

Table of Content

| | |
|---|------------|
| Acknowledgment | i |
| Summary | iii |
| Zusammenfassung | v |
| Table of Content | vii |
| List of Symbols | xi |
| List of Abbreviations | xix |
| Chapter 1 Introduction | 1 |
| 1.1 Basic idea of the research | 1 |
| 1.2 Declaration of obstacles | 2 |
| 1.3 Aim of the research | 4 |
| 1.4 Thesis divisions and overview | 5 |
| Chapter 2 Theoretical Background of Pressure | 7 |
| 2.1 Theory of pressure | 7 |
| 2.2 Pressure modes | 8 |
| 2.3 Principles of pressure measurement | 9 |
| 2.3.1 Liquid column manometer | 9 |
| 2.3.2 Classical deadweight pressure balance | 10 |
| 2.3.3 Force-compensated piston gauges | 12 |
| 2.4 Necessary corrections for pressure calculation | 14 |
| 2.4.1 Air buoyancy effect on masses | 14 |
| 2.4.2 Effect of temperature on the effective area | 14 |
| 2.4.3 Head correction due to height difference | 15 |
| 2.5 Literature review | 15 |
| 2.5.1 Force-compensated piston gauges | 15 |

| | | |
|------------------|---|-----------|
| 2.5.2 | Dimensional measurement | 18 |
| 2.5.3 | Theoretical effective area | 19 |
| Chapter 3 | Force-Balanced Piston Gauge | 21 |
| 3.1 | Construction and operation theory | 21 |
| 3.2 | Construction of the FPG chambers | 22 |
| 3.2.1 | FPG pressure modes | 23 |
| 3.3 | Metrological properties of FPG | 24 |
| 3.3.1 | Calibrated parameters | 24 |
| 3.3.2 | Ambient conditions' parameters | 24 |
| 3.3.3 | Determined parameter | 24 |
| Chapter 4 | Effective Area | 25 |
| 4.1 | Dimensional measurements | 25 |
| 4.1.1 | Straightness | 27 |
| 4.1.2 | Roundness | 27 |
| 4.1.3 | Diameter | 28 |
| 4.2 | Filtering of dimensional data | 28 |
| 4.3 | Least-squares method and radii determination | 30 |
| 4.4 | Correction of radii coordinates | 35 |
| 4.5 | Determination of the effective area | 37 |
| 4.5.1 | Theoretical determination of the effective area | 37 |
| 4.5.2 | Determination of the pressure distribution | 40 |
| 4.5.3 | Experimental determination of the effective area | 48 |
| Chapter 5 | Experimental Setup | 51 |
| 5.1 | Balance calibration | 51 |
| 5.2 | Internal mass calibration | 53 |
| 5.3 | Comparison of the FPG with a classical pressure balance | 53 |
| 5.4 | Comparison of the FPG with a liquid column manometer | 57 |
| 5.5 | Comparison of the FPG with a static expansion system | 61 |
| Chapter 6 | Results and Discussion | 65 |
| 6.1 | Dimensional properties of the PCA | 65 |
| 6.2 | Theoretical effective areas | 69 |
| 6.3 | Axial non-symmetry | 72 |
| 6.4 | Experimental effective areas | 75 |
| 6.5 | Results of the balance calibration | 77 |

| | | |
|-------------------|--|------------|
| 6.6 | Results of the internal mass calibration | 77 |
| 6.7 | Comparison of the FPG with the HgLM | 79 |
| 6.8 | Comparison of the FPG with the SES | 81 |
| Chapter 7 | Uncertainty | 83 |
| 7.1 | Pressure uncertainty due to PCA's effective area | 84 |
| 7.1.1 | Uncertainty of the theoretical effective area | 86 |
| 7.1.2 | Uncertainty of the experimental effective area | 91 |
| 7.2 | Pressure uncertainty due to balance readings | 93 |
| 7.2.1 | Uncertainty of the balance repeatability | 93 |
| 7.2.2 | Uncertainty of the balance readability | 93 |
| 7.2.3 | Uncertainty of the balance hysteresis | 94 |
| 7.2.4 | Uncertainty of the standard mass | 94 |
| 7.2.5 | Uncertainty of the buoyancy effect | 94 |
| 7.2.6 | Uncertainty of the uncorrected error | 95 |
| 7.3 | Pressure uncertainty due to the force coefficient | 95 |
| 7.3.1 | Uncertainty of the force coefficient due to the internal mass | 96 |
| 7.3.2 | Uncertainty of the force coefficient due to the mass density | 98 |
| 7.3.3 | Uncertainty of the force coefficient due to the gas medium density | 98 |
| 7.3.4 | Uncertainty of the force coefficient due to the balance reading | 99 |
| 7.3.5 | Uncertainty of the force coefficient due to gravity acceleration | 99 |
| 7.4 | Pressure uncertainty due to the balance reading corrections | 99 |
| 7.5 | Pressure uncertainty due to the thermal expansion coefficient | 101 |
| 7.6 | Pressure uncertainty due to the temperature of the PCA | 102 |
| 7.7 | Pressure uncertainty due to the head correction | 102 |
| 7.7.1 | Pressure head correction uncertainty due to the height difference | 102 |
| 7.7.2 | Uncertainty of the verticality position | 102 |
| 7.7.3 | Pressure head correction uncertainty due to the gravity acceleration | 102 |
| 7.7.4 | Pressure head correction uncertainty due to the gas medium density | 103 |
| 7.8 | Pressure uncertainty due to the residual pressure | 103 |
| Chapter 8 | Conclusions | 105 |
| 8.1 | PCA dimensional properties | 105 |
| 8.2 | Determination of the effective area | 105 |
| 8.3 | Verification of the FPG | 106 |
| References | | 107 |

| | |
|--|------------|
| Biography | 113 |
| List of publications | 115 |
| List of conferences and presentations | 116 |