Table of Contents

Abstract	i
Acknowledgements	ii
Table of Contents	iii
List of Figures	viii
List of Tables	xx
Nomenclature	xxii

Chapter 1: Introduction

1

Chapter 2: Development of a Windows[™] application for signal processing and control

2.1	Introduction	14
2.2	Need for a portable PC based system	14
2.3	Design of the software package	15
2.4	Control of proprietary hardware	19
	2.4.1 GPIB (IEEE-488) software and data capture	19
2.5	Signal processing techniques	24
	2.5.1 Calculation of ultrasonic attenuation	25
	2.5.2 Calculation of ultrasonic phase velocity	27
	2.5.3 Distilled water reference measurements	29
	2.5.4 Software for signal processing	31
	2.5.5 Optimised FFT routine	35
2.6	Summary and conclusion	36

Chapter 3: Development of test-cell hardware and instrumentation for temperature control

3.1	Introduction	38
3.2	Specification	39
3.3	Choice of transducer technology	40
3.4	Choice of test-cell materials for industrial application	44
	3.4.1 A prototype PMMA test-cell	44
	3.4.2 Development of a stainless steel test-cell	47
3.5	Acoustic isolation from test-cell body	47
3.6	Development of a modular test-cell	49
3.7	Temperature control	52
	3.7.1 Choice of technology for temperature control	53
	3.7.2 Implementation of temperature controlled test-cell	55
	3.7.3 Control strategies	65
	3.7.4 Acquisition of system response	68
	3.7.5 Three term PID controllers	71
	3.7.6 Design of temperature controller hardware	78
	3.7.7 Switched-mode power supply design	80
	3.7.8 Sampling the system temperature	84
	3.7.9 Calibration of the temperature controller	85
	3.7.10 Temperature controller performance	86
3.8	Conclusions	89

4.1	Introduction	90
4.2	Copper(II) sulphate pentahydrate crystallization	91
4.3	Nucleation of copper(II) sulphate	93
4.4	Copper(II) sulphate solution concentration measurements	95
4.5	Experimental apparatus	97
4.6	Characterisation of the continuous phase	98
4.7	Recovery and analysis of crystals	107
4.8	Crash crystallization of copper(II) sulphate	108
	4.8.1 Comparison of experimental and modelled data	112
4.9	Temperature controlled crystallization from saturated solution	118
	of copper(II) sulphate pentahydrate	
	4.9.1 Effect of batch time on metastable zone width	126
4.10	Observations of ripening processes in crystallizing solutions of	127
	copper(II) sulphate	
4.11	Seeded crystallization from saturated solution of copper(II)	132
	sulphate pentahydrate	
	4.11.1 Production of seed crystals	133
	4.11.2 Seeded crystallization experiments	136
	4.11.3 Estimation of product crystal size	144
4.12	Summary and conclusions	150

Chapter 5: Application to industrial milling processes

5.1	Introduction	152
5.2	Commercial dyes	153
5.3	Specific industrial system	154
5.4	Determination of the thermophysical parameters for modelling	157
5.5	Ultrasonic measurements	164
5.6	Comparison of experimental and modelled data	171
5.7	Summary	177
5.8	Conclusions	179

Chapter 6: Studies of other industrial particulate mixtures

6.1	Introduction	180
6.2	Crystallization of an orange reactive dye-stuff	181
6.3	Monitoring of a barium sulphate precipitation titration	190
6.4	The long term monitoring of colloidal stability in commercial	196
	detergents	
6.5	Variability in the PSD on the modelling and measurement of	198
	aqueous titanium dioxide dispersions	
6.6	Conclusions	203

7.1	Introduction	205
7.2	Summary	207
7.3	Discussion	213
7.4	Conclusions	215
7.5	Further work	218
References		225
Appendix A: Additional data and thermophysical properties		234
Appendix B: Photographs of test-cells and temperature control		238
hardware		
Арре	endix C: A brief tour of the Windows [™] application software	240
Appendix D: Published papers		253