

Optical Sensing of the Corona Wind

Kathleen Therese Jones, BSc (Hons.) Dip.Ed. (UNE)

A thesis submitted for the degree of Doctor of Philosophy
of the University of New England.

August, 1997.

I certify that the substance of this thesis has not already been submitted for any degree and is not being currently submitted for any other degree.

I certify that any assistance received in the preparation of this thesis, and all sources used, have been acknowledged in this thesis.

A solid black rectangular box used to redact the signature of the author.

Kathleen Therese Jones

Acknowledgments

I wish to express my sincere gratitude and appreciation to my supervisor, Assoc. Prof. G.A. Woolsey, for making available his theoretical and technical knowledge: for providing a working environment both happy and conducive to study, and a shoulder to cry on; and finally for his constant encouragement and unerring belief in my studies.

I also wish to acknowledge the following people:

To Dr G.B. Scelsi, my co-supervisor; thank you for the advice, encouragement, expertise and friendship given to me throughout my studies.

To my colleagues in the Optical Fibre Sensing Group at the University of New England; Mr G. Hyde, Mr T. Priest, Mr V. Everett and Mr D. Vukovic, thank you for the discussions and interest you have all shown in this work and the friendly atmosphere created by the group.

Many thanks are due to the technical staff of the Science Engineering Workshop, especially Mr M. Beveridge for the construction of the discharge chamber.

To Mrs J. Taylor, thank you for your friendship, knowledge of procedural matters and for assistance with proofreading this thesis.

Thanks are due to the Australian Commonwealth Government for the provision of an Australian Postgraduate Award and the Australian Electricity Supply Industry Research Board and the Australian Research Council for the provision of funding for equipment purchase.

To the members of the Division of Physics and Electronics Engineering, please accept my thanks for the interest you have all shown in my research.

Finally, a very special mention is given to my husband Chris, my sons Timothy and Michael and the entire Keoghan family. No undertaking of this magnitude is possible without constant support and care from those you love. This thesis was a family effort and I thank you all for putting up with the stresses and strains that this work has imposed.

Contents

Acknowledgements	iii
1 Introduction	1
2 Corona Discharges and the Corona Wind	5
2.1 Corona discharges in air	6
2.1.1 The positive corona discharge in air	7
2.1.2 The effect of pressure on corona discharges	12
2.2 Corona discharges in SF ₆	13
2.3 Applications of corona discharges	15
2.4 The corona wind	17
2.4.1 Electrohydrodynamic theory of the corona wind	20
2.4.2 The effect of pressure on the corona wind	26
2.5 The corona wind in practical systems	27
2.5.1 Heat-transfer applications	27
2.5.2 Electrostatic precipitation	29
2.5.3 High-voltage gas insulation	31
2.6 Measurement of the corona wind speed	32
2.6.1 Pressure measurement with manometer systems	32
2.6.2 Anemometry	34
2.6.3 Laser Doppler anemometry	35

3	Review of Optical Fibre Sensing	40
3.1	Principles of optical fibre sensors	41
3.1.1	Optical fibre interferometers	42
3.1.2	Optical fibre low-coherence interferometry	45
3.2	Optical fibre temperature sensors	46
3.3	Optical fibre flow sensors	48
3.4	The hot-fibre anemometer	50
4	Generation and Measurement of the Corona Wind	52
4.1	The discharge system	53
4.2	The discharge chamber	54
4.3	The vacuum system	58
4.4	The optical fibre Fabry-Perot sensor	59
4.5	The laser Doppler anemometer	62
4.5.1	The smoke generator	64
5	The Speed of the Corona Wind in Air	67
5.1	The optical fibre Fabry-Perot sensor	68
5.1.1	The heat-balance equation	69
5.2	Calibration of the optical fibre Fabry-Perot sensor	71
5.2.1	Parameters for calibration	72
5.3	The corona wind and electrode configuration	75
5.3.1	Experimental data	76
5.3.2	Discussion	83
5.4	Corona wind speed and the corona current	86
5.5	Corona wind speed using LDA	87
5.6	Comparison of the OFFPS and LDA results	88

6 The Corona Wind in Sulphur Hexafluoride	94
6.1 The infrared spectrum of SF ₆	95
6.2 Calibration of the OFFPS in SF ₆	95
6.3 Experimental results and discussion for SF ₆	97
6.3.1 Electrode configuration and the corona wind	99
6.3.2 The corona wind speed in SF ₆ and the corona current	103
6.3.3 The effect of pressure on the corona wind speed	105
6.4 The corona wind speed in air and SF ₆	109
7 Two Measurement Postscripts	113
7.1 High temperature calibration of an optical fibre	114
7.1.1 The thermal coefficient of a fibre	114
7.1.2 Experimental arrangement	116
7.1.3 The thermal coefficient of expansion	117
7.1.4 Results and discussion	119
7.2 The effect of streamers on the optical fibre sensor	121
7.2.1 Results and discussion	122
8 Summary and Conclusions	125
Appendix A: Laplacian electric field	128
Appendix B: Mathematical analysis of laser Doppler anemometry	134
Appendix C: Calculation of the heat-balance equation parameters	137
Appendix D: The speed of the corona wind in air	142
Appendix E: The effect of pressure on the OFFPS	145
References	148
Publications and Conference Proceedings	155