

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references.....	10
3 Terms and definitions	10
4 Glossary of symbols and abbreviations	13
4.1 General.....	13
4.2 Acronyms used in this standard	13
4.3 Symbols used in this standard	15
5 General models and assumptions	18
5.1 Constituents of up and down times	18
5.2 Introduction to models and assumptions	19
5.3 State-transition approach	20
5.4 Model and assumptions for non-repairable individual items	22
5.5 Assumptions and model for repairable individual items.....	23
5.5.1 Assumption for repairable individual items	23
5.5.2 Instantaneous repair	24
5.5.3 Non-instantaneous repair	25
5.6 Continuously operating items (COI) versus intermittently operating individual items (IOI).....	26
6 Mathematical models and expressions	27
6.1 Systems.....	27
6.1.1 General	27
6.1.2 Availability related expressions	29
6.1.3 Reliability related expressions	36
6.1.4 Mean operating time between failures [192-05-13] and mean time between failures.....	40
6.1.5 Instantaneous failure rate [192-05-06] and conditional failure intensity (Vesely failure rate).....	41
6.1.6 Failure density and unconditional failure intensity [192-05-08].....	44
6.1.7 Comparison of $\lambda(t)$, $\lambda_V(t)$, $z(t)$ and $f(t)$ for high and small MTTRs	47
6.1.8 Restoration related expressions	47
6.2 Non-repairable individual items.....	49
6.2.1 General	49
6.2.2 Instantaneous availability [192-08-01].....	50
6.2.3 Reliability [192-05-05]	50
6.2.4 Instantaneous failure rate [192-05-06]	51
6.2.5 Mean failure rate [192-05-07]	52
6.2.6 Mean operating time to failure [192-05-11].....	53
6.3 Repairable individual items with zero time to restoration	54
6.3.1 General	54
6.3.2 Reliability [192-05-05]	54
6.3.3 Instantaneous failure intensity [192-05-08].....	56
6.3.4 Asymptotic failure intensity [192-05-10]	58
6.3.5 Mean failure intensity [192-05-09].....	59
6.3.6 Mean time between failures (see 3.3)	60

6.3.7	Mean operating time to failure [192-05-11].....	60
6.3.8	Mean operating time between failures [192-05-13].....	61
6.3.9	Instantaneous availability [192-08-01], mean availability [192-08-05] and asymptotic availability [192-08-07]	61
6.3.10	Mean up time [192-08-09]	61
6.4	Repairable individual items with non-zero time to restoration.....	62
6.4.1	General	62
6.4.2	Reliability [192-05-05]	62
6.4.3	Instantaneous failure intensity [192-05-08].....	64
6.4.4	Asymptotic failure intensity [192-05-10]	67
6.4.5	Mean failure intensity [192-05-09].....	68
6.4.6	Mean operating time to failure [192-05-11].....	69
6.4.7	Mean time between failures (see 3.3)	70
6.4.8	Mean operating time between failures [192-05-13]	71
6.4.9	Instantaneous availability [192-08-01].....	71
6.4.10	Instantaneous unavailability [192-08-04].....	73
6.4.11	Mean availability [192-08-05].....	74
6.4.12	Mean unavailability [192-08-06].....	76
6.4.13	Asymptotic availability [192-08-07]	78
6.4.14	Asymptotic unavailability [192-08-08].....	78
6.4.15	Mean up time [192-08-09]	79
6.4.16	Mean down time [192-08-10]	81
6.4.17	Maintainability [192-07-01]	82
6.4.18	Instantaneous repair rate [192-07-20].....	84
6.4.19	Mean repair time [192-07-21]	86
6.4.20	Mean active corrective maintenance time [192-07-22].....	87
6.4.21	Mean time to restoration [192-07-23]	88
6.4.22	Mean administrative delay [192-07-26]	89
6.4.23	Mean logistic delay [192-07-27].....	90
Annex A (informative)	Performance aspects and descriptors	91
Annex B (informative)	Summary of measures related to time to failure	92
Annex C (informative)	Comparison of some dependability measures for continuously operating items	95
Bibliography		97
Figure 1 – Constituents of up time.....		18
Figure 2 – Constituents of down time.....		19
Figure 3 – Acronyms related to failure times		19
Figure 4 – Simple state-transition diagram.....		21
Figure 5 – Sample realization (chronogram) related to the system in Figure 4		22
Figure 6 – State-transition diagram of a non-repairable individual item		22
Figure 7 – Sample realization of a non-repairable individual item		23
Figure 8 – State-transition diagram of an instantaneously repairable individual item		24
Figure 9 – Sample realization of a repairable individual item with zero time to restoration		25
Figure 10 – State-transition diagram of a repairable individual item.....		25

Figure 11 – Sample realization of a repairable individual item with non-zero time to restoration	26
Figure 12 – Comparison of an enabled time for a COI and an IOI	26
Figure 13 – Equivalent operating time for IOI items	27
Figure 14 – State-transition graph for a simple redundant system	27
Figure 15 – Markov graph for a simple redundant system	28
Figure 16 – Evolution of the state probabilities related to the Markov model in Figure 15	28
Figure 17 – Evolution of $A(t)$ and $U(t)$ related to the Markov model in Figure 15	29
Figure 18 – Evolution of the $Ast_i(0, t)$ related to the Markov model in Figure 15	31
Figure 19 – Instantaneous availability and mean availability of a periodically tested item	33
Figure 20 – Example of a simple production system	34
Figure 21 – Evolution of $A(t)$ and $K(t)$	35
Figure 22 – Illustration of a system reliable behaviour over $[0, t]$	36
Figure 23 – Illustration of a system reliable behaviour over time interval $[t_1, t_2]$	37
Figure 24 – State-transition and Markov graphs for reliability calculations	37
Figure 25 – Evolution of the state probabilities related to the Markov model in Figure 24	38
Figure 26 – Evolution of $R(t)$ and $F(t)$ related to the Markov model in Figure 24	39
Figure 27 – Evolution of $Ast_i(0, t)$ related to the Markov model in Figure 24	40
Figure 28 – Time between failures versus operating time between failures	40
Figure 29 – Comparison between $\lambda(t)$ and $\lambda_V(t)$ related to the model in Figure 24	43
Figure 30 – Comparison between $z(t)$ and $f(t)$	46
Figure 31 – Comparison of $\lambda(t)$, $\lambda_V(t)$, $z(t)$ and $f(t)$ for high and small values of MTTRs	47
Figure 32 – Illustration of reliable behaviour over $[t_1, t_2]$ for a zero time to restoration individual item	55
Figure 33 – Sample of possible number of failures at the renewal time t	56
Figure 34 – Illustration of reliable behaviour over $[t_1, t_2]$ for a non-zero time to restoration individual item	62
Figure 35 – Evolution of $R(t, t + 1/4)$	64
Figure 36 – Sample of possible number of failures at the renewal time t	64
Figure 37 – Evolution of the failure intensity $z(t)$	66
Figure 38 – Evolution of the mean failure intensity $z(t, t + 1/4)$	69
Figure 39 – Illustration of available behaviour at time t for a non-zero time to restoration individual item	71
Figure 40 – Evolution of the instantaneous availability $A(t)$	73
Figure 41 – Illustration of unavailable behaviour at time t for a non-zero time to restoration individual item	73
Figure 42 – Evolution of the instantaneous unavailability $U(t)$	74
Figure 43 – Evolution of the mean availability $\bar{A}(t, t + 1/4)$	76
Figure 44 – Evolution of the mean unavailability $\bar{U}(t, t + 1/4)$	77
Figure 45 – Sample realization of the individual item state	80
Figure 46 – Plot of the up-time hazard rate function $\lambda_U(t)$	80
Figure 47 – Evolution of the maintainability $M(t, t + 16h)$	84
Figure 48 – Evolution of the lognormal repair rate $\mu(t)$	86

Figure A.1 – Performance aspects and descriptors91

Table B.1 – Relations among measures related to time to failure of continuously
operating items92

Table B.2 – Summary of characteristics for some continuous probability distributions of
time to failure of continuously operating items93

Table B.3 – Summary of characteristics for some probability distributions of repair time94

Table C.1 – Comparison of some dependability measures of continuously operating
items with constant failure rate λ and restoration rate μ_R 95