

TRANSPORT PHENOMENA IN MHD GENERATORS

by

Bhumesh Kumar Gupta

Thesis submitted to the Indian Institute of Technology, Delhi  
for the award of the Degree of  
DOCTOR OF PHILOSOPHY

Department of Physics  
Indian Institute of Technology, Delhi

February, 1979

## ACKNOWLEDGEMENTS

I find no words to express my deep sense of gratitude to Professor M.S.Sodha for his generosity, valuable guidance, kind encouragement and inspiration throughout the course of this work, without which the present work would not have been possible. I am grateful to Professor A.K.Ghatak for his helpful encouragement and keen interest shown in my work.

I am much indebted to Dr.R.P.Sharma and Dr.S.C.Kaushik for unstinting guidance and their contribution to my education in MHD research.

I am thankful to Dr. B.K.Sawhney, Dr. A.Chandra and Dr. R.P.Dahiya for the helpful discussions at various stages of this work.

I wish to thank Mr. S.Q.Hussain, Mr. B.D.Gupta, Mr. Govind, Mr. G.Umesh, Mr. T.K.Naidu, Mr. D.Subbarao, Dr. L.A.Patel, Mr. K.P.Maheshwari and other members of MHD and Electrophysics Laboratories for their friendly cooperation and helpful discussions.

I would be failing in my duty if I do not acknowledge the help rendered knowingly or unknowingly by many friends and others during the course of this work.

It gives me great pleasure in thanking Mr.T.N.Gupta for the elegant typing of the present thesis and for helping in different ways.

Finally, I would like to record my gratitude to my maternal uncle, parents, both the sisters and Jijajis who provided the kind of support which makes all the difference between success and failure.

Bhumesk Kumar Gupta  
(Bhumesk Kumar Gupta)

## SUMMARY

This thesis presents the investigations of transport phenomena in MHD generators in the presence of inhomogeneities caused by the growth of ionization instability and velocity/temperature boundary layers. Presence of the boundary layers leads to nonuniform heating of electrons across the channel cross-section. The nonuniform heating of electrons affects considerably the growth of ionization instability and the power output. It has been shown that the power output and growth rate of ionization instability both are reduced on account of the boundary layers. Ratio of the power (in the presence of ionization instability) to the power (without ionization instability) is found to increase with the increasing boundary layer thickness. Further, the nonuniform heating of electrons coupled with the temperature boundary layer creates large electron temperature gradients inside the plasma. Consequently, the diffusion of charge carriers across the channel cross-section becomes significant and the electron density is found to deviate from the electron density predicted by the condition of local equilibrium. It is concluded that the overall electron density gets enhanced if recombination and diffusion times are of the same order. The overall conclusion of the present thesis is

that the deterioration in the generator performance on account of boundary layers may not be as serious as believed and careful investigations, which include other boundary effects such as electrical sheath, finite segmentation, leakage currents, end effects, are needed to predict accurately the effect of boundary layers on generator performance.

## CONTENTS

PREFACE	1
CHAPTER 1	
IONIZATION INSTABILITY IN NONEQUILIBRIUM MHD GENERATORS	12
1.1 Introduction	12
1.2 Growth Rate of Instability	13
Phenomenological Approach	13
Semi-Kinetic Approach	17
1.3 Discussion and Conclusion	25
FIGURE CAPTIONS	28
CHAPTER 2	
TRANSPORT PHENOMENA IN MHD GENERATORS: EFFECT OF BOUNDARY LAYER	29
2.1 Introduction	29
2.2 Electron Distribution Function	31
2.3 Conductivity and Power Output	39
2.4 Results and Discussion	42
FIGURE CAPTIONS	45
CHAPTER 3	
EFFECT OF FINITE BOUNDARY LAYER ON THE IONIZATION INSTABILITY IN NONEQUILIBRIUM MHD GENERATORS	46
3.1 Introduction	46
3.2 Electron Distribution Function	48
3.3 Growth Rate of Instability	52
3.4 Discussion	58
3.5 Conclusions	62
FIGURE CAPTIONS	63

CHAPTER 4	
POWER OUTPUT OF AN MHD GENERATOR: EFFECT OF IONIZATION INSTABILITY AND BOUNDARY LAYER *	65
4.1 Introduction	65
4.2 Effective Conductivity and Power Output	66
4.3 Evaluation of the Fluctuation in Conductivity	70
4.4 Results and Discussion	76
FIGURE CAPTIONS	79
CHAPTER 5	
EFFECT OF DIFFUSION ON ELECTRON DENSITY ACROSS THE NONEQUILIBRIUM MHD CHANNEL	80
5.1 Introduction	80
5.2 Diffusion Equation	84
5.3 Discussion	87
5.4 Conclusion	92
FIGURE CAPTIONS	94
REFERENCES	96
BIODATA	99
REPRINTS/PREPRINTS	100