

PART I

TABLE OF CONTENTS

	<u>page:</u>
1.1 BRIEF HISTORY OF PROBLEMS ASSOCIATED WITH STEAM WETNESS	1 - 1
1.2 STATE OF THE ART OF WET STEAM TURBINES	1 - 10
1.2.1 Conventional Low-Pressure Condensing Turbines	1 - 10
1.2.1.1 General Remarks	1 - 10
1.2.1.2 Design of the LP Turbine; Expansion Line	1 - 10
1.2.1.3 Effects and Handling of Moisture in LP Turbines	1 - 11
1.2.2 Nuclear High-Pressure Wet-Steam Turbines	1 - 16
1.2.2.1 General Remarks	1 - 16
1.2.2.2 Design of the HP Turbine	1 - 18
1.2.2.3 Process of Expansion in HP Turbines	1 - 24
1.2.2.4 Effects and Handling of Moisture in HP Turbines	1 - 26
1.3 PROPERTIES OF WET STEAM	1 - 28
1.3.1 Composition, Vapour Pressure	1 - 28
1.3.2 Physical Data of Steam and Water	1 - 29
1.3.2.1 General Data	1 - 29
1.3.2.2 Equations of State	1 - 30
1.3.2.3 Other Property Data	1 - 32
1.3.3 Structure of Wet Steam	1 - 49
1.3.4 Supersaturation and Subcooling	1 - 54
1.4 BEHAVIOUR OF WET STEAM	1 - 60
1.4.1 Thermodynamics of Steam/Droplet Mixtures	1 - 60
1.4.1.1 Critical Droplet Size	1 - 60
1.4.1.2 Molecular Clusters in the Vapour Phase	1 - 61
1.4.2 Heat Transfer in Wet Steam	1 - 64
1.4.2.1 Temperature within Droplets; Flashing	1 - 64
1.4.2.2 Heat Transfer between Vapour and Droplets	1 - 66
1.4.2.3 Heat Transfer to Walls	1 - 67
1.4.2.4 Thermal Lag Effects in Wet Steam	1 - 68
1.4.3 Mechanics of Steam/Droplet Mixtures	1 - 70
1.4.3.1 Drag Forces, Terminal Settling Speed	1 - 70
1.4.3.2 Coagulation	1 - 72
1.4.3.3 Impact, Deposition, Rebounding	1 - 76
1.4.3.4 Droplet Deformation and Break-Up	1 - 77
1.4.4 Motion of Liquid on Channel Walls	1 - 80
References to Part 1	1 - 83

P A R T 1

I N T R O D U C T I O N1.1 BRIEF HISTORY OF PROBLEMS ASSOCIATED WITH STEAM WETNESS

The problems of wet steam are almost as old as steam turbines. Why ?

At any time during the early history of steam turbine development there existed, as we all know, an upper limit of live-steam temperature compatible with the strength of available and reliable structural materials. This temperature limit barred the most straightforward way of increasing the efficiency of steam turbine plants. It was therefore natural that steam turbine designers tended from early days to increase the efficiency (i.e. to raise the mean temperature level \bar{T} of heat addition in the boiler) by increasing the turbine admission pressure p_0 , as illustrated in Fig. 1.1.1, (a) and (b). It turned out soon however that limits were set for p_0 , too. Astonishingly, the limits on live-steam pressure were not set by the high-pressure, high-temperature parts of the boiler or of the turbine; they were rather set by the fact that the wetness fraction $1 - X_E$ at the turbine exit increased, parallel with p_0 , to dangerous levels.

With increasing the exit wetness, two problems were encountered. First, severe erosion was found to occur in the blading at the low-pressure end of the turbine. After a few months or few years of service, the low-pressure moving blades were damaged (roughened, pitted or even mutilated) and had to be replaced. In order to avoid grave erosion damage, a limitation of exit wetness to about 12 percent became and remained compulsory, even though considerable improvements in design and construction were made as