J Pharm Innov (2011) 6:125–141
DOI 10.1007/s12247-011-9108-4

RESEARCH ARTICLE

A Fuzzy Logic Model of Deionised and Water for Injection Systems for Sizing and Capacity Assessment Under Uncertainty

Frank Riedewald · Edmond Byrne · Kevin Cronin

Published online: 29 July 2011

Abstract The operating performance of deionized and water for injection (DI/WFI) distribution systems can be difficult to analyse due to the highly variable demand that is drawn from these systems, a situation compounded by schedule uncertainties. This paper presents a fuzzy logic (FL) model of a typical DI/WFI system simulating schedule uncertainties in the opening and closing events of the offtake valves based on operator behaviour, e.g. tiredness of the operators. The model utilises discrete-event simulation to calculate the demand profile of the distribution system and a continuous simulation to compute the variation of the level in the storage tank. It is shown that the FL model may be useful in the design of new DI/WFI systems if little historical data are available.

Keywords WFI · DI · Capacity extension · Fuzzy logic · Uncertainty · High-purity water

Nomenclature

$act_{i,k}$	Opening/closing event of valve i, k
$act_{i,k}^{Wait}$	Opening/closing event of valve i, k waiting to be served
f_{Div}	Diversity factor
i	Integer parameter
k	Integer parameter
n	Integer parameter
n_{op}	Number of operators
$n_{op,min}$	Minimum number of operators
$Pr_{i,k}$	Priority rules for each $act_{i,k}$
t	Time (h:m:s)
tap_i	Valve of offtake point (tap) i along the distribution system
$t_{2,j}^{B}$	Beginning of core break (h:m:s)
$t_{3,j}^{B}$	End of core break (h:m:s)
$t_{i,k}^{close}$	Scheduled closing time for each $act_{i,k}$ (h:m:s)
$t_{i,k,new}^{close}$	New closing time for each $act_{i,k}$ (h:m:s)
$t_{i,k}^{D}$	Time delay for each $act_{i,k}$ (h:m:s)
$t_{i,k}^{D,De}$	Defuzzified time delay for each $act_{i,k}$ (%)
$t_{i,k}^{Delay,1}$	Time delay caused by operator for each $act_{i,k}$ (h:m:s)
$t_{i,k}^{Delay,2}$	Time delay caused by operator for each $act_{i,k}$ (h:m:s)
$t_{i,k}^{Delay,NoOp.}$	Delay caused by no operator being available for $act_{i,k}$ (h:m:s)
$t_{i,k}^{min,D}$	Minimum duration of each $act_{i,k}$ (h:m:s)
$t_{i,k}^{open}$	Scheduled opening time for each $act_{i,k}$ (h:m:s)
$t_{i,k,new}^{open}$	New closing time for each $act_{i,k}$ (h:m:s)
$t_{i,k,new}^{open,R1}$	New opening time due to influence of rule 1 (h:m:s)
$t_{i,k,new}^{open,R4}$	New opening time due to influence of rule 4 (h:m:s)
$t_{i,k,new}^{open,R5}$	New opening time due to influence of rule 5 (h:m:s)
t^{sim}	Simulated time (s)

F. Riedewald (✉) · E. Byrne · K. Cronin
Department of Process and Chemical Engineering,
University College Cork,
Cork, Ireland
e-mail: frankriedewald@gmail.com