

Flight Testing of Fixed-Wing Aircraft

TU Darmstadt
FB Maschinenbau



60004650

Table of Contents

Preface	xvii
---------------	------

Part 1 Performance Flight Testing

Chapter 1. Introduction	3
1.1 Introduction to Flight Testing	3
1.2 Types of Flight Tests	4
1.3 Sequence of Flight Testing	4
1.4 Planning the Test Program	4
1.5 Governing Requirements and Regulations	6
1.6 The Atmosphere	9
1.7 Aircraft Weight and Center of Gravity	12
1.8 Flight Testing Tolerances	15
References	16
Chapter 2. Methods for Reducing Data Uncertainty in Flight Test Data	19
2.1 Introduction	19
2.2 Sources and Magnitudes of Errors	19
2.3 Avoiding or Minimizing Errors	22
2.4 Error Analysis	25
References	28
Chapter 3. Airspeed Systems Theory and Calibration	29
3.1 Introduction	29
3.2 Federal Aviation Regulation Requirements	29
3.3 Theory of Airspeed Systems	30
3.4 Position Error	32
3.5 Lag Errors	33
3.6 Altimeter Position Error	33
3.7 In-Flight Calibration Methods	34
3.8 Temperature Probe Calibration	37
References	38
Chapter 4. Stall Speed Measurement	39
4.1 Introduction	39

4.2	Federal Aviation Administration Requirements	39
4.3	Stall Theory	42
4.4	Aircraft Loading	47
4.5	Safety Considerations	48
4.6	Flight Test Method	48
4.7	Data Reduction Method	49
	References	52
Chapter 5. Determination of Engine Power in Flight		53
5.1	Introduction	53
5.2	Power Measurement of an Internal Combustion Engine in Flight	54
5.3	Installed Horsepower Losses and How They Affect Power Measurement	58
5.4	Power Corrections	59
5.5	Critical Altitude Determination	61
	References	62
Chapter 6. Propeller Theory		63
6.1	Introduction	63
6.2	Propeller Theory	63
6.3	Propeller Polar Diagram	67
6.4	Constant Speed or Controllable Propellers	67
6.5	Activity Factor	67
6.6	Propeller Noise	68
	References	68
Chapter 7. Jet Thrust Measurement In Flight		69
7.1	Introduction	69
7.2	Basic Theory	69
7.3	Methods of In-Flight Thrust Measurement	72
	References	74
Chapter 8. Level Flight Performance Theory		75
8.1	Introduction	75
8.2	Thrust Required	75
8.3	Effects of Variables on Thrust Required	77
8.4	Power Required	78
8.5	Effects of Variables on the Power Required Curves	79
8.6	Effects of High Mach Number	81
8.7	Thrust or Power Available	82
	References	82

Chapter 9. Level Flight Performance Flight Test and Data	
Reduction Methods for Propeller-Driven Aircraft.	83
9.1 Introduction	83
9.2 Federal Aviation Administration Requirements.	83
9.3 PIW-VIW Method.	83
9.4 Flight Test Method	84
9.5 Reduction of Observed Data.	85
9.6 Expansion of Observed Data.	90
Reference	96
Chapter 10. Level Flight Performance Jet Aircraft	97
10.1 Introduction	97
10.2 Theory	97
10.3 Flight Test Techniques	100
10.4 Data Reduction.	103
References	103
Chapter 11. Range and Endurance	105
11.1 Introduction	105
11.2 Range—Propeller-Driven Airplanes	106
11.3 Range—Jet Aircraft.	111
11.4 Effects of Wind on Range	115
11.5 Endurance—Propeller-Driven Aircraft.	117
11.6 Endurance—Jet Aircraft.	117
References	118
Chapter 12. Climb Performance Theory.	119
12.1 Introduction	119
12.2 Climb Theory.	119
References	126
Chapter 13. Climb Performance Methods, Data Reduction,	
and Expansion.	127
13.1 Introduction	127
13.2 Federal Aviation Administration Regulations	127
13.3 Test Methods	129
13.4 Reduction Methods for Steady Climbs	131
13.5 Expansion Methods.	140
References	142
Chapter 14. Energy Approach to Performance Flight	
Testing	143
14.1 Introduction	143
14.2 Theory	143
14.3 Application to Climb Performance.	145

14.4	Other Applications of Energy Methods	147
14.5	Level Acceleration Flight Test Method	149
	References	151
Chapter 15.	Turning Performance	153
15.1	Introduction	153
15.2	Forces on an Aircraft during a Level Turn	153
15.3	Turning Performance Limitations	155
15.4	Flight Test Method	157
	References	159
Chapter 16.	Methods for Drag Determination in Flight	161
16.1	Introduction	161
16.2	Speed Power Method	161
16.3	Prop-Feathered Sinks or Glide Polars	164
16.4	Incremental Drag Method	166
16.5	Incremental Power Method	167
	References	167
Chapter 17.	Airspeed vs Flight Path Angle Performance	
	Method for Powered-Lift Aircraft	169
17.1	Introduction	169
17.2	V - γ Method	169
	References	174
Chapter 18.	Takeoff and Landing Theory and Methods	177
18.1	Introduction	177
18.2	Federal Aviation Administration Regulations	177
18.3	Theory	180
18.4	Test Methods	184
18.5	Test Procedures	187
18.6	Data Reduction	188
18.7	Rejected Takeoff Distances	197
	References	197

Part 2 Stability and Control Flight Testing

Chapter 19.	Introduction to Stability and Control Flight	
	Testing	201
19.1	Introduction	201
19.2	Regulations	201
19.3	Reference Axes Systems	201
19.4	Definitions of Stability and Controllability	202

19.5	Relation of Stability and Control to the Aircraft's c.g. Envelope	206
19.6	Control System Characteristics	207
	References	207
Chapter 20.	Static Longitudinal Stability Theory	209
20.1	Introduction	209
20.2	Stick-Fixed Static Longitudinal Stability	210
20.3	Longitudinal Control	215
20.4	Elevator Position Stability	216
20.5	Stick-Free Longitudinal Stability	218
20.6	Control Force Stability	219
20.7	Stick-Free Longitudinal Static Stability for an Irreversible Control System	221
	References	221
Chapter 21.	Static Longitudinal Stability Flight Test	
	Methods	223
21.1	Introduction	223
21.2	Federal Aviation Administration Regulations	223
21.3	Stick-Fixed Neutral Point Determination	224
21.4	Stick-Free Neutral Point Determination	225
21.5	Flight Test Method for Determination of Neutral Points	230
21.6	Other Static Longitudinal Stability Tests	230
	References	233
Chapter 22.	Dynamic Longitudinal Stability Theory	235
22.1	Introduction	235
22.2	Theory	236
22.3	Long Period or Phugoid	238
22.4	Short Period	240
22.5	Elevator Short Period	246
	References	246
Chapter 23.	Dynamic Longitudinal Stability Flight Test	
	Methods and Data Reduction	247
23.1	Introduction	247
23.2	Federal Aviation Administration Regulations	247
23.3	Flight Test Methods for Evaluating the Phugoid	248
23.4	Phugoid Data Reduction	248
23.5	Short Period Flight Test Methods	249
23.6	Short Period Data Reduction	252
	References	253

Chapter 24. Longitudinal Maneuvering Stability Theory	255
24.1 Introduction	255
24.2 Elevator Position Maneuvering Stability	257
24.3 Stick-Force Maneuvering Stability	259
24.4 Compressibility Effects.	264
References	264
Chapter 25. Maneuvering Stability Methods and Data	
Reduction.	265
25.1 Introduction	265
25.2 Federal Aviation Administration Regulations	265
25.3 Evaluation by Pilot Opinion	266
25.4 Flight Test Methods for Quantitative Evaluation	267
25.5 Data Reduction Techniques.	271
References	273
Chapter 26. Longitudinal Control and Trim Theory and	
Flight Test Methods	275
26.1 Introduction	275
26.2 Federal Aviation Administration Regulations	276
26.3 Longitudinal Control	278
26.4 Longitudinal Trim	280
References	283
Chapter 27. Methods for Improving Longitudinal Stability	
and Control	285
27.1 Introduction	285
27.2 Control System Gadgets	285
27.3 Elevator Tabs	288
27.4 Aerodynamic Balance	292
References	296
Chapter 28. Lateral-Directional Stability Theory and Flight	
Test Methods	297
28.1 Introduction	297
28.2 Federal Aviation Administration Regulations	297
28.3 Theory	299
28.4 Directional Stability	300
28.5 Lateral Stability	302
28.6 Side Force	304
28.7 Control-Free, Lateral-Directional Stability	306
28.8 Flight Test Methods.	308
References	310

Chapter 29. Dynamic Lateral-Directional Stability Theory and Flight Test Methods	311
29.1 Introduction	311
29.2 Federal Aviation Administration Regulations	311
29.3 Theory	312
29.4 Spiral Mode	314
29.5 Roll Mode	315
29.6 Dutch Roll Mode	315
29.7 Effects of Lateral-Directional Parameters on Lateral-Directional Dynamics	316
29.8 Flight Test Methods for Evaluating Dynamic Lateral-Directional Stability	320
References	322
Chapter 30. Lateral Control Power (Rolling Performance)	323
30.1 Introduction	323
30.2 Federal Aviation Administration Regulations	323
30.3 Single Degree of Freedom Roll Response	324
30.4 Influence of Various Parameters on Rolling Performance	327
30.5 Lateral Control in the Real Case	331
30.6 Other Methods of Roll Control	340
References	340
Chapter 31. Directional Control	341
31.1 Introduction	341
31.2 Federal Aviation Administration Regulations	341
31.3 Directional Control—Single-Engine Airplanes	344
31.4 Directional Control—Multiengine Airplanes	345
31.5 Methods for Determining $C_{N_{\delta r}}$	349
References	357
Chapter 32. Flying Qualities	359
32.1 Introduction	359
32.2 Federal Aviation Administration Regulations	359
32.3 Cooper-Harper Pilot Rating Scale	359
32.4 Levels of Flying Qualities	361
32.5 Flight Test Procedures	361
References	363

Part 3 Hazardous Flight Tests

Chapter 33. Stall Characteristics	367
33.1 Introduction	367
33.2 Federal Aviation Administration Regulations	367

33.3	Stall Characteristics Theory	372
33.4	Aircraft Loading	372
33.5	Safety Considerations	372
33.6	Flight Test Method	373
33.7	Data Requirements	375
33.8	Potential Problems	376
33.9	Problem Fixes	377
	References	381
Chapter 34. Airplane Spin Testing		383
34.1	Introduction	383
34.2	Federal Aviation Administration Regulations	384
34.3	Spin Theory	390
34.4	Planning for Spin Testing	405
34.5	Flight Test Method	409
	References	415
Chapter 35. Dive Testing for Flutter, Vibration, and		
	Buffeting	417
35.1	Introduction	417
35.2	Federal Aviation Administration Regulations	417
35.3	Theory	419
35.4	Safety Considerations	422
35.5	Instrumentation	424
35.6	Flight Test Method	424
35.7	Data Analysis	426
	References	426