CONTENTS

PREFACE ix
1. INTRODUCTION 1

2. METHODS OF OBSERVATION OF A SINGLE AVALANCHE
2.1. Cloud chamber method 3
2.1.1. Principle of the method 3
2.1.2. Data obtained by the cloud chamber 6
2.1.2.1. Drift velocity of electrons 6
2.1.2.2. Thermal velocity of electrons 6
2.1.3. Experimental details 8
2.1.3.1. The chamber 8
2.1.3.2. The voltage pulse 10
2.1.4. Sensitivity for detection of an avalanche 12
2.2. Electrical method 13
2.2.1. Principle of the method 13
2.2.2. The carrier currents of an avalanche 14
2.2.2.1. Current of electrons 14
2.2.2.2. Current of positive ions 14
2.2.2.3. Current of negative ions 15
2.2.2.4. Current of an avalanche started by an α-particle 17
2.2.2.5. Avalanche currents in inhomogeneous fields.. 19
2.2.3. The voltage pulse produced by the carrier currents .. 21
2.2.4. Experimental details 27
2.2.4.1. The discharge gap 27
2.2.4.2. The voltage source 28
2.2.4.3. Electronic device 29
2.2.4.4. The production of start electrons 35
2.2.5. Sensitivity of the electrical method 38
2.3. Optical method 40
2.3.1. Principle of the method 40
2.3.2. Experimental details 42
2.3.3. Sensitivity of the optical method 46

3. RESULTS OF EXPERIMENTS ON AVALANCHES
3.1. Time constant of the growth of electrons and photons .. 50
3.1.1. Growth of electrons 50
3.1.2. Growth of photons 53
3.1.3. Anomalous electron components in O_2 and air .. 54

3.2. Thermal diffusion of electrons 55
3.3. Statistics of avalanche amplification 58
3.4. Drift velocity of carriers.. 62
3.4.1. Drift velocity of electrons 62
3.4.1.1. Methods 62
3.4.1.2. Results 64
3.4.2. Drift velocity of positive ions 66
3.4.3. Drift velocity of negative ions 72
3.5. Determination of the ionization coefficient α 72
3.5.1. Determination from the statistical distribution of the carrier number 73
3.5.2. Determination from the time constants of the current 74
3.5.3. Determination from the height of the electron component 76
3.6. Determination of the attachment coefficient η 77
3.7. Avalanches of high amplification. Space charge effects .. 78
3.7.1. General remarks 78
3.7.2. Observations of the space charge influence on amplification 79
3.7.2.1. Distribution of carrier number n 79
3.7.2.2. Rise time constant of the electron component 79
3.7.2.3. Measurement of α^* from $RC\,\alpha^* v_+ = 1$ .. 81
3.7.2.4. Transition time 82
3.7.2.5. Enlargement of the head of the avalanche .. 83
3.7.3. Discussion of the observations 84

4. AVALANCHES WITH SUCCESSORS

4.1. General remarks 90
4.2. Avalanches with successors, produced by photoeffect at the cathode; number of primary electrons $n_0 \gg 1$.. 90
4.2.1. Electron current 90
4.2.1.1. The primary electrons are produced by a light flash 92
4.2.1.2. The primary electrons are produced by an α-particle 93
4.2.2. Total current 94
4.3. Avalanches with successors, produced by positive ions at the cathode; $n_0 \gg 1$ 98
4.4. Avalanches with successors in an inhomogeneous field .. 102
4.5. Avalanches with successors, started by one electron; $n_0 \sim 1$ 102

4.5.1. Theoretical considerations 102
4.5.1.1. Probability for the production of secondary electrons 103
4.5.1.2. Probability for the production of a given number of generations 104
4.5.1.3. Mean number of avalanches per generation and the current of series of avalanches .. 105
4.5.2. Experiments 109
4.5.3. Fluctuation of the generation time T_g 110

5. BREAKDOWN
5.1. Generation mechanism 114
5.1.1. Experimental facts 114
5.1.2. Theoretical considerations 116
5.1.3. Comparison of the results with theory; discussion .. 120
5.2. Streamer Mechanism or Kanalaufbau.. 124
5.2.1. Experiments in the cloud chamber 124
5.2.1.1. Results 124
5.2.1.2. Discussion of the results. Nature of streamers 126
5.2.2. Experiments with oscilloscopic methods on single avalanches 132
5.2.2.1. General results 132
5.2.2.2. Probability of breakdown 133
5.2.2.3. Time of streamer development (T_K) 135
5.2.2.4. Rise time constant of the current growth (τ_K) 136
5.2.3. Experiments with the oscilloscopic method on avalanches started by $n_0 \gg 1$ 136
5.2.3.1. General results 136
5.2.3.2. The critical carrier number 137
5.2.3.3. Time of streamer development (T_K) 138
5.2.3.4. Rise time constant of the current growth (τ_K) 139
5.2.3.5. Discussion of results 139
5.3. Transition of breakdown types 140
5.4. Breakdown in air and other electronegative gases 143
5.5. Spatial expansion of the discharge 148

6. APPLICATIONS
6.1. Plate counter 154
6.1.1. Avalanche counter 154
6.1.2. Spark counter 154
6.1.3. Special qualities of these counters 155
6.1.4. Spark chamber as particular detector 157

CONTENTS

APPENDIX

7. THEORY OF THE TRANSIENT CURRENT OF A GAS DISCHARGE

7.1. General considerations 161

7.2. The current of a series of avalanches with photosuccessors, started with n_0 primary electrons as a δ-function; $n_0 \gg 1$ 164

7.2.1. General solution 164

7.2.2. Current in the external circuit 166

7.2.2.1. Electron current 167

7.2.2.2. Ion current and the total current 170

7.3. The mean current of a series of avalanches with photosuccessors, started by one electron 171

7.4. The current of a series of avalanches with photosuccessors, started by $i_0(t)$ 173

7.4.1. The primary electron current is produced by a light flash with finite duration.. 173

7.4.2. The primary electron current is produced by a constant illumination 175

7.5. The primary electrons are spatially distributed in the gap at $t = 0$ 178

7.6. The current of a series of avalanches with successors produced by ion impact on the cathode 180

7.7. The electron current of an avalanche with a delayed production of electrons 183

INDEX 189

ERRATA

Page 68. Second line of legend should read: × transit time method[3]

Page 77. Equation at top of page should read: $I_-(T_-) = \frac{\varepsilon}{T_-}\frac{\bar{\rho}_0 d}{\alpha d} \ldots$

Page 104. Equation, line 19, should read $\overline{(v-\bar{v})^2} \ldots$

Page 105. Third line of legend should read: ent on v; parameter: $\mu \ldots$

Page 114. First line should read: streamer mechanism . . .

Page 140. Sixth line from bottom should read: mechanism will then go on, if $1/\gamma \geqslant \bar{n}_{\text{crit}} \ldots$

Page 165. Equation 7.22 should read: $i_-(0, \xi) = f(\xi)\frac{\varepsilon n_0}{T_-} g(\xi) \ldots$

Page 167. Line 13 should read: *First generation* $0 \leqslant t \leqslant T_-$

Page 176. Line 16 should read: $\sum_{\nu=0}^{\infty} \ldots$.

Page 179. Equation 7.80 should read: $I_-(t) = \frac{\varepsilon}{T_-} Fd\left\{\rho_0 \int_{v_- t}^{d} \ldots\right.$

Page 190. Line 5, column 1, should read: N_2, O_2, air, ether, 63–67
Line 51, column 1, should read: of a Townsend discharge, 90, 161

Page 191. Line 37, column 2, should read: changing $\gamma_{Ph} \ldots$