battery</i>	80
Maintenance	80
Summary/Conclusions	81
References	82

Contact Information	83
Acknowledgments	84
Appendix	84

CHAPTER 9

Energy Storage for Commercial Hybrid Electric Aircraft	87
Introduction	88
Methods	88
Results and Discussion	89
Summary/Conclusions	92
References	93
Contact Information	94
Disclaimer	94
Acknowledgments	94
Definitions/Abbreviations	94

CHAPTER 10

Comparison of Hydraulic Accessory Systems and Electrical in Aircraft	95
About the Author	104

CHAPTER 11

Protection of Electrical Systems on Military Aircraft	105
General System Characteristics	107
Generator Circuits	107
Distribution Network	108
Individual Load Feeder Circuits	108
Summary	110
About the Author	111