TRANSIENT EFFECTS IN

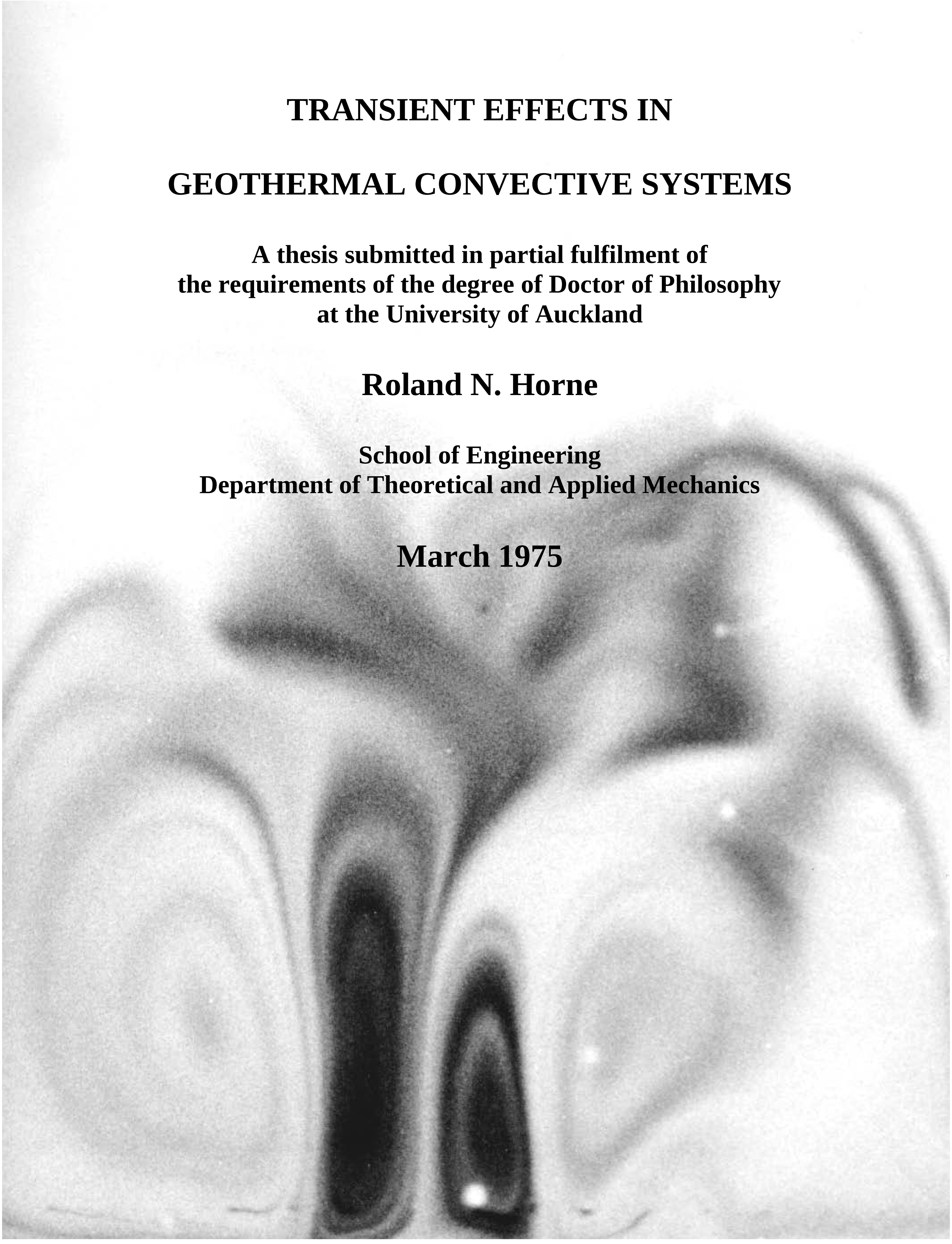
GEOTHERMAL CONVECTIVE SYSTEMS

A thesis submitted in partial fulfilment of the requirements of the degree of Doctor of Philosophy at the University of Auckland

Roland N. Horne

School of Engineering
Department of Theoretical and Applied Mechanics

March 1975



(blank)

ABSTRACT

This work is a detailed analysis of the transient behaviour of geothermal convective systems. The flow in these systems is found to be fluctuating or regular oscillatory in a simplified two-dimensional model and these unsteady effects persist when the model is refined to include the concepts of temperature dependent viscosity and fluid withdrawal and recharge. The analysis is extended into three dimensions to verify this behaviour. The supplementary exploration of added salinity gradients indicates transient effects of a different kind in this case. The examination of the porous insulator problem confirms the results of previous authors and verifies the viability of the numerical methods that are used throughout the investigation.

ACKNOWLEDGEMENTS

During the last three years the research that has lead to the presentation of this thesis has been assisted by many people. Most credit is due to my supervisor Dr M.J. O'Sullivan who originally inspired the work and has given much advice since.

The Hele-Shaw apparatus used for the experimental work was borrowed from the Department of Civil Engineering and I am grateful for the assistance of technicians Mr C. Raymond and Mr D. Browne, who helped set it up. I am also indebted to Dr John Meikle and the Auckland Industrial Development Division of the D.S.I.R. for the use of their AGA Thermovision camera. The many photographs taken of these experiments were processed by the Photographic departments of the University of Auckland and the A.I.D.D.

Referencing of earlier publications has been facilitated by the library staff of the School of Engineering, particularly Mrs Alison Reid who helped with several translations from French.

A large portion of this work has depended on the extensive use of computer facilities and the aid of the University of Auckland Computer Centre is appreciated. Most of the calculations were performed on the Burroughs B6700 although early development of the programs was done on the IBM 1130 in 1972.

Parts of the work have appeared previously in Horne and O'Sullivan (1974 a and b) and I am indebted to Ms Kitty Young for the preparation of these two papers.

I would also like to thank Professor C.M. Segedin of the Department of Theoretical and Applied Mechanics, Associate Professor M.P. Hochstein of the Department of Geology, University of Auckland, and Dr Ian Donaldson and Dr Robin Wooding of the D.S.I.R., Wellington for the various helpful discussions I have had with each of them.

The text has been typed by Ms Mamie Long who was fortunately persuaded out of her retirement from such tasks.

CONTENTS

NOTATION

All variables and operators used are defined when they first appear in the text, however the commonly used ones are summarised here.

Dimensional Variables

b_1, b_2, b	- Coefficients of variation of viscosity ν with temperature T.
g	- The gravitational acceleration
k	- The permeability of the medium
m	- The porosity of the medium
P	- The dynamic pressure
S	- The mean flux velocity
t	- Time
$\underset{\sim}{x}$	- Spatial dimensions
C	- Concentration of dissolved mineral salts
C_o, C_1	- Minimum and maximum values of C
$\underset{\sim}{F}$	- Buoyancy force
K_{ij}	- Thermal dispersion tensor
T	- Temperature
T_o, T_1	- Maximum and minimum values of T
α	- Thermal expansion coefficient
α_1, α_2	- Linear and quadratic thermal expansion coefficient
α'	- Solutal expansion coefficient
β_1, β_2, β_3	- Viscosity variation coefficients
κ	- Thermal. diffusivity
κ'	- Solutal diffusivity
χ	- Ratio of volumetric heat capacities
μ	- Dynamic viscosity of fluid
ν	- Kinematic viscosity of fluid
ν_o	- Low temperature value of ν
ρ	- Density of fluid
ρ_o	- Low temperature value of ρ

Non-Dimensional Variables

f	- Fraction of lower boundary heated
q	- Strength of fluid sink
$\underset{\sim}{u}$	- Velocity due to flow into sink
$\underset{\sim}{u}'$	- Velocity not due to flow into sink
C	- Concentration

Nu	-	Nusselt number
P	-	Pressure
R	-	Rayleigh number
S	-	Solutal Rayleigh number
$\underset{\sim}{U}$	-	Fluid velocity
χ	-	Spatial dimensions
γ	-	Buoyancy ratio
AX, ΔY	-	Spatial increments
$\Delta\tau$	-	Time increment
ν'	-	Viscosity
ρ'	-	Density
θ	-	Temperature
ψ	-	Stream function
θ	-	Vector potential
τ	-	Time

<u>Operators</u>

δ	-	Jacobian
∇^2	-	Laplacian