Weiterentwicklung und Verifikation/Validierung von Rechenprogrammen für die Reaktorsicherheit

Ein Bericht zum Stand der Entwicklung und zur wissenschaftlichen Weiterführung von Arbeiten der staatlich geförderten Reaktorsicherheitsforschung

im Auftrag des Bundesministeriums für Wirtschaft und Technologie (BMWi)
herausgegeben vom Projektträger Reaktorsicherheitsforschung des BMWi

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@:1 V*5.9<8*-'0-'T<.8$*9K$<'7O%.EF.'/$' ..... 1>

@:1:1]-&$99*$%.'/0-'+$7<587_78$5$' ..... 1>

@:1:1:1 (-5O-'$'8$'*5 I$%K.'& ..... 1>

@:1:1:3 M$EL%<8$'5-&99 6N% P-F%9$*8.'/$' ..... 1@

@:1:3]-&99'8#*EL9.'/ 6N%<.79$/.'/7NK$%7EF%$*8$'&$ \%$*/''*77$ 1I

@:1:3:1 P$<L8-%&%.ELK$FB98$% K$* ($%'7EF5$9A$' 1I

@:1:3:3 W'8$/%*8B8 .'& Y*EF8F$*8 0-' V*EF$%F$*87K$FB98$%'<.7 V8<F9K$8-' 1i

@:1:3:@ V8<F9K$8-'78%.L8.%$' K$* *'#*%L.'/$' 0-'<.,$' 31

@:1:@]-&99'8#*EL9.'/ A.% V8%.L8.%A.0$%9B77*/L$*8 O<77*0$% (-5O-'$'8$' 33

@:1:@:1 P-F%9$*8.'/$' ..... 3@

@:1:@:3 Y%.ELK$FB98$% 3m

@:1:@:@ V*EF$%F$*87K$FB98$% 3n

@:3 T%.EF5$EF<'*7EF$ ^'<9_7$5$8F-&$' 3d

@:@]-&99'8#*EL9.'/ A. b$%L78-66$*/$'7EF<68$' ..... @@

@:I a$%78)%.'/76%$*$ b$%L78-66O%N6.'/ ..... @m

@:= o<9*6*A*$%.'/75$8F-&$' 6N% ^'<9_7$#$%LA$./$.'& T$'.8A$% ..... @d

@:m a.7<55$'6<77.'/A.5 R-%7EF.'/7K$%$*EF
!(-5O-'$'8$'7*EF$%F$*8 .'& W'8$/%*8B87K$#$%8.'/; I1

@:n M*8$%<8.%A.5 R-%7EF.'/7K$%$*EF
!(-5O-'$'8$'7*EF$%F$*8 .'& W'8$/%*8B87K$#$%8.'/; ..... I@

r0:@ U-8$'A*<9 0-' ZRY2Z-&$7 ..... 1m

r0:l]-&$99F*$%<%EF*$' 6N% $*'OF<7*/$ V8%)5.'/$' 1n

r0:=]-&$99F*$%<%EF*$' 6N% 5$F%OF<7*/$ V8%)5.'/$' 1m

r0:m D.5$%*7EF$ I$%6<F%$' 1n

r0:n '57$8A.'/ &$% *'2 .'&]$F%OF<7$'5-&99*' ZRY2Z-&$7 ..... 1n

r0:i o<9*8B87L-'8%-99$ ..... 1i>

r0:d a.LN'68*/$ ^'#$'&.'/7K$%$*EF$.'& Y$6*A*8$0-' ZRY2I$%6<F%$' 1i1

r0:1> D-8#$'&*/$ b$*8$%$'8#*EL9.'/$' 0-' ZRY2I$%6<F%$' ..... 1i=

r0:11 a.7<55$'6<77.'/A.5 R-%7EF.'/7K$%$*EF
!(NF9L%$*79<.6 ZRY2Z-&$7; 1ii

r0:13 M*8$%<8.%A.5 R-%7EF.'/7K$%$*EF (NF9L%$*79<.6 ZRY2Z-&$7 ..... 1d1

7 Stör-/Unfallanalyse Sicherheitsbehälter 194

r1 V8<'& &$%]-&$99*$%.'/ <5 T$*7O*$9 Z[Z[VjV 1dm

r3 \%6-%&$%9*EF$ \'8#*EL9.'/7<%K$*8$' ..... 3>=

r3:1 \%F)F.'/ &$% ^.77</$/$'<.*/L$*8 0-' o998%5<'<9_7$' ..... 3>m

r3:1:1 T$%$EF'.'/ &$7 Oc2b $%8$7 ..... 3>m

r3:1:3 f-&0$%F<98$' ..... 3>i

r3:1:@ P$7.7O$'7*-'70-%/B'/$.'& *F%$ p<'8*8<8*0$ T$&$.8.'/ 31l

r3:1:l PNEL#*%L.'/L<8<9_8*7EF$% P$L-5K*'<8-%$' .'& 0-' c32I$%K%$'2
'.'/70-%/B'/$' <.6 &<7 ^$%-7-90$%F<98$' .'& &*$ f-&EF$5*$ 31n

r3:1:= ^$%-7-9&%<*'</$C I$%F<98$' 9)79*EF$% .'& .'9)79*EF$% V8-66$ 31i

r3:1:m VO<98O%-&.L8 S^$%-7-9X2I$%F<98$' *' T$8-'%*77$'kM$EL</$' 31d

r3:3 !\e2I$77$9;2VEF5$9A$0$%F<98$' ..... 33>

r3:3:1 Z-%*.52T$8-' b$EF7$9#*%L.'/S]ZZW ..... 33>

r3:3:3 (NF9K<%L$*8 ..... 33=

r3:3 :@ VEF5$9A$<.78%</ <.7&$5 P$<L8-%&%.ELK$FB98$%: 33m

r3:3:l VEF5$9A$2(NF95*88$92b $EF7$9#*%L.'/ SY<5O6$eO9-7*-'X 33d

r3:@ I$%0-9978B'&*/.'/ &$% V8)%6<997*5.9<8*-' ..... 3@1

r3:@:1 HK$%/<'/ 0-' VB88*/.'/A.HK$%F*8A.'/J ^K8%-EL'$' 0-'
(-'&$'7<86*95$' ..... 3@1

r3:@:3 V.5O65-&$99*$%.'/ ..... 3@1

r3:@:@ U<%8*L$98%<'7O-%8*' b<77$% S!7.5O E9-//*'/;X ..... 3@@

b$*8$%$J &.%EF<.7 /$#-998$ +%$'A$' 0-' PEF'O%-/%<55$' KA#: ^'<9_7$5-&99' $%/$K$' 7*EF <.7 &$' 7O$A*$99$' ^'6-%&$%.'/$' &$% ^'#$'&.'/J &*$ $*'$ <&Bp<8$ T$7EF%B'L.'/ <.6 &<7 U%-K9$5 .'& <.6 &*$ /$'<. F*$% '-8#$'&*/$ +$'<.*/L$*8 '*EF8 '.% $%9<.K8 7-'&$%' <.7 +%N'&$' &$% gL-'-5*$ 7-/<% $%6-%&$%8: PEF'O%-/%<55$ KA#: ^'<9_7$5-&$99$ 7-99$' 7- /$'<. .'& 7- .56<77$'& #*$ ')8*/J <K$% 7- $*'6<EF .'& 7- <.6 &<7 L-'L%8 U%-K9$5 A./$7EF'*88$' 7$*'J #*$ 5)/9*EF:

f$&$% PEF'E-&$ 5.77 $*'$ I*$9A<F9 6N% 7*EF /$'-55$' .'$*'/$7EF%B'L8 %*EF8*/$%J 7*EF *' *F%$% +$7<58F$*8 <K$% A.5 G$*9 <.77EF9*$,$'&$% R-%&$%.'/$' $%6N99$': V- 7-99 $*' P$EF$'E-&$ $*'$%7$*87 $*'6<EF .'& 7EF'$99 7$*' .'& #$'*/ PEF'%L<O<A*8B8 K$')8*/$'J<'&$%$%7$*87 \%/$K'*77$ 5*8 /%-,$% +$'<.*/L$*8 .'& Y$8<*98%$.$9*6%':

*'$])/9*EFL$*8 O$%5<'$'8$% I$%K77%.'/ $e*78*$%$'&$% ^'<9_7$8$EF'*L $%/*K8 7*EF <.7 &$' 6-%89<.6$'&$' R-%87EF%*88$' *' &$% W'6-%5<8*-'78$EF'-9-/*$ *5 #$*8$78$' V*'':
Y.%EF *55$% 9$*78.'/76BF*/$%$ PEF'% .'& R-%87EF%*88$ *' &$% V-68#<%$$'8#*EL9.'/ #*%& <.EF *5 T$%$*EF &$% ($%'8$EF'*L $*'$ ^'<9_7$8$EF'*L 5)/9*EFJ &*$ &*$ \66*A*$'A .'& &*$ ^.77</$7*EF$%F$*8 &$% 0-%F<'&$'$' 0$%K$77$%' L<'':

W' &$' 6-9/$'&$' (<O*8$9' #*%& 6N% &*$ <'<9_8*7EF$' R-%7EF.'/7/$K*8 &$% P$<L8-%7*EF$%F$*8 $*'$ (.%AK$7EF%$*K.'/ /$/$K$' .'& $7 #$%&$' &*$ &$%A$*8 $%L$''K<%$' Y$6*A*8$ 7-#*$ &*$ D-8#$'&*/L$*8 &$% b$*8$%$'8#*EL9.'/ <'/$/$K$' .'& K$/%N'&$8:

'$ 8<K$99<%*7EF$ a.7<5$'6<77.'/ 6'&$8 7*EF *5 ^'F<'/J *' &$% .:<: <.EF &*$ ^L%-'_5$.'& &*$ \'8#*EL9$% &$% Z-&$7 A.6*'&$' 7*'&:

3 Komponentensicherheit und Integritätsbewertung

Y*$ W'8$/%*8B8 0-' (-5O-'$'8$' *78 0-' /%.'&9$/$'&$% T$&$.8.'/ 6N% &<7 T<%%*$%$'L-'A$O8 *' &$% P$<L8-%7*EF$%F$*8J .5 7*EF$%A.78$99$'J &<77 L$*'$ P<&*-<L8*0*8B8 *' &*$ ‘5#$98 $'8#$*EF8: PEF'O%-/%<55$.'& ^'<9_7$5-&99 7*'& '-8#$'&*/$ c*%675*88$9 6N% ^.79$/./' .'& V*EF$%F$*87K$#$%8.'/ &$% (-5O-'$'8$': b$*8$%$'8#*EL9.'/ .'& ^'#$'&.'/ 0-' P$EF$'O%-/%<55$' 7O*9' &$7F<9K $*'$ c<.O8%-99$ *5 ^.6/<K$'7O$L8%.5 &$% K$8$*9*/8$' R-%7EF.'/7*'78*.8*-'$': Y$% .56<77$'&$ T$78<'& <' <'<9_8*7EF$' b$%LA$./$' *78 78B'&*/ <'F<'& '$.$% \%L$''8'*77$ <.7 R-%7EF.'/ .'& T$8%*$K7$%6<F%.'/ A.<L8.<9*7*$%$':

Y*$ /%.'&7B8A9*EF$' ^'6-%&$%.'/$' A.5 D<EF#$*7 &$% W'8$/%*8B8 0-' 7*EF$%F$*87%$9$0<'8$' (-5O-'$'8$' .'& V_78$5$' 7*'&*' I-%7EF%*68$'J P*EF89*'*$' .'& P$/$9#$%L$' $'8F<98$': Y*7 R789/.'/$' K*$8$' h$&-EF &*$])/9*EFL$*8*'&*O*&.99% T$8%<EF8$'72.'& I-%/F'7#$*7$' 5*8.'8$%7EF*$&9*EF$' ^'7B8A$':

T$78*55$'&$ ^'6-%&$%.'/$' <' &*$ \'8#*EL9.'/ 0-' PEF'O%-/%<55$' KA#: ^'<9_7$5-&99 *5 T$%$*EF &$% (-5O-'$'8$'7*EF$%F$*8 7*'& &*$ \'8#*EL9.'/ 0$%$*'6<EF8$% T$%$EF'.'/70$%6<F%$' A: T: A.% \%5*889.'/ &$% V8%.L8.%A.0$%9B77*/L$*8 O<77*0$% (-5O-'$'8$'J &*$ b$*8$%$'8#*EL9.'/ 0-' b$%L78-665-&99' .'& I$%7</$'7L%*8$%*$' A.% V*5.9<8*-' &$7 $9<78-2O9<78*7EF$']<8$%*<90$%F<98$'7 .'& &$7 (%*EF'7 7-#*$ &*$ V*5.9<8*-' A$%78)%.'/76%$*$% U%N65$8F-&$' A.% R$F9$%/%),$'K$78*55.'/: Y<A. /$F)%$' <.EF &*$ \%#$*8$%.'/ &$% ^'#$'&.'/7/$K*$8$ 0-' R*'*8$2\9$5$'8$2U%-/%<557_78$5$' A.% V*5.9<8*-' &$7 V8%.L8.%0$%F<98$'7 O<77*0$% (-5O-'$'8$' 7-#*$ 0-' U%-/%<55$' A.% 8F$%5-&_'<5*7EF$' V*5.9<8*-' <8-5<%$% U%-A77 .'& &*$ I<9*&*$%.'/ $'8#*EL$98$% ^'<9_7$5-&99:

RN% &*$ T$#$%8.'/ <L8*0$% (-5O-'$'8$' SA: T: I$'8*9$J (9<OO$'X *'7K$7-'&$%$ K$AN/9*EF R.'L8*-' .'& a.0$%9B77*/L$*8 #$%&$' NK$%#*$/$'& *'/$'*$.%5B,*/$ ^K7EFB8A.'/$' <.6 T<7*7 &$% VO$A*6*L<8*-'$' .'& &$% T$8%*$K7$%6<F%.'/ &.%EF/$6NF%8: RN% &$8<*99*$%8$ R%</$78$99.'/$' 78$F$' O%*'A*O*$99 PEF'#$%LA$./$ A.% I$%6N/.'/: ^'<9_7$5-&99 5N778$' h$&-EF h$ '<EF R%</$78$99.'/ $'8#*EL$98 .'& $%O%-K8 #$%&$':

Y*$ /%.'&9$/$'&$' a.7<55$'FB'/$ A#*7EF$' 0$%$*'6<EF8$' .'& L-5O9e' T$%$EF'.'/70$%6<F%$' 7-#*$ &*$ *'8$%&*7A*O9*'B%$ I$%L'NO6.'/ A#*7EF$' 0$%7EF*$&$'$' R<EF/$K*$8$' 7*'&*' T*9& @21 &<%/$78$998:

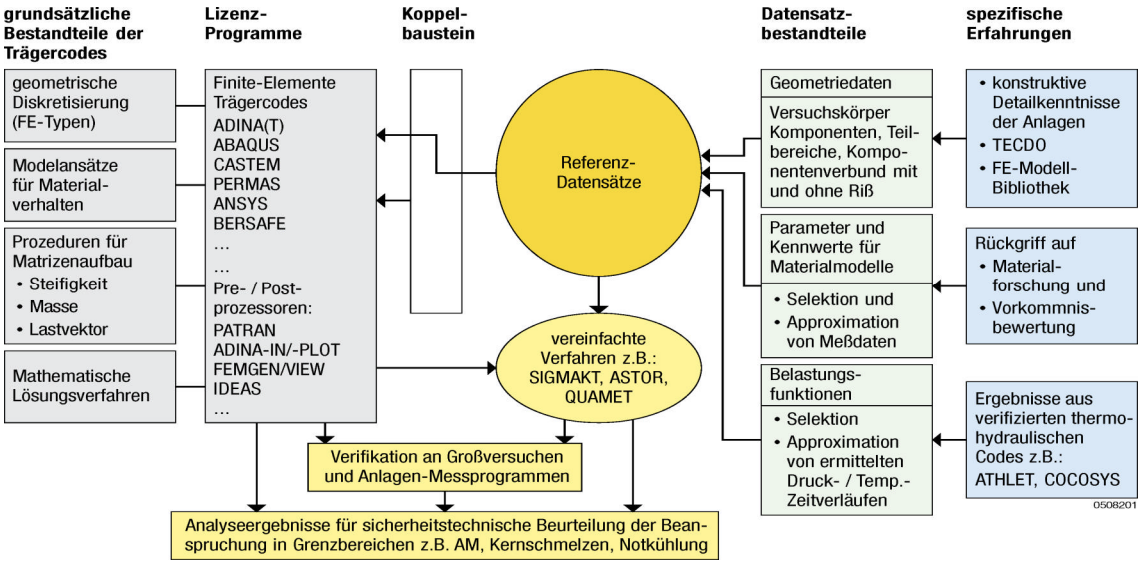


Bild 3-1: +%.'&9</$' 6N% &$' *'7<8A 78%.L8.%5$EF<'*7EF$% ^'<9_7$5$8F-&$'

W5 P<F5$' 0$%7EF*$&$'$% 7*EF$%F$*878$EF'*7EF %$9$0<'8$% 78%.L8.%5$EF<'*7EF$% R%</$78$99.'/$' #$%&$' .'*0$%7$99$ R*'*8$2\9$5$'8$2U%-/%<557_78$5$ SA: T: ^T^ó VJ ^YWD^J ^DVjVX $*'/$7$8A8: ^'#$'&.'/7/$K*$8$ 7*'& A: T: &*$ V*5.9<8*-'&$7 I$%F<98$'7 0-' P*77$' *' T$FB98$%' .'& P-F%9$*8.'/$' .'8$% 5$EF<'*7EF$' .'&8F$%5*7EF$' T$9<78.'/78%<'7*'8$'J &*$ VEFB&*/.'/75$EF<'*LJ &<7 (-50-'$'8$'20$%F<98$' K$* ($%'7EF5$9AK$9<78.'/$' SA: T: b$EF7$9#*%L.'/ A#*7EF$' P$<L8-%2&%.ELK$FB98$% .'& Z-%*.5XJ D-86<997EF.8A5<,'<F5$'J b<77$%7EF9</ .'& \%&KK'J &*$ G%</6BF*/L$*8 0-' V8<F9K$8-'78%.L8.%$' 5*8 .'& -F'$ I-%7O<''.'/ 7-#*$ &<7 I$%F<98$' 0-' T%$''$9$5$'8FN99%-F%$' K$* T$9<78.'/$' *'6-9/$ (NF95*88$92 0$%9.7878)%6B99$': Y*$ $%6-%&$%9*EF$' o<9*6*A*$%.'/75<,'<F5$' 6N% &*$ ^'<9_7$ 2#$%LA$./$ 7-#*$ 6N% &$%$' ^'#$'&$% #$%&$' *5 P<F5$' 0-' T$%$EF'.'/$' A.I$%7.EF$' KA#: *'8$%'<8*-'<9$' I$%/9$*EF7<'<9_7$' &.%EF/$6NF%8: R*'*8$2\9$5$'82U%-/%<557_78$5$ K*8' VEF'*8878$99$'J NK$% &*$ &$% ^'#$'&$% $*/$'$ \'8#*EL9.'/$'<'K*'&$' .'& &$' ^'#$'&.'/7K$%$*EF &$% U%-/%<557_78$5$ $%#$*8$%' L<'': Y*$7K$8%*668 *'7K$7-'&$%$ &*$ T$%NEL7*EF8*/.'/ 7O$A*99%]<8$%*<95-&$99$ A.% V*5.9<8*-'0-' UFB'-5$'$' #*$ P*77$'878$F.'/ .'& ?#<EF78.5 K$* \%5N&.'/J P<8EF$8*'/ -&$%UF<7$'.5#<'&9.'/$' K$* VEF#$*,0-%/B'/$': R$%'$% 7*'& &*$ I$%7</$'7L%*8$%*$' K$*$9<78-2O9<78*7EF$5]<8$%*<90$%F<98$' 7-#*$ (%*EF' *' I$%K*'&.'/ 5*8$eO$%*5$'8$99$' \%L$''8'*77$' A. $%#$*8$%':

b$*8$%F*' *78 6N% 7O$A*$99$ R%</$78$99.'/$' SA: T: V*5.9<8*-' 0-' b<77$%7EF9B/$' *' P-F%9$*8.'/$'J M$EL0$%F<98$' K$* ^.778%)5.'/$'J 78%)5.'/7*'&.A*$%8$ VEF#*'/.'/7<'%$/.'/ 0-' ($%'$*'K<.8$'J ^.6O%<99 69N77*/L$*87/$6N998$% T$FB98$% <.6 T$8-'78%.L8.%$'X $*'$ R9.*&2V8%.L8.%2(-OO9.'/ $%6-%&$%9*EF: Y*$7 $%6-%&$%8 $*'$ b$*8$%$'8#*EL9.'/ 0-' VEF'*8878$99$' A#*7EF$' 8F$%5-F_&%<.9*7EF$' .'& 78%.L8.%5$EF<'*7EF$' V*5.9<8*-'7O%-/%<55$':

T$%$EF'.'/72 KA#: V*5.9<8*-'70$%6<F%$' 7O*9' 7-#-F9 K$* &$% \'8#*EL9.'/ A$%78)%.'/76%$*$% U%N65$8F-&$' <97 <.EF K$* &$%]-&$99*$%.'/ &$% U%N6O9<'.'/ .'& U%N6&.%EF6NF%.'/ 7-#*$ K$* &$% W'8$%O%$8<8*-' &$%]$77$%/$K'*77$ $*'$ K$&$.8$'&$ P-99$: Y<K$* 7*'& 7O$A*6*7EF$ ^'9</$'K$&*'/.'/$'J (-5O-'$'8$'/$-5$8%*$.'& b$%L78-66$*/$'7EF<68$' A.K$%NEL7*EF8*/$':

^.7/<'/7O.'L8 6N% &*$ \'8#*EL9.'/ &*7% T$%$EF'.'/70$%6<F%$' *78 &*$ T$7EF%$*K.'/ $*'$7 OF_7*L<9*7EF$']-&$997 6N% &*$ b$EF7$9#*%L.'/ &$% 7O$A*$99 /$#BF98$' \'$%/*$6-%5 6N% &*$ A$%78)%.'/76%$*$ U%N6.'/ S'98%<7EF<99J]</'$86$9&$%J b*%K$978%-56$9&$%J P)'8/$'78%<F9$'X: Y<K$* 78<'& .'& 78$F8 &*$ b$EF7$9#*%L.'/ &$% \'$%/*$6-%5$' 5*8 b$%L78-66*5O$%6$L8*-'$' SR$F9$%X *5 I-%&$%/%.'& &$% ^L8*0*8B8$'J &*$ '<EF [%8J R-%5J +%),$.'& [%*$'8*$%.'/ T$%NEL7*EF8*/.'/ 6*'&$': Y<7 &$' R$F9$% .5/K'&$ '56$9& S]*L%-/$6N/$J VO<''.'/72 .'& */$'7O<''.'/7A.78<'&X 5.77Jh$ '<EF V8B%L$ &$7 *'69.77$7 <.6 &*$ b$EF7$9#*%L.'/J K'7- K$<EF8$8 #$%&$' #*$ &$% R$F9$% 7$9K78: Y$% *'69.77 6*'&$8 *'/<'/ *' &*$ OF_7*L<9*7EF$']-&$99$ &$% b$EF7$9#*%L.'/ &.%EF T$%NEL7*EF8*/.'/ 0-' I$%8$*9.'/$' 0-' *'8%*'7*7EF$']<8$%*<9$*/$'7EF<68$' #*$ K$*7O*$97#$*7$ $9<78*7EF$ (-'78<'8$' S<.EF F)F$%$% [%&.'/XJ 9L8%*7EF$ M$*86BF*/L$*872 .'& 5</'$8*7EF$ U$%5$<K*9*8B87#$%8$J V8$'/$9L%*78<996-%5 .'&?<.7O%B/.'/*' VEF#$*,'BF8$'J$8E:

Y*$]<8F$5<8*7*$%.'/ &$% OF_7*L<9*7EF$']-&99 6NF%8 O%*'A*O*$99 A. 5<8F$5<8*7EF$' R%</$78$99.'/$' &$% M)7.'/ O<%8*99% Y*66$%$'8*<9/9$*EF.'/$' $*'7EF9*$,9*EF &$% M)7.'/ 0-' ^'6<'/7#$%82J P<'&#$%82 .'& HK$%/<'/7#$%8K$&*'/.'/$'J KA#: 0-' W'8$/%<9/9$*EF.'/$': a.% M)7.'/ /*K8 $7 6-9/$%*EF8*/ $*'6<EF$.'& &<5*8 7EF'99 DBF$%.'/$' &*$.'8$% K$78*55 8$' ^''<F5$' &*$ %<9 b$98 A.5*'&$78$'7 *' K$L<''8$' G$*9K$%$*EF$' /$'<. /$'./ K$7EF%$*K$': *' T$*7O*$9 &<6N% *78 &*$ ^.7K%$*8.'/ $9<78*7EF$% b99' S'98%<7EF<99X *' $*'$5 $9<78*7EF$']$&*.5 '.% <97 Y%.EL2 -&$% VEF$%#$99$J -F'$ &*$ '5#<'&9.'/ &$% $*'$' b99'<%8 *' &*$ <'&$%$ b99'<%8 K$* &$% b$EF7$9#*%L.'/ <5 R$F9$% A. K$%NEL7*EF8*/$' SkVZ] i@kX: c*$% 6*'&$' <.EF <'<9_8*7EF$ DBF$%.'/$' SA: T: R$%'6$9&'BF$%.'/$'X *F%$ ^'#$'&.'/J .5

A: T: &*$ b 99'6$9&$% 0-' U%N6L)O6$' <97 R.'L8*-' &$% U%N6L-O66-%5J 2K<.#$*7$.'& 26%p'A A. -O8*5*$%$': W' &$% L-5O9$e$%$' V8.6$ &$% 5<8F$5<8* 7EF$' ^.7#$%8.'/ #$%&$' $*/$'$'8#*EL$98$ U%-/%<5 57_78$5$ <.6 &$% T<7*7 %$*' '.5$%*7EF$% P$EF'.'/$' SA: T: \9<78-&_'<5*7EF$ R*'*8$ W'8$/%<8*-'78$EF'*LJ \RWGJ kM^D i=kXJ <K$% <.EF .'*0$%7$99$ R*'*8$ \9$5$'8$ Z-&$7 #*$ A: T: ^DVjV $*'/$7$8A8:

3.1 Simulation von Bauteilbeanspruchungen

3.1.1 Modellierung von Gesamtsystemen

3.1.1.1 Komponenten im Verbund

T$* &$% V*EF$%F$*87K$#$%8.'/ 0-' (-5O-'$'8$' #*%& *' &$% P$/$9 &*$ T$<'7O%.EF.'/ &$% (-5O-'$'8$ &.%EF &*$ ^'<9_7$ $*'$7 <.7 &$5 I$%K.'& F$%<.7/$9)78$' 7$O<%<8$'J *' 7*EF /$7EF9-77$'$' V8%.L8.%5-&$997 $%5*88$98: T*9& @23 A$*/8 T$%$EF'.'/75-&$99$ 0-' (-5O-'$'8$' $*'$7 Y%.EL#<77$%%$<L8-%2(NF9L%$*79<.67: Y*$ T$9<78.'/$' <.7 <'7EF9*$,$'&$' T<.8$*9$'J #*$ K$*7O*$97#$*7$ NK$% P-F%9$*8.'/$' $*'/$9$*8$8$ (%B68$J T*$/$2 .'& G-%7*-'75-5$'8$ 7-#*$ I$%6-%5.'/$' L)''$' *' &$' *'A$95-&$99$' '.% 'BF$%.'/7#$*7$.'& 5$*78$'7 <97 A$*89*EF .'0$%B'&$%9*EF$ P<'&K$&*'/.'/ K$%NEL7*EF8*/8 #$%&$': Y<K$* L)''$' b$EF7$9#*%L.'/$' A#*7EF$' 0$%7EF*$&$'$' (-5O-'$'8$' '*EF8 <K/$K*9&$8 #$%&$':

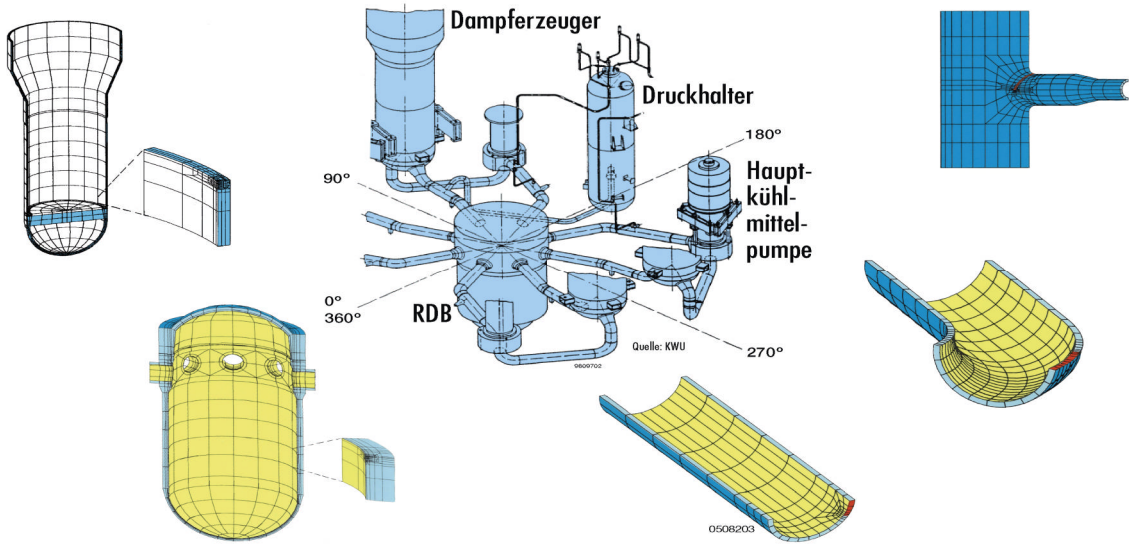


Bild 3-2: T$%$EF'.'/75-&99 0-' (-5O-'$'8$' $*'$% Y b P2(NF9L%$*79<.67EF9$*6$

W5 P<F5$' 0-' R-%7EF.'/7<%K$*8$' &$% I-%F<K$' Sk c [\ dkh k+P\ ddkX #.%&$ $*'$ ^'<9_7$5$8F-&*L $'8#*EL$98 .'& $%O%-K8J 5*8 &$% &*$ /$/$'7$*9*/$ 78%.L8.%5$EF<'*7EF$ T$$*'69.77.'/ &$% (-5O-'$'8$' $*'$% Y%.EL#<77$%%$<L8-% SY b PX2(NF9L%$*729<.67EF9$*6$ 7*5.9*$%8 #$%&$' L<'': T*9& @2@ A$*/8 $*' ^'<9_7$5-&$99 0-' (-5O-'$'8$' $*'$% Y b P2(NF9L%$*79<.677EF9$*6$ *5 I$%K.'&: Y<5*8 L)''$' &*$ 6N% 78%.L8.%2 5$EF<'*7EF$ ^.77</$' 5<,/$K9*EF$' UFB'-5$'$ *5 c*'K9*EL <.6 &*$ V*EF$%F$*872 .'& G%</6BF*/L$*87%$7$%0$' &$7 V_78$57 .'8$% K$8%*$K9*EF$' 7-#*$.'8$% <.,$%/$#)F'9*EF$' T$9<78.'/$' 5*8 F-F$% +$'<.*/L$*8 K$7EF%*K' #$%&$':

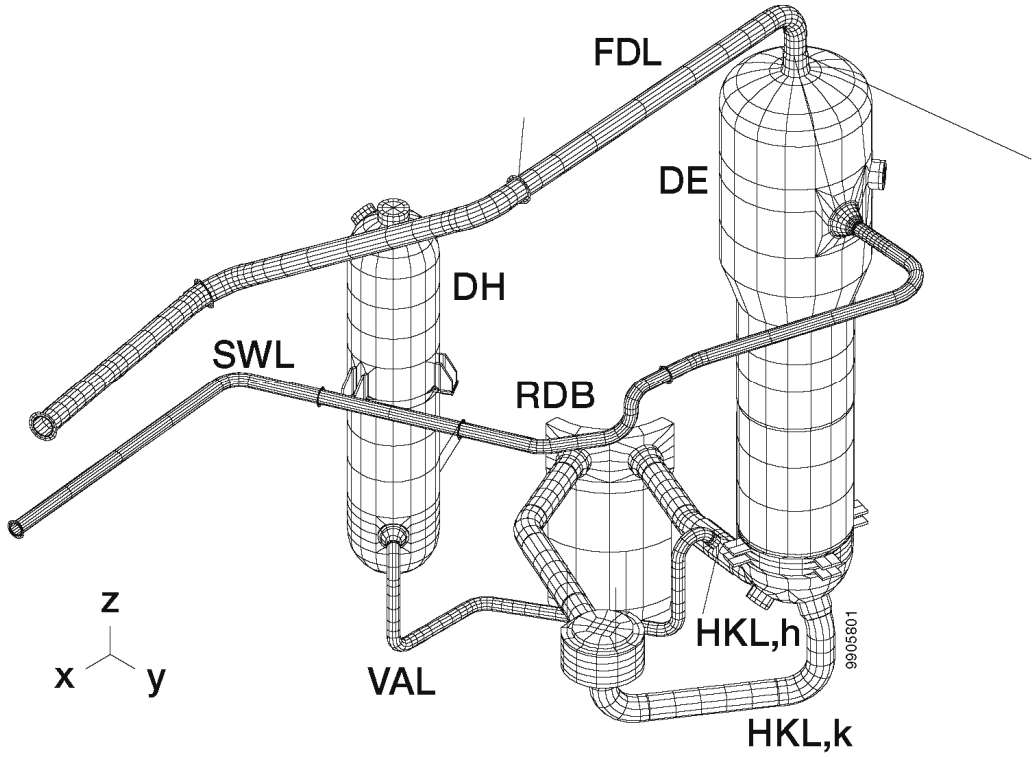


Bild 3-3: T$%$EF'.'/75-&$99 $*'$% Y b P2(NF9L%$*79<.67EF9$*6$

a.% I<9*&*$%.'/ &$7 (%$*79<.67EF9$*6$'5-&$997 #.%&$ $*' K$8%*$K9*EF$% ^'6<F%0-%/<'/ 5*8]$77&<8$'$%6<77.'/ '<EF/$%EF'8: ^' <.7/$#BF98$' U-7*8*-'$' #.%&$' K$%$EF'8 I$%7EF*$K.'/$' 5*8 $'87O%$EF$'&$' 0$%6N/K<%$']$77#$%8$' 0$%/9*EF$': W5 P<F5$' &$% b$*8$%$'8#*EL9.'/ &$7 ^'<9_7$5-&$997 #.%&$' 7EF%*88#$*7$ I$%K$77$%.'/$' <5 ^'<9_7$5-&$99 0-%/$'-55$': W5 b7'89*EF$' F<'&$98$ $7 7*EF &<K$* .5 &*$ \%/B'A.'/ '-EF 6$F9$'&$% M</$% <' R%*7EF&<5O69$*8.'/ SRYMX .'& VO$*7$#<77$%9$*8.'/ SV b MX 7-#*$ .5 ś&$%.'/$ ' K$* &$% b B%5$&$F'.'/ &$% U$'&$9FB'/$%: Y*$ HK$%$*'78*55.'/ &$% I$%6-%5.'/7#$%8$ *78 A.6%*$&$' 78$99$'&:

^K#$*EF.'/$' A#*7EF$']$77.'/ .'& P$EF'.'/ 6NF%$' K$* &$' L9$*'$%$' b$%8$' 8$*9#$*7$ A. F-F$' U%-A$'8A<F9$'J <K7-9.8 /$7F' 9*$/$' 7*$ *5 T$%$*EF #$'*/$%]*99*5$8$%: Y*$ '%7<EF$ 6N% &*7 Y*66$%$'A$' 9*$/8 *5 b7'89*EF$' *' '-EF 0-%F<'&$'$' ''8$%7EF*$&$' A#*7EF$' &$' *5]-&$99 <'/$'-55$'$' V8%.L8.%8$5O$%<8.%$' .'& &$' *5 D-%5<9K$8%*$K *' &$% ^'9</$ 8<87BEF9*EF 0-%F<'&$'$' b$%8$': *' G$5O$%<8.%.'8$%7EF*$& 0-' 1>tZ 6NF%8 K$*7O*$97#$*7$ K$* $*'$% 1> 5 9<'/$' P-F%9$*8.'/ A. $*'$5 ''8$%7EF*$& *' &$% 6%$*$' 8F$%5*7EF$' ^.7&$F'.'/ 0-' $8#< 1J= 55: *'$ #$*8$%$ I$%K$77$%.'/ L<'' '.% *5 P<F5$' <'9</$'7O$A*6*7EF$% ''8$%7.EF.'/$' 5*8 $%/B'A$'&$']-&$990$%6$*'$%.'/$' .'& A.7B8A9*EF$']$77.'/$' $%%$*EF8 #$%&$':

]*8 &$5 &$%A$*8 $%%$*EF8$' \'8#*EL9.'/778<'& L)''$' 78<8*7EF$.'& &_'<5*7EF$ 78%.L8.%5$EF<'*7EF$ ^.77</$' A.5 I$%6-%5.'/72 .'& I$%9</$%.'/70$%F<98$' 0-' (-5O-'$'8$' *5 I$%K.'& /$#-''$' #$%&$'J 5*8 &$'$' &$% VO<''.'/72 .'& Y$F'.'/7A.78<'& 7-#*$ $*' 5)/9*EF$% R.'L8*-'70$%9.78 O%-K9$5/$%$EF8 K$.%8$*98 #$%&$' L<'': Y<K$* L<'' $*' R.'L8*-'70$%9.78 7-#-F9 *' $*'$5 W'8$/%*8B870$%9.78 &$% &%.EL6NF%$'&$' '57EF9*$,.'/ &.%EF HK$%K$9<78.'/ SM$ELJ T%.EFJ (-99<K*$%$'X <97 <.EF *5 I$%7</$' 0-' ''8$%78N8A.'/$' .'& Y.%EF6NF%.'/$' -&$% *' NK$%5B,*/$' I$%9</$%.'/$' 0-' (-5O-'$'8$' S^K%*77 0-' ^'78$.$%.'/$'J I$%7-%/.'/ 5*8]$&*$' -&$% VEF*$678$99.'/X A. 7$F$' 7$*': ^.EF &*$ 5$F%&*5$'7*-'<9$' 78%.L8.%5$EF<'*7EF$' ^.7#*%L.'/$' &$% K$* D-86<997EF.8A5<,'<F5$' <.68%$8$'&$' 9-L<9$' 8F$%5-F_&%<.9*7EF$' \66$L8$ SA: T: *'6-9/$ A_L9*7EF$% Y%.EL2 .'& G$5O$%<8.%0$%9B.6$J (<98$*'7O$*7.'/$'J VEF*EF8.'/$'X L)''$' $%6<778 #$%&$': b$*8$%F*' L)''$' 5*8 &$% $'8#*EL$98$']$8F-&*L T$*8%B/$ A.% T$.%8$*9.'/ 0-' V*EF$%F$*875<%/$' $%<%K$*8$8 #$%&$': Y*$7 L<'' 7*EF 7-#-F9 <.6 ^.79$/.'/778)%6B99$ <97 <.EF <.6*' &$' ^'9</$' K$-K<EF8$8$ UFB'-5$'$.'& V8)%.'/$' K$A*F'J &*$ *' &$% ^.79$/.'/ '*EF8 $eO9*A*8J 7-'&$%' '.% *5 P<F5$' &$% V*EF$%F$*875<%/$' <K/$&$EL8 7*'&J #*$A: T:

- $%F)F8$ T$7EF9$.'*/.'/7<5O9*8.&$' K$* \%&KK'J
- b<77$%7EF9</*'6-9/$ I$'8*97EF9*$,$'7 -&$% Y<5O6K9<7$'L-'&$'7<8*-'J
- VEF*EF8.'/*' F-%*A-'8<9$' P-F%9$*8.'/$'J
- T$F*'&$%.'/ &$% 6%$*$' ^.7&$F'.'/<' ^K78N8A.'/$' .'& Y.%EF6NF%.'/$'J
- GF$%5-7EF-EL K$* (<98$*'7O$*7.'/$'J

- P$<L8*-' <.6 V8%<F9L%B68$ <.7 O-78.9*$%8$' M$EL7 .'& T%NEF$'J

- <&2F-E2T$#$%8.'/$' 0-' '*EF8 0-%F$%/7F$'$' \%$*/'*77$':

Die Methodik kann zweckmäßig auch zur Untersuchung der strukturmechanischen Auswirkungen sicherheitstechnischer Weiterentwicklungen und zur Beurteilung des integralen strukturmechanischen Verhaltens anderer Reaktortypen eingesetzt werden.

W'7/$7<58 9B778 7*EF 6$7878$99$'J &<77 &*$ #$*8$%$'8#*EL$98$ ^'<9_7$5$8F-&*L K$* &$% T$#$%8.'/ L-5O9e% R%</$78$99.'/$' A.% W'8$/%*8B8 0-' (-5O-'$'8$'J*'7K$7-'&$%$ A.% o<'8*6*A*$%.'/ 0-' V*EF$%F$*87<K78B'&$'J $*'/$7$8A8 #$%&$' L<'': b$*8$%F*' L)''$' ^.77</$' A.% +$'<.*/L$*8 7-#*$ ^'7B8A$ A.% I$%K$77$%.'/ &$% +$'<.*/L$*8 0$%$*'6<EF8$% I$%6<F%$' <K/$9$*8$8 #$%&$':

RN% 7O$A*$99$ R%</$78$99.'/$'J K$* &$'$' &*$ 78%.L8.%5$EF<'*7EF$ I$%6-%5.'/ PNEL#*%L.'/ <.6 &*$ T$78*55.'/ &$% M<78<''<F5$' F<K$' L<''J A:T: K$* &$% V*5.9<8*-' 0-' b<77$%7EF9B/$' *' P-F%9$*8.'/$' -&$% &$7 M$EL0$%F<98$'7 K$* ^.778%)5.'/$' *78 $*'$ (-OO9.'/ A#*7EF$' 78%.L8.%5$EF<'*7EF$' .'& 8F$%5-F_&%<.9*7EF$' ^'<9_7$5$8F-&$' $%6-%&$%9*EF: Y*$7 $%6-%&$%8 $*'$ b$*8$%$'8#*EL9.'/ 0-' VEF'*8878$99$' A#*7EF$' /$$*/'8' V*5.9<8*-'7O%-/%<55$' .'& $'87O%$EF$'&$ I<9*&*$%.'/:

b$*8$%F*' *78 $7 $%6-%&$%9*EFJ &*$ K*7F$% 6N% Y b P $'8#*EL$98$ ^'<9_7$5$8F-&*L 6N% <'&$%$ ^'9</$'8_O$' A:T: V b P #$*8$%A.$'8#*EL$9':

3.1.1.2 Leckratenmodelle für Rohrleitungen

a.% ^K7EFB8A.'/ 0-' ^.778%)5%<8$' &.%EF $'/$ %*77BF'9*EF$ VO<98$ *' P-F%9$*8.'/$' 6N% .'8$%LNF98$7 b<77$% K*7 F*' A. V<88&<5O6K$&*'/.'/$' k+P\ d3k #.%&$' A#$* &$8$%5*'*78*7EF$]-&99 SO-' \UPW .'& 0-' U<'<X K$%$*8/$78$998 .'& <' cYP2 I$%7.EF$' $%O%-K8: Y*$ K*7F$%*/$' ^'#$'&.'/$' 5*8 &*7' M$EL%<8$'5-&99' A$*/$'J &<77 &*7 $*'&*5$'7*-'<9$']-&$99$J &*$ <.6 &$% R$789$/.'/ $*'$7 8F$%5-F_&%<.9*7EF$' Y.%EF5$77$%7 K<7*$%$'J &*$.'8$%7.EF8$' I$%7.EF$ 8$*9#$*7$ '.% .'K$6%*$&*/$'& K$7EF%$*K$' L)''$': Y<F$% #.%&$ <.7 &$' \%/$K'*77$' 0-' $8#<1i> I$%7.EF$' 0-' 0$%7EF*$&$'$' W'78*8.8*-'$' *' 0$%7EF*$&$'$' MB'&$%' k+P\ ddk $*' $5O*%*7EF$7]-&$99 *' &$% R-%5 $*'$% I*$%2R<L8-%$'2R-%5$9 $'8#*EL$98J &*$ &*$ I$%7.EF$ *'7/$7<58 K$77$% <OO%-e*5*$%8 <97 &*$ <'&$%$' $*'&*5$'7*-'<9$']-&$99$:

Y*$ <'/$7O%-EF$'$' M$EL%<8$'5-&$99$ 78F' *' &$5 U%-/%<55 bWDM\Z(A.% I$%6N/.'/:W'7/$7<58 &$.8$' &*$ ''8$%7.EF.'/7$%/$K'*77$ h$&-EF &<%<.6F*'J &<77 &*$ UFB'-5$'$ K$*5 ^.778%)5$' &.%EF %*77<%8*/$ M$EL7 &.%EF $*'&*5$'7*-'<9$]-&99 '*EF8 A.6%*$&$' 78$99$'& K$7EF%*K' #$%&$' L)''$': \%78$ A#$*&*5$'7*-'<9$ P$EF'.'/$' 5*8 $*'$5 ^'<9_7$5-&$99J &<7 <.7 A#$* O<%<99$9$' U9<88$' K78F8J K$78B8*/$' &*$7: V-5*8 *78 &*$ T$%$EF'.'/ 0-' M$EL%<8$' #$*8$%F*' 5*8 /%-,$' ''7*EF$%F$*8$' 0$%K.'&$': G%-8A &$% 0$%K77%8$' ^'O<77.'/ <' 0$%6N/K<%$ I$%7.EF7$%/$K'*77$ &.%EF &*$ $5O*%*7EF$ I2R<L8-%$'2R-%5$9 *78 $*'$ b$*8$%$'8#*EL9.'/ K<7*$%$'& <.6 5$F%&*5$'7*-'<9$' T$%$EF'.'/75$8F-&$' '-8#$'&*/:

3.1.2 Modellentwicklung für auslegungsüberschreitende Ereignisse

3.1.2.1 Reaktordruckbehälter bei Kernschmelzen

T$* $*'$5 7EF#$%$' V8)%6<99 5*8 <'7EF9*$,$'&$% VEF5$9A0%9</$%.'/ *' &<7 .'8$%$ U9$'.5 78$998 &$% P$<L8-%&%.ELK$FB98$% SPYTX &*$ 9$8A8$ V*EF$%F$*87K<%%*$%$ 0-% $*'$% &*%$L8$' T$9<78.'/ &$7 Z-'8<*'5$'87 &<%: RN% &*$ P*7*L-<K7EFB8A.'/ KA#: &*$ \%5*889.'/ &$7 o$998$%57 *78 $*' &$8<*99*$%8$7 I$%78B'&'*7 &$% 8F$%5-69.*&&_'<5*7EF$' .'& 5$EF<'*7EF$' I-%/B'/$J &*$ K$* $*'$% ($%'7EF5$9A$ <.68%8'J $%6-%&$%9*EF: UFB'-5$'-9-/*7EF 7*'& &*$ I-%/B'/$ *5 PYT K$* ($%'A$%78)%.'/ *5 (<O*8$9 n8 K$7EF%*$K$': D<EF &$5 ^K7EF5$9A$' &$7 ($%'7 .'& I$%9</$%.'/ &$% Z-%.57EF5$9A$ *' &*$ T-&$'L<9-88$ $*'$7 PYT L-55 8 $7 A. $e8%$5$' 8F$%5*7EF$' .'& 8F$%5-5$EF<'*7EF$' T$<'7O%.EF.'/$' &$7 PYT: \7 /*98 6$78A.78$99$'J -K &*$ VEF5$9A$ *5 I$%9<.6 &$7 <'/$'-55$'$' VA$'<%*-7 9<'/6%*78*/ *' &$% T-&$'L<9-88$ 78<K*9*7*$%8 #$%&$' L<'' -&$% -K &$% Y%.ELK$FB98$% '<EF $*'$% K$78*55 8$' a$*8 0$%7</8: RN% VA$'<%*$' 5*8 I$%7</$' L<'' 5<' I$%7</$'7A$*8$' .'& I$%7</$'75-&* &$7 T$FB98$%7 O%-/'-78*A*$%$':

^.6 &$% T<7*7 L-55$%A*99% Z-&$7 SA: T: ^DVjVJ ^T^óVJ ^YWD^X # .%&$' R*'*8$2 \9$5$'8$2]-&$99$ $'8#*EL$98J &*$ 7-#-F9 &<7 G$5O$%<8.%6$9& *' &$% PYT2b<'& <97 <.EF &*$ $9<78-2O9<78*7EF$]$EF<'*L &$% T$FB98$%#<'& K$%$EF'$': W5 ^99/$5$*'$' %$*EF8 $*' <e*<97_55$8%*7EF$7]-&$99 <.7:

Y*$ G$5O$%<8.%6$9&K$%$EF'.'/$' &*$'$' &<A.J &*$ 8F$%5*7EF$ T$9<78.'/ &$% T$FB98$%#<'& A. $%5*88$9': Y<7 8F$%5*7EF$]-&$99 5.77 &$' VEF5$9A$O--9 *'L9.7*0$

&$% *' '$%$' bB%5$p99' SD<EFA$%6<997#B%5$X 7-#*$ &*$ T$FB98$%#<'& $'8F<98$': ^97 P<'&K$&*'/.'/ 6N% &<7 8F$%5*7EF$]-&$99 #*%& &*$ bB%5$<K78%<F9.'/ 0-' &$% VEF5$9A$-K$%69BEF$.'& 0-' &$% T$FB98$%<.,$'7$*8$ K$%NEL7*EF8*/8: W5 R<99$ &$% $e8$%'$' R9.8.'/ &$7 PYT *78 &$% O-9<%#*'L$9<KFB'/*/$ bB%5$78%-5 *' &<7 b<77$% A. 5-&$99*$%$': Y*$]-&$99*$%.'/ &$% GF$%5-69.*&&_'<5*L *' &$% VEF5$9A$ L<'' 5*8 c*%6$ 0-' ZRY2]-&99' SbB%5$8%<'7O-%8 &.%EF (-'0$L8*-' .'& bB%5$9$*8.'/X $%6-9/$': Y*$ A$*8<KFB'/*/$ Y*EL$ &$% VEF5$9A$L%.78$ $%/*K8 7*EF <.7 &$% G$5O$%<8.% &$% K$8%66'&$' \9$5$'8$: T$* ''8$%7EF%$*8.'/ &$% V-9*&.78$5O$%<8.%*' <99$' ('-8$' $*'$7 R9.*&$9$5$'87 #$%&$' &*$]<8$%*<9$*/$'7EF<68$' &$7 \9$5$'87 /$B'&$%8J #-&.%EF 7*EF /9$*EFA$*8*/ $%/*K8J &<77 &<7 \9$5$'8 '*EF8 9B'/$% A.5 R9.*&/$K*$8 ABF98J 7-'&$%' A.5 R$78L)%O$%/$K*$8 /$F)%8: '5/LF%8 0$%FB98 $7 7*EF K$* &$% HK$%7EF%$*8.'/ &$% M*p*&.78$5O$%<8.%:

^99$%&*'/7 F<8 &*$ ZRY2]-&$99*$%.'/ <.EF $*'*/$ D<EF8$*9$: *'$%7$*87 #*%& K$A#$*6$98J &<77*5 R<99$ O%-8-8_O*7EF$% V*5.9<8*-'$' 5*8 P<_9$*/F2a<F9$' *5 T$%$*EF 0-' 1>1l K*7 1>1m &*$ \%/$K'*77$ <.7 ZRY2P$EF'.'/$' 5*8 &$' A.% I$%6N/.'/ 78F'&$' G.%K.9$'A5-&99' &$% A. $%#<%8$'&$' P$<9*8B8 $'87O%$EF$' kYWD dh a.7B8A9*EF *78 $*' F-F$% ^.6#<'& <' PEF'9$*78.'/ '-8#$'&*/J &$% &*$ ^.76NF%.'/ 0-' I<%*<8*-'7<'<9_7$' $%7EF#$%8: ^'&$%$%7$*87 *78 &*$ /$'<.$ G$5O$%<8.%O$%8$*9.'/*' &$% VEF5$9A$ 6N% &*$ 5$EF<'*7EF$ P$EF'.'/ '*EF8 '-8#$'&*/: Y<F$% *78 $7 <.7%$*EF$'&J #$'' $*']-&$99 K$%$*878$F8J &<7 &*$ T$%$EF'.'/ &$% bB%5$78%)5$ <' &$' +%$'A69BEF$' &$% VEF5$9A$ NK$% /$$*/'8 $5O*%*7EF$ (-%%$9<8*-'$' /$#BF%9$*78$8: Y<F$% #.%&$ <97 ^98$%'<8*0$ &<7]-&$99 &$% 66L8*0$' (-'0$L8*-' .'& bB%5$9$*8.'/ S\ZZ]J \66$E8*0$2Z-'0$E8*0*8_2Z-'&.E8*0*8_2]-&$9X $'8#*EL$98: \7 *78 $*' %$*'$7 bB%5$9$*8.'/75-&$99 5*8 A-'$'<KFB'/*/$' .'& 8$*9#$*7$ <'*7-8%-O$' bB%5$9$*8A<F9$' kT'W diJ T\P dik:

a.% V*5.9<8*-' &$7 8F$%5*7EF$' I$%F<98$'7 0-' /$7EF5-9A$'$5 ($%'5<8$%*<9 *5 .'8$%$' U9$'.5J &$% (%.78$'K*9&.'/J &$% (NF9.'/ &$% VEF5$9A$ &.%EF $*'$ 8%<'7*$'8$J A#$*OF<7*/$ V8%)5.'/ *' $*'$5 VO<98 A#*7EF$' (%.78$.'& P$<L8-%&%.ELK$FB98$% 7-#*$ &$7 5$EF<'*7EF$' I$%F<98$'7 &$% PYT2b<'& #.%&$ $*' 0$%$*'6<EF8$7 ^'<9_7$5-&$99 $'8#*EL$98 kVZ^ ddk:]*8 &$5 8F$%5-F_&%<.9*7EF$']-&$998$*9 ^WY^ S^'<9_7*7 -6 8F$ W'8$%<E8*-' K$8#$$' Z-%$ Y$K%*7 <'& 8F$ PUI &.%*'/ V0%$ ^EE*&$'87X L)''$' &*$ 8F$%5*7EF$' T$9<78.'/$' &$% PYT2b<'& K$%EF'8 #$%&$':]*8 &$5]-&$998$*9 ^VG[P S^OO%-e*5<8$& V8%.E8.%<9 G*5$ -6 P.O8.%$X 78$F8 $*' 0$%$*'6<EF8$7 I$%6<F%$' A.% ^K7EFB8A.'/ &$% V8<'&A$*8$' $*'$7 P$<L8-%&%.ELK$FB98$%K-&$'7 .'8$% M<786B99$' 5*8 %-8<8*-'77_55$8%*7EF$% 7-#*$

'*EF8$*'F$*89*EF$% G$5O$%<8.%O$%8$*9.'/ SF-8 7O-8X A.% I$%6N/.'/: Y<K$* #.%&$' 6N% &$' PYT2T-&$' I$%7</$'7A$*869BEF$' <.6 &$% T<7*7 $*'$% K$/%$'A8$' ^'A<F9 0-' R*''*8$2 \9$5$'8$2T$%$EF'.'/$' .'8$% a./%.'&$9$/.'/ $*'$% 9*'$<%$' VEF<&$'7<LL.5.9<2 8*-'7%$/$9 K$78*5 58:

W' &*$ 5$EF<'*7EF$' T$%$EF'.'/$' 6N% &*$ T$FB98$%#<'& /F' 'K' &$5 G$5O$%<8.%6$9& <.EF &$% W''$'&%.EL .'& &<7 */$'/$#*EF8 <97 T$9<78.'/ $*': T$* &$% I$%6-%5.'/ &$7]<8$%*<97 7*'& O%*'A*O*$99 &%$* ^'8$*9$ *' T$8%<EF8 A. A*$F$'C &*$ $9<78*7EF$ I$%6-%5.'/J &<7 (%*$EF$' .'& &*$ O9<78*7EF$ I$%6-%5.'/: Y<7 (%*$EF$' *78 $*' A$*8<KFB'/*/$% I-%/<'/J &$% K$* F)F$%$' G$5O$%<8.%$' SK$* V8<F9 -K$%F<9K =>> tZX $*'7$8A8 .'& 78<%L 0-' &$' VO<''.'/70$%FB98'*77$' <KFB'/8: Y$5/$/$'NK$% *78 &*$ O9<78*7EF$ I$%6-%5.'/ $*' O%-5O8$% I-%/<'/J &$% <K$% $%78 -K$%F<9K $*'$% K$78*5 58$' VO<''.'/77EF#99 ? &$% R9*$,7O<''.'/ ? $*'7$8A8: Y*$ U9<78*A*8B8 L<'' O%*'A*O*$99 7EF-' <K P<.58$5O$%<8.% $*'7$8A$'J h$&-EF '*558 &*$ VEF#99 SR9*$,7O<''.'/X 5*8 78$*/$'&$% G$5O$%<8.% <K: T$*&$ I$%6-%5.'/7<'8$*9$ L)''$' /9$*EFA$*8*/ <.68%$8$' .'& 7*'& NK$% &*$ /$-5$8%*7EF$ \'86$78*/.'/ &$% V8%.L8.% 5*8$*'<'&$% /$L-OO$98 SA: T: &.%EF 0$%6-%5.'/7K$&*'/8$ b<'&&*EL$'<K'<F5$.'& &<5*8 0$%K.'&$'$5 ^'78$*/$' &$% #<F%$' VO<''.'/X: Y*$ $9<78*7EF$ I$%6-%5.'/ *78 L9$*' /$/$'NK$% &$% (%*$EF0$%6-%5.'/ .'& &$% O9<78*7EF$' I$%6-%5.'/: I$%6-%5.'/7K$F*'&$%.'/$' 6NF%$' A. VO<''.'/$': Y<7 $9<78*7EF$]<8$%*<90$%F<98$' #*%& <97 *7-8%-O <'/$'-55$' .'& *78 &<F$% &.%EF &$' 8$5O$%<8.%<KFB'/*/$' \2]-&.9 .'& &*$ L-'78<'8$ o$%L-'8%<L8*-'7A<F9 0-9978B'&*/ K$78*55 8:

+%.'&9</$ 6N% &*$ \%78$99.'/ &$% 0*7L-O9<78*7EF$']<8$%*<9&<8$'K<7*7 7*'& &*$ eO%*5$'8$99$' \%/$K'*77$ 0-' a$*878<'&70$%7.EF$' S(%*$EF0$%7.EF$X .'& a./0$%7.EF$*5 G$5O$%<8.%K$%$*EF 0-' E<: ⇔ tZ K*7 1@>> fZ: RN% &$' 6%<'A)7*7EF$' PYT2V8<F9 1ŋhDY= #.%&$' &*$7$ Y<8$' K$*7O*$97#$*7$ *5 P<F5$' &$7 P\IWV^ 2 U%-h$L8$7 K$78*558 SI: P<F5$'O%-/%<55 &$% \'X SkV^WdiJ W([ddkX: ß'9*EF$ ''8$%7.EF.'/$' #.%&$' 6N% &$' <5$%*L<'*7EF$' V8<F9 V^ =@@ T Sk] [D >>kX KA#: 6N% &$' &$.87EF$' V8<F9 3>]'] -D*=:= Sk[TV idkJ k]U^ ddkX &.%EF/$6NF%8: Y*$]<8$%*<97EFB&*/.'/ *'6-9/$ 0-' 7*/'*6*L<'8$' (%*$EF&$F'.'/$' KA#: O9<78*7EF$' Y$F'.'/$' #*%& 5*8 $*'$5 7L<9<%$' VEFB&*/.'/7O<%<5$8$% Y K$7EF%*K'J &$% K$* h$&$5 M<787EF%*88 Sa$*87EF%*88X &$% R*''*8$2\9$5$'8$SR\X2^'<9_7$ *'L%5'8*$%8 #*%&: Y<7 VEFB&*/.'/7*'L%5'8 #*%& *: ^99/: <.7 &$5 a.#<EF7 <' 0*7L-O9<78*7EF$% Y$F'.'/ $%5*88$98J #-K$* &*$]$F%<EF7*/L$*8 &$7 VO<''.'/7A.78<'&7 K$%NEL7*EF8*/8 #*%&: W' &$% R\2^'<9_7$ #*%& 6N% h$&$7 \9$5$'8 &$% VEFB&*/.'/7O<%<5$8$% Y K$%EF'8: b$'' 6N% $*'$ \9$5$'8 &$% b$%8 Yu1 $%%$*EF8 #*%&J 7- #*%& $7 &$<L8*0*$%8J A: T: *'&$5 7$*'$

V8$*6*/L$*8 5*8 1>2m 5 .98*O9*A*$%8 #*%&: Y*$ *' &$' L-5 5$%A*99' R*'*8$2\9$5$'82] $8F-&$2 Z-&$7 0$%6N/K<%$' (%*$EF2 .'& VEFB&*/.'/75-&99 7*'& *: ^99/: '*EF8 <.7%$*EF$'&J 7-&<77 0-5 U%-/%<5 5K$'.8A$% $'8#*EL$98$ P-.8*'$' 5*8 0$%K77%8$']-&$99<'7B8A$' NK$% &*$ 5$*78 0$%6N/K<%$' '7$%7EF'*8878$99$' <' &$' Z-&$<'/$K.'&$' #$%&$':

Y*$ I<9*&*$%.'/ &$%]-&99 $%6-9/8 <'F<'& 0-' U%$2 .'& U-782G$782P$EF'.'/$' A.\eO$%*5$'8$': c*$% 7*'& &*$ R[P\I\P2\eO$%*5$'8$ <' &$% ()'*/9*EF G$EF'*7EF$' c-EF7EF.9$ V8-ELF-95 .'& &*$ McRk[McR \eO$%*5$'8$ <' &$' V<'&*< D<8*-'<9 M<K-%<8-%*$7 S':V:^:X A. '$''$' kV\c ddJ Zc' ddJ V^D >3k: T$* &$% V*5.9<8*-' &$7 T$FB98$%0$%7</$'7 *5 P<F5$' 0-' 5*88$97L<9*/$' W'2I$77$92P8'8*-'2\eO$%*5$'8$' L<'' 5<' &$' &$%A$*8*/$' b*77$'778<'& #*$ 6-9/8 A.7<5 5$'6<77$' kZc' ddJ ^MG>@J \WV >@kC

- Y*$ G$5O$%<8.%$' *' &$% T$FB98$%#<'& L)''$' A.6%*$&$' 78$99$'& 0-%F$%/$7</8 #$%&$': T$*5 I$%/9$*EF 0-' K$%$EF'8' .'& /$5$77$'$' G$5O$%<8.%$' $%/*K8 7*EF *' &$% P$/$9 $*' 7_78$5<8*7EF$% R$F9$%J #$*9 $7 5$778$EF'*7EF 7EF#*$%*/ *78J [K$%69BEF$'8$5O$%<8.%$' /$'<. A. $%6<77$':

- Y*$ I$%7</$'7O-7*8*-' L<'' /.8 0-%F$%/$7</8 #$%&$':

- Y*$ I-%F$%7</$ &$% I$%7</$'7A$*8 L<'' 5*8 $*'$% V8%$.K%$*8$ 0-' 3>vK*7 @>v0-%F$%/$7</8 #$%&$': Y*$ '%7<EF$ &*7% ''7*EF$%F$*8 9*$/8 $*'$%7$*87 *' &$% V8%$..'/ &$%]<8$%*<9$*/$'7EF<68$' S*'7K$7-'&$%$ &$7 (%*$EF0$%F<98$'7X .'& <'&$%$%7$*87 *' $*'$% 78<%L$' G$5O$%<8.%<KFB'/*/L$*8 &$% 0*7L-O9<78*7EF$' I$%6-%5.'/: T$%$*87 $*' G$5O$%<8.%.'8$%7EF*$& 0-' #$'*/$' ($90*' 6NF%8 A.7*/''6*L<'8 .'8$%7EF*$&9*EF$' (%*$EF/$7EF#*'&*/L$*8$':

- Y*$ T$%$EF'.'/ &$%]<8$%*<97EFB&*/.'/ $%/<K $*'$ p<9*8<8*0 /.8$ HK$%$*'78*55.'/ 5*8 5$8<99-/%<OF*7EF$' D<EF.'8$%7.EF.'/$' <' U%-K$' &$% A$%78)%8$' T$FB98$%:

(N'68*/$ ^%K$*8$' 7-998$' 7*EF 0-%<99$5 <.6 6-9/$'&$ '-EF -66$'$U.'L8$ L-'A$'8%*$%$'C

- Y*$]-&$99*$%.'/ &$% 8F$%5-2EF$5*7EF$' b$EF7$9#*%L.'/ A#*7EF$' Z-%*.5 .'& PYT2b<'&:

-]-&$99*$%.'/ &$% 8F$%5-25$EF<'*7EF$' (-'7p'A$' &$% R9.8.'/ &$% P$<L8-%/%.K$:

- c$%78$99.'/ $*'$% $EF8$' (-OO9.'/ A#*7EF$']$EF<'*L .'& GF$%5-69.*&&_'<5*L ST$$*'69.77.'/ &$% bB%5$78%)5$ &.%EF b<'&&*EL$'<K'<F5$KA#: b<'&$%-7*-'X:

3.1.2.2 Integrität und Dichtheit von Sicherheitsbehältern aus Stahlbeton

W' R%<'L%$*EF 7-#*$ *' -78$.%-OB*7EF$' MB'&$%' *78 $*'$ +%-,A<F9 9<.6$'&$% ($%'L%<68#$%L$ 5*8 V*EF$%F$*87K$FB98$%' <.7 0-%/$7O<''8$5 T$8-' <.7/$%N78$8: W5 P<F5$' 0-' D$.K<.8$' 7*'& *' &*7' MB'&$%' K'6<997 VO<''K$8-'K$FB98$% 0-%/$7F': W' Y$.87EF9<'& #.%&$' V*EF$%F$*87K$FB98$% <.7 VO<''K$8-' 6N% &*$ V*$&$#<77$%%$<L8-%SV bPX2T<.9*''*$ß $*'/$7$8A8:

W5 P<F5$' 0-' &$.87EF$' V*EF$%F$*8778.&*$' #.%&$' ^K7EFB8A.'/$' A.5 G%</0$%F<98$' 0$%7EF*$&$'$% V*EF$%F$*87K$FB98$%L-'78%.L8*-'$' &.%EF/$6NF%8J .5 VEF#<EF78$99$' A. *&$'8*6*A*$%$': b$*8$%F*' #.%&$' O<%8*$99 eO%*5$'8$99$ ''8$%7.EF.'/$' &.%EF/$6NF%8J .5 P*775.78$% <' /%),$%$' U%-K$' <.7 V8<F9K$8-'A. K$78*55$': Y*$ A.% \%5*889.'/ &$7 +%$'A8%</0$%F<98$'7 &$%<%8*/$% T<.#$%L$ $*'/$7$8A8$' PEF'0$%6<F%$'J *'7K$7-'&$%$ &*$]-&99 A.% T$7EF%$*K.'/ &$7 T$8-'0$%F<98$'7 5*8 P*77K*9&.'/ $%6-%&$%' $*'$ b$*8$%$'8#*EL9.'/ .'& $*'$ I$%K$77$%.'/ F*'7*EF89*EF &$7 I$%*6*L<8*-'778<'&$7: Y<K$* *78 A. K$<EF8$'J &<77 R%</$78$99.'/$' <' 0-%/$7O<''8$' T$8-'K$FB98$%' &.%EF &*$A.7B8A9*EF$ T$9<78.'/ &$% I-%7O<''.'/ /$/$'NK$% R%</$78$99.'/$' <' '*EF8 0-%/$7O<''8$'J &:F: 7EF9<66 K$#$F%8$' T$8-'K$FB98$%' L-5O9e% 7*'& .'& &<F$%9$8A8 /$'<''8$ 5*8 <K&EL':

Y*$ 78%.L8.%5$EF<'*7EF$']$8F-&$' A.% T$7EF%$*K.'/ &$% G%</6BF*/L$*8 0-' V*EF$%F$*87K$FB98$%78%.L8.%$' #.%&$' *' &$' 9$8A8$' f<F%$' #$*8$%$'8#*EL$98: Y*$]<8$%*<95-&99 L)''$' *'7K$7-'&$%$ P*77K*9&.'/ *'6-9/$ 0-' Y%.EL2 KA#: a./7O<''.'/$' NK$%#*$/$'& <97 !0$%7EF5*$%8$ P*77$; K$7EF%$*K$'J #-K$* K$AN/9*EF &$% T$9<78.'/$' 5$EF<'*7EF$ #*$ <.EF 8F$%5*7EF$ ^'8$*9$ K$%NEL7*EF8*/8 #$%&$' L)''$': Y<7 VO<''.'/72Y$F'./72Y*</%<55 6N% T$8-' *5 a./K$%$*EF 0$%9B.68 '<F$A. 9*'$<% K*7 A.5 \%%$*EF$' &$% VO<98A./6$78*/L$*8: *'$ #$*8$%$ Y$F'./7A.'<F5$ *78 5*8 $*'$% ^K'<F5$ &$% VO<''.'/$' *'6-9/$ T*9&./ 0-'

]*L%-%*77$' 0$%K.'&$': Y.%EF #$*8$%$' VO<''.'/7<KK<. .'& a.'<F5$ &$% I$%6-%5.'/ $'878$F$']<L%-%*77$: b$*8$%$'8#*EL9.'/7K$&<%6 K78F8*'7K$7-'&$%$ K$* &$% V*5.9<8*-' &$% T*9&.'/ 0-' P*77$' .'8$% T$%NEL7*EF8*/.'/ 0-' W'F-5-/$'*8B8$' *' +$-5$8%*$.'&]<8$%*<9$*/$'7EF<68$' 7-#*$ &$7 I$%K.'&0$%F<98$'7 A#*7EF$' T$#$F%.'/778BK$' .'& T$8-'J &< &*$7 6N% &*$ T$78*55.'/ &$% G%</6BF*/L$*8 .'& &$% Y*EF8F$*8 0-' V8<F9K$8-'78%.L8.%$' 0-' T$&$.8.'/ *78:

GF$%5-F_&%<.9*7EF$]-&99 A.% T$7EF%$*K.'/ 0-' M$EL%<8$' K$* *''$'2 &%.ELK$9<78$8$' VO<''K$8-'L-'78%.L8*-'$' .'8$% T$%NEL7*EF8*/.'/ &$%]$&*$'2 K$&*'/.'/$' SM.68J b<77$%&<5O6X K$')8*/$' <.7 &$% V8%.L8.%5$EF<'*L &*$ T$78*55.'/ 0-' M$ELO6<&$' &.%EF a.7<55$'#<EF7$' 0-']*L%-%*77$' 7-#*$ $*'$ ^K7EFB8A.'/ &$% $'87O%$EF$'&$' M$EL69BEF$' <.6 &$% T<7*7 K$%EF'8$% P*77)66'.'/$':

RN% &*$ T$7EF%$*K.'/ 0-' M$EL%<8$' K$* *''$'&%.ELK$9<78$8$' VO<''K$8-'2 L-'78%.L8*-'$' #.%&$' $%78$]-&99'8#*EL9.'/$' *' 0$%7EF*$&$'$' MB'&$%' K$/-''$'J.5 &*$ L-5O9e'])/9*EFL$*8$' &$% T*9&.'/ 0-' M$EL</$O6<&$' 5*8 .'& -F'$ M*'$% $*'7EF9*$,9*EF &$% *5 P*77 *''$%F<9K &$% T$8-'#<'& 78<886*'&$'&$' (-'&$'7<8*-'70-%/B'/$ A. K$7EF%$*K$': M$EL</$' L)''$' '.% $%6-9/$'J #$'' &*$]*L%-%*77$ *5 T$8-' &.%EF &*$ /$7<58$ b<'& F*'&.%EF/F': Y< &*$]*L%-%*77$ 7$F% $'/ .'& .'%$/$95B,*/ /$6-%58 7*'&J #*%L$' 7*$ #*$ $*' R*98$% <.6 &$' M$EL</$5<77$'78%-5 .'& 7*'& *'' &$% M</$J VEF<&78-66$J ^$%-7-9$.'& VO<98O%-&.L8$ <.7 &$5 M$EL</$5<77$'78%-5 F$%<.7A.6*98$%' .'& &$' Y<5O6<'8$*9 *5 M$EL</$5<77$'78%-5 A. L-'&$'7*$%$': Y.%EF &<7 (-'&$'7<8 L)''$' &*$ P*77$ 6N% +<7<.778%)5.'/ 8$5O-%B% #*$&$% 0$%7EF9-77$' #$%&$': Y*$7$ ^K9</$%.'/72 .'& (-'&$'7<80-%/B'/$ 7*'& 78<%L 0-' &$' 7*EF *' &$% V8%.L8.% $'8#*EL$9'&$' G$5O$%<8.%$' <KFB'/*/: Y*$7 $%6-%&$%8 L-5O9e]-&$99<'7B8A$: RN% &*$ T$78*55.'/ &$% 8F$%5-F_&%<.9*7EF$' P<'&K$&*'/.'/$' <' &$% W''$'7$*8$ &$7 V*EF$%F$*872 K$FB98$%7 #$%&$' U%-/%<55$ #*$ A: T: Z [Z [VjV $*'/$7$8A8:

]*8 &$5 R*'*8$ \9$5$'8$ PEF'O%-/%<55 ^YWD^ #.%&$ &<7 78%.L8.%5$EF<'*7EF$ I$%F<98$' $*'$7 V8<F9K$8-'2]-&$99E-'8<*'5$'87 5*8 V8<F99*'$% *5]<,78<K 1Cjm&<7 *5 V^DYW^ D<8*-'<9 M<K-%<8-%_ S‘V^X .'8$% <'78$*/$'&$5 W''$'&%.EL eO%*5$'8$99 .'8$%7.EF8 #.%&$J 7*5.9*$%8 kT^Z idk: b$*8$%6NF%$'&$ T$%$EF'.'/$' #.%&$' A. $*'$5 I$%7.EF <' $*'$5 1CI]-&$99E-'8<*'5$'8 <.7 V8<F9K$8-' 5*8 I-%7O<''.'/ .'& V8<F99*'$%J &<7 K'6<997 K$* V^DYW^ &.%EF <'78$*/$'&$' W''$'&%.EL K*7 F*' A.5 /%-,69BEF*/$' I$%7</$' .'8$%7.EF8 #.%&$J &.%EF/$6NF%8: W5 P<F5$' &$7

W'8$%'<8*-'<9$' V8<'&<%&O%-K9$57 SWVUX Ii &$% [\ZY2D\^ #.%&$' I$%/9$*EF72 <'<9_7$' A. &*$7$5 I$%7.EF &.%EF/$6NF%8J &*$ $*'$' *'&%.EL A.5 \'8#*EL9.'/778<'& &$% ^'<9_7$5$8F-&$' .'& &$%$' ^.77</$/$'<.*/L$*8 /$K$': T$* &$% \'8#*EL9.'/ &$% ^'<9_7$5-&$99$ #$%&$' &$% T$8-'J &$% M*'$%J &*$ VO<''L<K$9 7-#*$ <99$ T$#$F%.'/778BK$ *' &$' 0$%7EF*$&$'$' P*EF8.'/$' /$-5$8%*7EF .'& K$AN/9*EF &$7 '*EF89*'$<%$']<8$%*<90$%F<98$'7 K$%NEL7*EF8*/8: Y*$ ''8$%7.EF.'/$' 5*8 %-8<8*-'77_55$8%*7EF$' ^'<9_7$5-&$99$' A$*/$'J &<77 &<7 78%.L8.%5$EF<'*7EF$ I$%F<98$' &$7 .'/$78)%8$' b<'&K$%$*EF7*' &$5 L$*'$V8)%78$99$' #*$ VEF9$.7$' .'& P-F%&.%EF6NF%.'/$' 9*$/$'J K*7 *' &$' T$%$*EF K$/*''$'&$% D*EF89*'$<%*8B8$' *5]<8$%*<90$%F<98$' 5*8 /.8$% HK$%$*'78*55.'/ A.5 \eO$%*5$'8 7*5.9*$%8 #$%&$' L<'': RN% &*$ V*5.9<8*-' &$7 V8%.L8.%0$%F<98$'7 K$* F)F$%$' Y%NEL$' 7*'& A.7B8A9*EF$ ''8$%7.EF.'/$' *'7K$7-'&$%$ A.% (-OO9.'/ A#*7EF$' T$8-' .'& T$#$F%.'/J A.% T*9&.'/ .'& A.5 I$%F<98$' 0-']*L%-%*77$' *5 T$8-' 7-#*$ A.5 *'69.77 &$% VO<''.'/75$F%<EF7*/L$*8 K$* &$% T$#$%8.'/ &$% O9<78*7EF$' Y$F'.'/$' *5 M*'$% $%6-%&$%9*EF: RN% &*$ T$78*55.'/ &$% I$%7</$'75$EF<'*75$' *5 T$%$*EF &$% V8)%78$99$' #.%&$ 5*8 &$% \'8#*EL9.'/ 9-L<9$% &%$*&*5$'7*-'<9$% ^'<9_7$5-&99 K$/-''$':

W5 P<F5$' &$7 \'kT]b^2R-%7EF.'/70-%F<K$'7 Z\V^ kRWP >>k #.%&$' I-%<.7%$EF'.'/$' A.5 V8%.L8.%0$%F<98$' .'& A. M$EL%<8$' &$7 6%<'A)7*7EF$']^\I^2]-&$99E-'8<*'5$'87 <.7 0-%/$7O<''8$5 T$8-'J &<7 eO%*5$'8$99 .'8$% 5$EF<'*7EF$% .'& 8F$%5*7EF$% T$<'7O%.EF.'/ .'8$%7.EF8 #.%&$J &.%EF/$6NF%8: W5 P<F5$' 0-' '*EF89*'$<%$' 78%.L8.%5$EF<'*7EF$' T$%$EF'.'/$' #.%&$ &*$ A$*89*EF$.'&)%89*EF$ G$5O$%<8.%0$%8$*9.'/ *' &$% T$FB98$%#<'& K$%EF'8 .'& A.7<55$' 5*8 &$% 8%<'7*$'8$' W''$'&%.ELK$9<78.'/ &*$ I$%6-%5.'/J &*$ VO<''.'/70$%8$*9.'/ .'& &*$ T$%$*EF$J *' &$'$' 7*EF]*L%-%*77$ K*9&$'J K$78*558: W5 I$%7.EF #<%$' UF<7$' 5*8 Y%NEL$' K*7 A.5 ^.79$/.'/7&%.EL 7-#*$ &<%NK$% *' M.68 KA#: Y<5O6<85-7OFB%$ 0-%/7F$': Y*$ ^'<9_7$' A$*/$'J &<77 7*EF *'7K$7-'&$%$ K$* Y<5O6OF<7$' 78<%L$ G$5O$%<8.%/%<&*$'8$' .'& &<5*8 '$''$'7#$%8$ a./2 .'& Y%.EL7O<''.'/$' *' &$% 0-%/$7O<''8$' T$8-'#<'& <.7K*9&$': b$/$' &$% /$%*'/$' a./6$78*/L$*8 &$7 T$8-'7 $'878$F$' &<&.%EF 7EF-' K$* Y%NEL$' *5 T$%$*EF &$7 ^.79$/.'/7&%.EL7 /%-,$ T$%$*EF$ 5*8]*L%-%*77$': Y*$ 78%.L8.%5$EF<'*7EF$' T$%$EF'.'/$' K*9&$' &*$ T<7*7 6N% &*$ M$EL%<8$'K$%$EF'.'/ &.%EF R789/.'/ &$% U-7*8*-'$' #<'&&.%EF&%*'/$'&$% P*77$ 7-#*$ &$%$' P*77)66'.'/: RN% &*$ M$EL%<8$'K$78*55.'/ #.%&$' &*7 P<'&K$&*'/.'/$' *' &*$ T$%$EF'.'/ 5*8 &$5 GF$%5-F_&%<.9*L U%-/%<55 Z[Z[VjV NK$%'-55$' .'& &*$ ^.778%)5%<8$' $'87O%$EF$'& &$5 A$*89*EF$' I$%9<.6 &$% I$%7.EF76<F%#$*7$ $%5*88$98: W5 P<F5$' &$% &.%EF/$6NF%8$' ^'<9_7$' F<K$' 7*EF

'7K$7-'&$%$ K$* &$% T$78*55./ &$% 6N% &$ M$EL%<8$'K$%$EF'./ $%6-%&$%9*EF$' P*77)66'./$' KA#: 269BEF$' MNEL$' *' &$% K*7F$% $*'/$7$8A8$' ^'<9_7$5$8F-&*L .'& 7-5*8 &*$ D-8#$'&*/L$*8 6N% $*'$ b$*8$%$'8#*EL9./ /$A$*/8:

a.% T$78*55./ &$% ^.7#*%L./$' KA#: &$% TF%%7EFK<%L$*8 7EF#$%$% V8)%6B99$ *78 $7 $%6-%&$%9*EFJ &*$]$8F-&$' 6N% V*EF$%F$*87'<EF#$*7$ A.% W'8$/%*8B8 .'& Y*EF8F$*8 0-' V*EF$%F$*87K$FB98$%' 9<.6$'&$% ^'9</$' #$*8$%A.$'8#*EL$9': a*$9 *78 $7J *5 a.7<55$'F<'/ 5*8 /%-,8$EF'*7EF$' \eO$%*5$'8$' &*$ ^'<9_7$5$8F-&*L K<7*$%$'& <.6 R*'*8$' \9$5$'8$' A.% T$78*55./ &$% W'8$/%*8B8 0-' T$FB98$%78%.L8.%$' <.7 0-%/$7O<''8$5 T$8-'7-#*$ &*$ M$EL%<8$'K$78*55./*5 c*'K9*EL <.6 &*$ Y*EF8F$*8 &$% V8%.L8.%$' #$*8$%A.$'8#*EL$9': Y<K$* *78 &*$ ^.77</$/$'<./L$*8 &$% ^'<9_7$5$8F-&*L K$AN/9*EF &$% V*5.9<8*-' &$7 I$%6-%5./70$%F<98$'7 0-' T$8-'78%.L8.%$' .'8$% T$%NEL7*EF8*/./ 0-' I-%7O<''./ .'& T$#$F%./ &.%EF ^'<9_7$' A. I$%7.EF$' <.6A.A$*/$': b$*8$%F*' 7*'& 7$*8$'7 &$% V8%.L8.%5$EF<'*L &*$ I-%<.77$8A.'/$' 6N% $*'$ M$EL%<8$'K$%$EF'./ A. 0$%K$77$%' .'& *' &$% 8F$%5-F_&%<.9*7EF$']-&99'8#*EL9./ 6N% &*$ M$EL%<8$'K$78*55./ A. K$%NEL7*EF8*/$':

3.1.2.3 Stahlbetonstrukturen bei Einwirkungen von außen

T$* &$% ^.79$/./ 0-' ($%'L%<68#$%L$' #.%&$' '$K$' &$' <'9</$'*'8$%'$' \%$*/'*77$' <.EF B.,$%$ *'#*%L./$' <.7 '<8.%K$&*'/8$' KA#: A*O*9*7<8-%*7EF K$&*'/8$' \%$*/'*77$' K$%NEL7*EF8*/8 KA#: &$%$' ^.7#*%L./$' .'8$%7.EF8: *'#*%L./$' Y%*88$%J A: T: *' R-%5 8$%%-%*78*7EF$% ^88<EL$'J #.%&$' '.% 6N% $*'$ M$EL%<8$'K$%$EF'./ A. 0$%K$77$%' .'& *' &$% 8F$%5-F_&%<.9*7EF$']-&99'8#*EL9./ 6N% &*$ M$EL%<8$'K$78*55./ A. K$%NEL7*EF8*/$':

3.1.2.3 Stahlbetonstrukturen bei Einwirkungen von außen

T$* &$% ^.79$/./ 0-' ($%'L%<68#$%L$' #.%&$' '$K$' &$' <'9</$'*'8$%'$' \%$*/'*77$' <.EF B.,$%$ *'#*%L./$' <.7 '<8.%K$&*'/8$' KA#: A*O*9*7<8-%*7EF K$&*'/8$' \%$*/'*77$' K$%NEL7*EF8*/8 KA#: &$%$' ^.7#*%L./$' .'8$%7.EF8: *'#*%L./$' Y%*88$%J A: T: *' R-%5 8$%%-%*78*7EF$% ^88<EL$'J #.%&$' '.% 6N% $*'$ M$EL%<8$'K$%$EF'./ A. 0$%K$77$%' .'& *' &$% 8F$%5-F_&%<.9*7EF$']-&99'8#*EL9./ 6N% &*$ M$EL%<8$'K$78*55./ A. K$%NEL7*EF8*/$':

W5 P<F5$' 0-' ''8$%7.EF./$' &$% !(*'$8*7EF$' +%$'A8%</6BF*/L$*8 0-' V8<F9K$8-'O9<88$'; #.%&$' K$%$*87 *' &$' i>$% f<F%$' A.5 ^.6O%<992 .'& U$'$8%<8*-'70$%F<98$' 0-' &$6-%5*$%K<%$' U%-h$L8*9$' +%-,0$%7.EF$ <.6 &$5 I$%7.EF7/$9B'&$*']OO' 7-#*$ T$%$EF'./$' A. &$' I$%7.EF$' &.%EF/$6NF%8:

W5 f<F%$ 1dii #.%&$ <.6 &$5 G$78/$9B'&$ &$% V^DYW^ D<8*-'<9 M<K-%<8-%*$7 *' &$' 'V^ &<7 ^.6O%<990$%F<98$' $*'$7 f</&69./A$./$7 <.6 $*'$ 78<%%$ b<'& eO%*5$'8$99 6N% $*'$ ^.6O%<99/$7EF#*'&*/L$*8 0-' 31= 5k7 .'8$%7.EF8J .5 &*$ M<782a$*82R.'L8*-' 6N% $*'$' &$%<%8*/$' ^.6O%<99 <KA.7*EF$%': Y*$ 5*8 &$5]*9*8B%h$8 *5 1C1]<,78<K &.%EF/$6NF%8$' I$%7.EF$ F<K$' /$A$*/8J &<77 &*$ +$7<5878%.L8.% &$7 f$87 K$*5

^.6O%<99 L-5O9$88 6%</5$'8*$%8$J #-K$* &*$ R%</5$'8$ NK$% $*'$' /%),$%$' (%$*7 <'/$-%&'$8 #<%$':

Y*$ Y.%EF6NF%.'/ 7_78$5<8*7EF$% U<%<5$8$%78.&*$' 6N% $*'$' R9./A$./<.6O%<99 5*8 c*%$ '.5$%*7EF$% V*5.9<8*-'$' $%6-%&$%8 $'8#$&$% $*'$ 78<%L$ I$%$*'6<EF.'/ &$% R9./A$./78%.L8.%J $*'$ T$7EF%B'L.'/ <.6 $*'A$9'$ V$L8*-'$' -&$% <.6 #$'*/$ %$O%B7$'8<8*0$ RB99$J .5 &*$ ^'6-%&$%.'/$' <' &*$ PEF'9$*78.'/$' *' 0$%8%$8K<%$' +%$'A$' A. F<98$': DK' &$' 0$%$*'6<EF8$']$8F-&$' A.% ZF<%<L8$%*7*$%.'/ &$% 5$EF<'*7EF$' *'#*%L.'/$' 0-'<.,$' .'& &$% T$78*55.'/ &$% b*&$%78<'&76BF*/L$*8 0-' T<%%*$%$' #$%&$' A.'$F5$'& <.6#B'&*/$%$]$8F-&$' K<7*$%$'& <.6 R*'*8$' \9$5$'8$' $*'/$7$8A8: *'$ <&Bp<8$ V*5.9<8*-' $%6-% &$%8 PEF'O%-/%<55$J &*$ <99$ #7'89*EF$' \9$5$'8$ $*'$7 ^.6O%<997 5-&$99*$%$' L)''$' 7-#*$ $'87O%$EF$'&$ &_'<5*7EF$]<8$%*<9L$''#$%8$:

3.1.3 Modellentwicklung zur Strukturzuverlässigkeit passiver Komponenten

T$* &$% T$#$%8.'/ &$% V*EF$%F$*8 0-' P-F%9$*8.'/$'J Y%.ELK$FB98$%'J V*EF$%F$*87K$FB98$%' .'& <'&$%$' O<77*0$' V8%.L8.%$' 78$F$' *' Y$.87EF9<'& K*7F$% &$8$%5*'*78*7EF$ I-%/F'7#$*7$' *5 I-%&$%/%.'&: W' 0$%7EF*$&$'$' 8$EF'*7EF$' T$%$*EF$' #*$ A: T: &$% T<.8$EF'*LJ &$5 V8<F9K<. .'& [667F-%$ (-'78%.L8*-'$' 7*'& P$/$9#$%L$ '<8*-'<9 .'& *'8$%'<8*-'<9 *'A#*7EF$' A.'$F5$'& <.6 &*$ p<'8*8<8*0$ T$78*55.'/ 0-' V8%.L8.%A.0$%9B77*/L$*8$' <.7/$%*EF8$8: ^.EF *5 T$%$*EF &$% ($%'8$EF'*L /$F$' 0$%7EF*$&$'$ *'8$%'<8*-'<9$ P$/$9#$%L$ *' &*$ P*EF8.'/J p<'8*8<8*0$ I-%/<K$' 6N% &*$ a.0$%9B77*/L$*8 #*EF8*/$% (-5O-'$'8$' A. &$6*'*$%$': V$*8 0*$9$' f<F%$' #$%&$' *'7K$7-'&$%$ *' &$' 'V^J VEF#$&$' .'& <.EF <'&$%$' MB'&$%' ^'7B8A$ 0$%6-9/8J %$/.9<8-%7EF$ D<EF#$*7A*$9$ <.6 &$% T<7*7 p<'8*8<8*0$% P*7*L-<'<9_7$' A. K$/%N'&$': W5 VO%<EF/$K%<.EF #$%&$' &<6N% !%*7L K<7$&;J !%*7L *'6-%5$&; -&$% !%*7L -%*$'8$&; 0$%#$'&$8: W5 T$%$*EF &$% #*$&$%L$F%$'&$' .'& A$%78)%.'/76%$*$' U%N6.'/$' #.%&$' !%*7L K<7$&; V8%<8$/*$' $'8#*EL$98J .5 &*$ ^.7#<F9 &$% A. O%N6$'&$' V8$99$' 7-#*$ &*$ a$*86-9/$.'& &$' '56<'/ &$% U%N6.'/$' $'87O%$EF$'& $*'$5 %*7*L-K<7*$%8$' P<'L*'/ &$% V8$99$' A.$*'<'&$% 0-%'$F5$' A. L)''$': Y<K$* #$%&$' A.'$F5$'& O%-K<K*9*78*7EF$]-&99 A.% \%5*889.'/ &$% V8%.L8.%A.0$%9B77*/L$*8 O<77*0$% (-5O-'$'8$' $*'/$7$8A8: W5 a.7<55$'F<'/ 5*8 O%-K<K*9*78*7EF$' V*EF$%F$*87<'<9_7$' SUV^X 0-' ($%'L%<68#$%L$' 7*'& ^.77</$' A.% V8%.L8.%A.0$%9B77*/L$*8 $%6-%&$%9*EF: a.5 $*'$' *78 <.6A.A$*/$'J #*$ &*$ W'8$/%*8B8 0-'

&%.EL6NF%$'&$' (-5O-'$'8$' $*'A.7EFB8A$' *78 *5 c*'K9*EL <.6 &*$ I$%5$*&.'/ 0-' *'9$*8.'/7$%$*/'*77$' 5*8 7*EF$%F$*87%$9$0<'8$' ^.7#*%L.'/$': a.5 <'&$%$' 7*'& &*$])/9*EFL$*8$' &$7 W'8$/%*8B870$%9.78$7 K$* $e8%$5$' *'#*%L.'/$' h$'7$*87 &$% ^.79$/.'/ A. K$%NEL7*EF8*/$': Y<K$* #.%&$' A:T: *5 P<F5$' &$% Y$.87EF$' P*7*L-78.&*$ UF<7$ T k+PV d>k #<F%7EF$*'9*EFL$*87K$F<68$8$ ^.77</$' A.% W'8$/%*8B8 KA#: T%.EF7*EF$%F$*8 0-' +%-,L-5O-'$'8$' *5 V*''$ 0-' \eO$%8$'7EFB8A.'/$' 0-%/$'-55$':

W5 c*'K9*EL <.6 &*$ T$#$%8.'/ &$7 V8%.L8.%0$%F<98$'7 O<77*0$% (-5O-'$'8$' F<8 7*EF &.%EF &*$ *5 P<F5$' .56<'/%$*EF$% '<8*-'<9$% .'& *'8$%'<8*-'<9$% R-%7EF.'/70-%F<K$' &.%EF/$6NF%8$' \eO$%*5$'8$ 7-#*$ &*$ \%/$K'*77$ 0-' V*5.9<8*-'$' 5*8 /.8 0<9*&*$%8$' P$EF$'5-&$99$' $*' $%F$K9*EF$% ($''8''7A./$#*''$%/K': T$* 7*EF$%F$*878$EF'*7EF$' T$#$%8.'/$' *78 $7 5*8 &$' F$.8$ A.% I$%6N/.'/ 78$F$'&$' ^'<9_7$#$%LA$./$' 5)/9*EFJ 5*8 7$F% K$/%$'A8$5 a$*8<.6#<'& &$8<*99*$%8$ ^'<9_7$' A.% h$#$*9*/$' U%-K9$578$99.'/ &.%EFA.6NF%$': Y*$ 0-%F<'&$'$' ''7*EF$%F$*8$' 9<77$' 7*EF &.%EF /$%*'/$']$F%<.6#<'& *' R-%5 0-' U<%<5$8$%78.&*$' p<' 8*6*A*$%$' .'& L)''$' *' &$% T$#$%8.'/ K$%NEL7*EF8*/8 #$%&$': *' #$*8$%$% #$7$'89*EF$% T$78<'&8$*9 &$7 \%6<F%.'/7A.#<EF7$7 9$*8$8 7*EF <.7 &$% T$8%*$K7$%6<F%.'/ 5*8 &%.EL6NF%$'&$' (-5O-'$'8$' *' ($%'L%<68#$%L$' <K: RN% &*$ *' &$.87EF$' ($%'L%<68#$%L$' <.6/$8%8'$' VEF<&$'7$%$*/''*77$ *78 $*'$ <.6K$%$*8$8$ Y<8$'K<7*7 0$%6N/K<%: Y<K$* 9*$/$' &*$ *'8%*887FB.6*/L$*8$' &$% &-L.5$'8*$%8$' \%$*/''*77$ #$/$' &$% /$%*'/$' U-O.9<8*-' 0$%/9$*EFK<%$% (-5O-'$'8$' *5 T$%$*EF 0-' 1>[21] K*7 1>[23] O%- f<F%: Y*$ Y<8$'K<7*7 &$% #$98#$*8$' T$8%*$K7$%6<F%.'/ $%5)/9*EF8 $*'$ &*%$L8$ o<'8*6*A*$%.'/ &$% V8%.L8.%A.0$%9B77*/L$*8 '.% K*7 A.5 T$%$*EF E<:1> [21] O%- P$<L8-%h<F%: a.% *'7EFB8A.'/ &$% V8%.L8.%A.0$%9B77*/L$*8 O<77*0$% (-5O-'$'8$' *5 T$%$*EF L9$*'$%$% b$%8$ *78 &$% *'7<8A O%-K<K*9*78*7EF$%]-&99 $%6-%&$%9*EF:

3.1.3.1 Rohrleitungen

Y*$ \'8#*EL9.'/ $*'$7 O%-K<K*9*78*7EF$' ^'<9_7$#$%LA$./$7 SUP [VG 2 U%-K<K*9*78*7EF$ V8%.L8.%K$%$EF.'/XJ &<7 A.'BEF78 <.6 P-F%9$*8.'/778NEL$ K$/%$'A8 *78J 7-99 &*$ T$%$EF'./' 0-' M$EL2 .'& T%.EF#<F%7EF$*'9*EFL$*8$' 6N% 0$%7EF*$&$'$ P-F%9$*8.'/7/$-5$8%*$'J T$9<78.'/7<''<F5$' .'& P*770$%8$*9.'/$' $%5)/9*EF$': \%78$ o<9*6*A*$%.'/ 77EF%*88$ 6N% &*$ $'8#*EL$98$' U%-/%<55 9$*78.'/$' #.%&$' <' $*'$5 ^'#$'&.'/7K$*7O*$9 A.5 VEF<&$'75$EF<''75.7 !8F$%5*7EF$ \%5N&.'/; &.%EF/$6NF%8: Y<K$* #.%&$' <.EF I$%/9$*EF7<'<9_7$' 5*8 $*'$% .5 K$78*55 8$

M$*78.'/$' $%#$*8$%8$' I$%7*-' &$7 0-' &$% ''*8$& V8<8$7 D.E9$<% P$/.9<8-%_ Z-55*77*-'S'VDPZX K$%$*8/$78$998$' U%-/%<557 UP^WV\ SU*O*'/ P$9*<K*9*8_ ^'<9_7*7 W'E9.&*'/ V$*75*E \0$'87X &.%EF/$6NF%8: W' &$5 ^'#$'&.'/7K$*7O*$9 #*%& 6N% $*'$.'8$%78$998$ P*770$%8$*9.'/ *' $*'$5 P-F%78%<'/ &$7 I-9.5$'%$/$97_78$57 $*'$7 YbP &*$ M$EL#<F%7EF$*'9*EFL$*8 *'6-9/$ \%5N&.'/ <.6/%.'& 8F$%5*7EF$% b$EF7$99<78$' <97 R.'L8*-' &$% T$8%*$K7A$*8 K$78*55 8S^'<9_7$5-&$99 7*F T*9& @2IX:

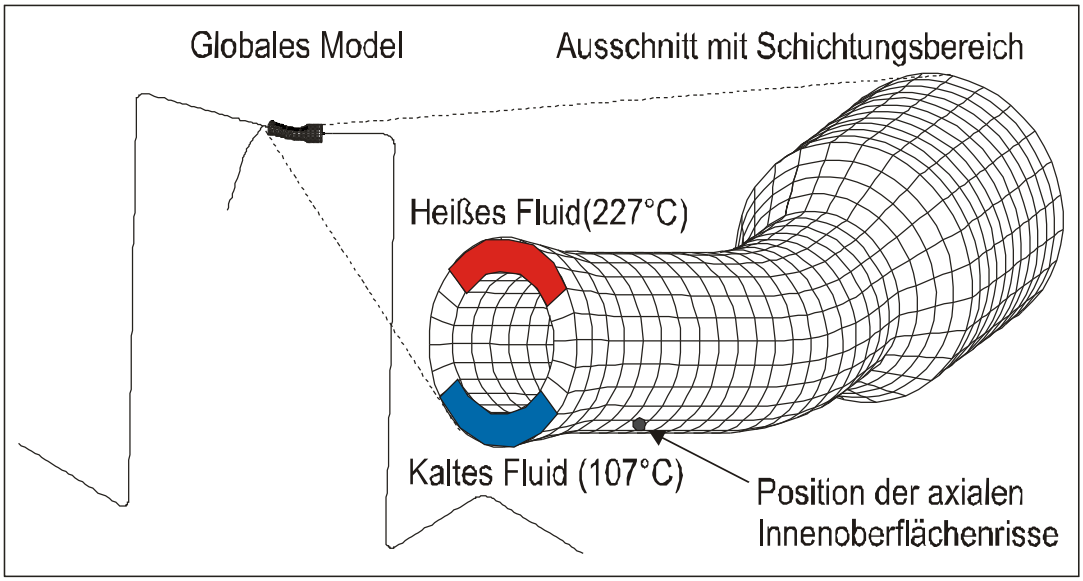


Bild 3-4C ^'<9_7$5-&$99 $*'$7 P-F%9$*8.'/7<K7EF'*887 SG_O I-9.5$'%$/$97_78$5X +$7<585-&$99 .'& ^.77EF'*88 &$7 P*772 .'& VEF*EF8.'/7K$%$*EF7

a.% T$%NEL7*EF8*/.'/ &$% ($''8''*7.'7*EF$%F$*8$' KA#: V8%$..'/$' *' &$']<8$%*<92 .'& +$-5$8%*$&<8$' 7-#*$ T$9<78.'/7O<%<5$8$%' #.%&$'*' &$5 ^'#$'&.'/7K$*7O*$9 $'87O%$EF$'&$ I$%8$*9.'/76.'L8*-'$' 7O$A*6*A*$%8: W5 P<F5$' $*'$% ''7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$ $%/<K 7*EFJ &<77 &*$ G$5O$%<8.%&*66$%$'A A.% ZF<%<L8$%*7*$%.'/ &$% T$9<78.'/ <.7 8F$%5*7EF$% VEF*EF8.'/J &*$ P*77#<EF78.57L-'78<'8$.'& &*$ b<'&&*EL$ &*$ #7'89*EF$' *'69.77/%),$' <.6 &*$ M$EL#<F%7EF$*'9*EFL$*8 7*'&:

a.% ^K%.'&.'/ &*7% ^%K$*8$' #*%& .:<: *5 P<F5$' &$% T8*9*/.'/ <5 \'2U%-h$L8 D'PTW] SD.E9$<% P*7L2T<7$& W'7O$E8*-']$8F-&-9-/_ 6-% U<77*0$ Z-5O-'$'87X &*$ M$*78.'/76BF*/L$*8 &$% *' 0$%7EF*$&$'$' $.%-OB*7EF$' [%/<'*7<8*-'$' $*'/$7$8A8$']-&99 A.% T$78*55.'/ &$% V8%.L8.%A.0$%9B77*/L$*8 0-' P-F%9$*8.'/$' 0$%/9*EF$': Y*7]-&99 #$%&$' *'7K$7-'&$%$ A.% \'8#*EL9.'/ %*7*L-K<7*$%8$% W'7O$L8*-'7L-'A$O8$ K$')8*/8 .'& 8$*9#$*7$ K$%$*87 $*'/$7$8A8: I$%/9$*EF7<'<9_7$' 5*8

&$' ^'<9_7$5$8F-&$' &$% U<%8'$% *5 \'2U%-h$L8 A$*/$' 6N% &*$.'8$%7.EF8$' ^.6/<K$'78$99.'/$' A.5 VEF<&$'75$EF<'*75.7 !\%5N&.'/;J &<77 &*$ 5*8 &$' 0$%7EF*$&$'$' U%-/%<55$' K$%$EF'8' M$EL#<F%7EF$*'9*EFL$*8$' /.8 NK$%$*'78*55$' .'& &*$ $%#<%8$8$' G%$'&7 <.6/A*/8 #$%&$': Y*$ <.6/$8%$8$'$' /$%*'/$' ^K#$*EF.'/$' L-''8$' <.6 +%.'&<''<F5$' &$% .'8$%7EF*$&9*EF$' ^'<9_7$E-&$7 A.%NEL/$6NF%8 #$%&$': Y*$ /.8$ HK$%$*'78*55.'/ &$% P$EF$'$%/$K'*77$ *78 *'7K$7-'&$%$ &<%<.6 A.%NELA.6NF%$'J &<77 &*$ ^.6/<K$'78$99.'/$' .'& *'7K$7-'&$%$ &*$ *'/<K$&<8$' L9<% .'& $*'&$.8*/ /$/$K$' #<%$' .'& 7-5*8 6N% &$' ^'#$'&$% L$*'$ ''7*EF$%F$*8$' &*$7K$AN/9*EF K$78<'&$': W5 P<F5$' 0-' U<%<5$8$%78.&*$' #.%&$ /A*/8J &<77 &*$ M$EL2 .'& T%.EF#<F%7EF$*'9*EFL$*8$' 78<%L 0-5 b$%8 &$% P*77#<EF78.57L-'78<'8$'J 0-' &$% M<78F)F$ 7-#*$ 0-' I<%*<8*-'$' *' &$% .'8$%78$998$' ^'6<'/7%*770$%8$*9.'/J *'7K$7-'&$%$ K$AN/9*EF &$% ^''<F5$ 0-' 8*6' ^'6<'/7%*77$'J<KFB'/*/ 7*'&:

]*8 &$5 U%-8-8_O &$7 PEF'O%-/%<557 UP[VG L)''$' K*7F$% M$EL2 .'& T%.EF#<F%7EF$*'9*EFL$*8$' 0-' P-F%9$*8.'/$' <97 R.'L8*-' &$% T$8%*$K7&<.$% .'8$% T$%NEL7*EF8*/.'/ &$7 VEF<&$'75$EF<'*75.7 !\%5N&.'/; <.6 T<7*7 $*'$7 A#$*2 O<%<5$8%*/$' I$%7</$'7L%*8$%*.57 K$78*5588 #$%&$':

W5 'BEF78$' VEF%*88 7-99 $*']-&.9 A.% T$%NEL7*EF8*/.'/ &$7 VEF<&$'75$EF<'*75.7 (-%%-7*-'J 7O$A*$99 *'8$%L%*78<99*'$ VO<''.'/7%*77L-%%-7*-' K$* <.78$'*8*7EF$' b$%L78-66$' .'& &$F'.'/7*'&.A*$%8$ P*77L-%%-7*-' K$* 6$%%*8*7EF$' b$%L78-66$' $'8#*EL$98 #$%&$': Y<K$* 7-99 <.7 &$% T$8%*$K7$%6<F%.'/ 5*8 <.78$'*8*7EF$' P-F%9$*8.'/$' *' &$.87EF$' V*$&$#<77$%%$<L8-%$'J<.7 $%/B'A$'&$' ''8$%7.EF.'/$' *5 P<F5$' 0-' ^.78<.7EF5<,'<F5$' 7-#*$ <.7 M<K-%O$%7.EF$' <' 0-%/$7EFB&*/8$' U%-K$' $*'$ I$%8$*9.'/76.'L8*-' 6N% P*77K*9&.'/ <97 R.'L8*-' &$% T$8%*$K7A$*8 6N% $*'$' K$78*558$' U<%<5$8$%K$%$*EF *5 V*''$ $*'$7 VEFB&*/.'/76$'78$%7 <K/9*8$8 #$%&$':

b$*8$%F*' 7-99$' $e*78*$%$'&$ I$%6<F%$' A.% T$%$EF'.'/ 0-' M$EL%<8$' S7*F (<O*8$9 @:1:1]-&$99*$%.'/ 0-' +$7<587_78$5$'X*' &<7 U%-/%<55 $*'/$K.'&$' #$%&$'J &<&*$ MEL%L$''.'/ $*'$' '$''$'7#$%8$' *'69.77 <.6 &*$ T%.EF#<F%7EF$*'9*EFL$*8 F<8: Y<K$* 7-99$']<,'<F5$'J &*$ &.%EF ^'A$*/$' &$% *' ($%'L%<68#$%L$' *'78<99*$%8$' M$ELNK$%#<EF.'/77_78$5$ $*'/$9$*8$8 #$%&$' L)''$'J K$%NEL7*EF8*/8 #$%&$':

3.1.3.2 Druckbehälter

W' $*'$5 7_78$5<8*7EF$' ^'7<8A kVW\ dd<k #.%&$' ''7*EF$%F$*8$' K$* &$% T$7EF%$*K.'/ &$7 P*770$%F<98$'7 *' Y%.ELK$FB98$%' *'6-9/$ 8F$%5-25$EF<'*7EF 8%<'7*$'8$% T$9<78.'/$' $%6<778: Y<A. #.%&$' 6N% <.7/$#BF98$ U<%<5$8$% A.% T$7EF%$*K.'/ &$% ^'<9_7$5-&99 I$%8$*9.'/76.'L8*-'$' 6$78/9/8 .'& .'8$% I$%#$'&.'/ 78<8*78*7EF$%]$8F-&$' U<%<5$8$%L-5K*'<8*-'$' K$78*55 8: RN% A#$* ^'#$'&.'/76B99$ #.%&$' h$#$*97 1>> 6*'*8$ \9$5$'8$ ^'<9_7$' &.%EF/$6NF%8J 7-&<77 ^.77</$' NK$% &*$ ''7*EF$%F$*8$' %$9$0<'8$% \%/$K'*77$ $%A*$98 #$%&$' L-''8$': Y<K$* L-''8$ &$% L-5K*'*$%8$ *'69.77 0-' ''7*EF$%F$*8$' F*'7*EF89*EF &$%]-&$92 .'& M)7.'/7<'7B8A$ 7-#*$ &*%$L8$% *'/<K$O<%<5$8$% A.% ZF<%<L8$%*7*$%.'/ &$% b$%L78-66$.'& &$% T$9<78.'/$' <.6 <.7/$#BF98$ K%.EF5$EF<'*7EF$ ^'<9_7$$%/$K'*77$ p<'8*6*A*$%8 #$%&$': ^97 T$*7O*9 6N% p<'8*8<8*0$ \%5*889.'/$' &$% ''7*EF$%F$*8$' #.%&$ A.'BEF78 &$% U%-K$L)%O$% $*'$7 GF$%5-7EF-EL2+%-,0$%7.EF7 .'& &<'' $*' P$<L8-%&%.ELK$FB98$% 5*8 $*'$5 .'8$%78$998$' F<9K$99*O8*7EF$' [K$%69BEF$'%*77 .'8$%7.EF8: ^97 PYT T$9<78.'/ #.%&$ $*'$ D-8LNF98%<'7*$'8$ *'6-9/$ $*'$7 .'8$%78$998$' O%*5B%7$*8*/$' M$EL7 5*8 (NF978%BF'$ <.7/$#BF98: Y*$ ''7*EF$%F$*8 &$7 VO<''.'/7*'8$'7*8B876<L8-%7 *5 T$%$*EF &$7 M<78O6<&5<e*5.57 %$9<8*0 A.% P6%$'A<'<9_7$ 9*$/8 K$* $8#< 1> vKA#: 21= v Y<K$* *78 A. K$<EF8$'J &<77 &*$ \%/$K'*77$ 78<%L 0-' &$' <'/$'-55$'$' I$%8$*9.'/76.'L8*-'$' A.% T$7EF%$*K.'/ &$% ''7*EF$%F$*8$' K$* &$% R$789$/.'/ &$% ^'<9_7$O<%<5$8$% <KFB'/$': Y*$ ^.7#$%8.'/ &$7 78<'&<%&*7*$%8$' P$/%$77*-'7L-$66*A*$'8$' <97 V$'7*8*0*B875<, A$*/8 '$K$' $%#<%8$8$' ^KFB'/*/L$*8$' &$% \%/$K'*77$ 0-' *'/<'/7O<%<5$8$%' L$*'$ 7*/'*6*L<'8$' \66$L8$: Y<5*8 #*%& &$% o<9*6*A*$%.'/778<'& &$% $*'/$7$8 A8$' K%.EF5$EF<'*7EF$' ^'<9_7$5$8F-&*L K<7*$%$'& <.6 &$5 f2W'8$/%<9 &$.89*EF:

a.% \%#$*8$%.'/ &$7 ^'#$'&.'/7K$%$*EF$7 &$7 *5 (<O*8$9 @:1:@:1 $%#BF'8$' U%-/%<557 UP[VG SU%-K<K*9*78*7EF$ V8%.L8.%K$%$EF'.'/X <.6 A_9*'&%*7EF$ T$%$*EF$ 0-' (-5O-'$'8$' #*$ &$' P$<L8-%&%.ELK$FB98$%J &$' Y<5O6$%A$./$% .'& &$' Y%.ELF<98$% 7-#*$ <.6 L-5O9e P<'&K$&*'/.'/$' K$AN/9*EF +$-5$8%*$.'& T$9<78.'/ 7-99 &*$ U%-/%<5578%.L8.% 0-' UP[VG $%#$*8$%8 #$%&$': T$* &$% I-%/$F$'7#$*7$ 7-99$' V_'$%/*$$66$L8$ K$%NEL7*EF8*/8 #$%&$'J &:F: K$78*558$ T$%$EF'.'/75-&.9$ L)''$' 7-#-F9 6N% &*$ T$78*55.'/ &$% V8%.L8.%A.0$%9B77*/L$*8 0-' P-F%9$*8.'/$' <97 <.EF 0-' T$FB98$%' /$'.8A8 #$%&$': b$*8$%F*' 7-99$']-&$99<'7B8A$ <.7 K$%$*87 $e*78*$%$'&$' VO$A*<9O%-/%<55$'J #*$ A.5 T$*7O*$9 &<7*5 ^.68%</ &$% 'V DPZ $'8#*EL$98$J O%-K<K*9*78*7EF$ Z-5O.8$%O%-/%<55 R^I[P SR%<E8.%$ ^'<9_7*7 I$77$97C [<L P*&/$X K$AN/9*EF */'.'/ .'& I$%#$'&K<%L$*8 6N% &*$

' &$.87EF$' ^'9</$' 0-%9*$/$'&$' b$%L78-66$/$'7EF<68$' .'& /$-5$8%*7EF$' +$/K'F$*8$' K$%NEL7*EF8*/8 #$%&$': Y*$ A. $'8#*EL$9'&$' T$%$EF'.'/72 5)/9*EFL$*8$' 7-99$' <' ^.6/<K$' <.7 &$' *5 P<F5$' &$% ZVDW SZ-55*88$$ -' 8F$ V<6$8_ -6 D.E9$<% W'78<99<8*-'7X ^%K$*87/%.OO$ W^+\ SW'8$/%*8_ -6 Z-5O-'$'87 <'& V8%.E8.%$7X &.%EF/$6NF%8$' *'8$%'<8*-'<9$' I$%/9$*EF7<'<9_7$' p<9*6*A*$%8 #$%&$':

T$* &$% b$*8$%$'8#*EL9.'/ &$7 O%-K<K*9*78*7EF$' ^'<9_7$#$%LA$./$7 UP[VG 7-99 *5 I-%&$%/%.'& 78F'J &<77 &*$ (-5O-'$'8$'/$-5$8%*$.'& &*$ T$9<78.'/ '*EF8 #*$ $8#< K$* UP^WV\ <.6 +$%<&%-F%$.'8$% W''$'&%.EL -&$% K$* R^I[P <.6 P$<L8-%&%.ELK$FB98$% .'8$% W''$'&%.EL .'& %-8<8*-'77_55$8%*7EF$% 8F$%5*7EF$% T$9<78.'/ K$7EF%B'L8 K9$*K$' 7-'&$%' &<77 L-5O9e%$ (-5O-'$'8$'/$-5$8%*$' .'& T$9<78.'/$' &.%EF $*'$ (-OO9.'/ <' &*$ 78%.L8.%5$EF<'*7EF$ R*'*8$2\9$5$'8$2 ^'<9_7$5$8F-&*L K$F<'&$98 #$%&$' L)''$': Y.%EF &*$7$ I-%/F'7#$*7$ L)''$' ^K7EFB8A.'/$' A.% V8%.L8.%A.0$%9B77*/L$*8 O<77*0$% (-5O-'$'8$' .'8$% %$<9*8B87'<F$' P<'&K$&*'/.'/$' $%6-9/$'J &< A:T: F-F$ \%5N&.'/7<.7'.8A.'/ KA#: VEFB&$' FB.6*/ <' /$-5$8%*7EF L-5O9$e$%$' V8%.L8.%8$*9$' #*$ V8.8A$' -&$% b<'&&*EL$'NK$%/B'/$' <.68%$8$': RN% &<A. '-8#$'&*/$ VO<''.'/72 .'& T%.EF2 5$EF<'*L<'<9_7$' 7-99 $*'$ $%O%-K8$ &8%5*'*78*7EF$ 78%.L8.%5$EF<'*7EF$ R*'*8$2 \9$5$'8$2^'<9_7$5$8F-&*L A:T: K<7*$%$'& <.6 &$5 U%-/%<557_78$5 ^YWD^ $*'/$7$8A8 #$%&$': Y*$7$ $%5)/9*EF8 &*$ V*5.9<8*-' &$7 V8%.L8.%0$%F<98$'7 0-' $*'A$9'$' (-5O-'$'8$' <97 <.EF $*'$% /$7<58$' (NF9L%$*79<.67EF9$*6$ K$* I<%*<8*-' &$% T$9<78.'/7O<%<5$8$%J &$%]<8$%*<9L$''#$%8$.'& &$% T$%$EF'.'/7O<%<5$8$% S7*$F$ (<O*8$9 @:1:1]-&$99*$%.'/ 0-' +$7<587_78$5$'X: Y*$ A. 0$%#$'&$'&$' P*770$%8$*9.'/$' 7-99$' K$8%*$K7K$&*'/8$ 7-#*$ F$%78$99.'/7K$&*'/8$ P*77$ K$%NEL7*EF8*/$': Y<A. 7-99$' 0$%6N/K<%$ \%/$K'*77$ 0-' $'87O%$EF$'&$']<8$%*<9.'8$%7.EF.'/$' <' *' &$.87EF$' (%<68#$%L$' 0$%#$'&$8$' P$<L8-%78BF9$' 7-#*$ T$8%*$K7$%6<F%.'/J &*$ &<7 *' &$.87EF$' (%<68#$%L$' 0-%F<'&$'$ V*EF$%F$*87'*0$<. #*&$%7O*$/$98J F$%<'/$A-/$' #$%&$': T$* &$% VEFB8A.'/ &$% b<F%7EF$*'9*EFL$*870$%8$*9.'/$' K$78*55 58$% *'/<K$O<%<5$8$% 7-99$' ($''8'*72 .'7*EF$%F$*8$' K$%NEL7*EF8*/8 #$%&$':

3.1.3.3 Sicherheitsbehälter

Y$% V*EF$%F$*87$*'7EF9.77 *78 &<7 V_78$5 <.7 V*EF$%F$*87K$FB98$% .'& .5/$K$'&$' +$KB.&$:]*8 &*$7$5 V_78$5 7-99 *'7K$7-'&$%$ K$* (NF95*88$90$%9.7878)%6B99$' &$% ^.78%*88 6%$*/$7$8A8$% %<&*-<L8*0$% VO<98O%-&.L8$ *' &*$ ‘5/$K.'/ 0$%F*'&$%8 KA#: <.6

&*$ A.9B77*/$' b$%8$ K$/%$'A8 #$%&$': Y.%EF &<7 K$* $*'$5 V8)%6<99 <.778%)5$'&$ (NF95*88$9 #*%& &$% V*EF$%F$*87$*'7EF9.77 Y%.EL2 .'& G$5O$%<8.%K$9<78.'/$' <.7/$7$8A8: W5 P<F5$' 0-' &$.87EF$' V*EF$%F$*8778.&*$' #.%&$' ^K7EFB8A.'/$' A.5 G%</0$%F<98$' 0$%7EF*$&$'$% V*EF$%F$*87K$FB98$%L-'78%.L8*-'$' &.%EF/$6NF%8J .5 VEF#<EF78$99$' A.*&$'8*6*A*$%$' SY$.87EF$ P*7*L-78.&*$ UF<7$ T k+PV d>kJ kc [\ dkX:

T$* V b P2^'9</$' &$% T<.9*'*$ 8 *78 &$% V*EF$%F$*87K$FB98$% $*'J A.% ^.,$'#<'& &$7 P$<L8-%/$KB.&$7 L-'A$'8%*7EF$%J A_9*'&%*7EF$% V8<F9K$8-'K$FB98$% 5*8 $*'$% b<'&&*EL$ *5 T$%$*EF 1:1 K*7 1:= 5: Y*7% T$FB98$% *78 *' ‘ 56<'/7%*EF8.'/ .'& *' 0$%8*L<9$% P*EF8.'/ 0-%/$7O<''8: Y.%EF &*$ <.6/$A#.'/$'$ I-%7O<''.'/ 78$F8 &*$7$% a_9*'&$% 78B'&*/ .'8$% Y%.EL7O<''.'/: b$*8$%F*' *78 $% &.%EF $*'$' *''$'9*$/$'&$'J $8#< i 55 &*EL$' 5$8<99*7EF$' M*'$% <.7/$L9$*&$8J &$% &*$ $%6-%&$%9*EF$ Y*EF8F$*8 7*EF$%78$99$' 7-99: ^'<9_7$5-&$99$ A.% V*5.9<8*-' &$7 78%.L8.%5$EF<'*7EF$' I$%F<98$'7 K$* K$8%*$K9*EF$' .'& K$* .'8$%78$998$' V8)%6<99K$9<78.'/$' $%6-%&$%' &*$ T$%NEL7*EF8*/.'/ &$7 T$8-'7J &$7 V8<F99*'$%7J &$% T$#$F%.'/J .'& &$% I-%7O<''L<K$9: RN% M<&$&$EL$9J VEF9$.7$' .'& Y.%EF6NF%.'/$' 7*'& Y$8<*95-&$99$ $%6-%&$%9*EF:

W5 +$/$'7<8A &<A.*78 K$* V b P2^'9</$' &$% T<.9*'*$ dn&$ % V*EF$%F$*87K$FB98$% $*' L./$96)%5*/$% V8<F9K$FB98$% SP<&*.7 $8#< 3n 5X 5*8 .'8$' <'/$7$8A8$5 a_9*'&$% .'& $*'$5 L9)OO$%K-&$'6)%5*/$' ^K7EF9.77J #-K$* &*$ b<'&&*EL$ &$% Y%.EL7EF<9$ *5 T$%$*EF 1m ? @> 55 9*$/8: \% *78 *' $*'$ (-'&$'7<8*-'72 .'& $*'$ Y%.ELL<55$% $*'/$8$*98J &*$ &<7 Y%.EL<KK<.7_78$5 &<%78$99$':

Y$.87EF$ Y b P2^'9</$' F<K$' $*'$ %$*'$ L./$96)%5*/$ V8<F97EF<9$J &*$ $*'$' P<&*.7 0-' 3i 5 .'& $*'$ b<'&&*EL$ *5 .'/$78)%8$' T$%$*EF h$ '<EF T<.<%8 0-' K$*7O*$97#$*7$ 3d 55 -&$% @i 55 F<K$':

a.% I$%K$77$%.'/ &$% +$'<.*/L$*8 0-' ^.77</$' A.% V8%.L8.%A.0$%9B77*/L$*8 0-' /$<98$%8$' V*EF$%F$*87K$FB98$%' *'7K$7-'&$%$ *5 P<F5$' 0-' O%-K<K*9*78*7EF$' V*EF$%F$*87<'<9_7$' *78 $*'$ b$*8$%$'8#*EL9.'/ &$% ^'<9_7$5$8F-&*L $%6-%&$%9*EF: Y<K$* 7*'& 0-%F<'&$'$ $%O%-K8$ &8%5*'*78*7EF$ ^'<9_7$#$%LA$./$ .5 O%-K<K*9*78*7EF$ ^'7B8A$ A. $%#$*8$%': ^'<9_7$5-&99 A.% T$78*55.'/ &$% G%</6BF*/L$*8 0-' V*EF$%F$*87K$FB98$%' /$/$'NK$% K$8%*$K9*EF$% T$9<78.'/$' 7-#*$.'8$%78$998$% V8)%6<99K$9<78.'/$' 7*'& A. $'8#*EL$9' .'& <.6 &$% T<7*7 0-%F<'&$'$% 78<8*78*7EF$%]$8F-&$' ‘'7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$' &.%EFA.6NF%$': Y<K$* 7-99$' ‘'7*EF$%F$*8$' *']<8$%*<9&<8$'J +$-5$8%*$&<8$'J P*77<''<F5$' .'& T$9<78.'/7<''<F5$' *' R-%5 0-' I$%8$*9.'/76.'L8*-'$' K$%NEL7*EF8*/8 #$%&$':

\%L$''8'*77$ <.7 ^'<9_7$' A. +%-,0$%7.EF$' <']-&$92Z-'8<*'5$'87 7*'& *5 c*'K9*EL <.6 &*$ o<9*6*A*$%.'/ &$% ^'<9_7$5$8F-&$' A. K$%NE L7*EF8*/$': Y.%EF T$#$%8.'/ <.7/$#BF98$% ^'<9_7$$%/$K'*77$ 5*8 /$$*/'8' I$%7</$'7L%*8$%*$' L)''$' &<'' ^.77</$' A.% M$EL#<F%7EF$*'9*EFL$*8 <K/$9$*8$8 #$%&$': W'7/$7<58 7*'& &*$ &<A. $%6-%&$%9*EF$' \'8#*EL9.'/7<%K$*8$' 6N% &*$ b$*8$%$'8#*EL9.'/ &$%]$8F-&$' A.% Y.%EF6NF%.'/ O%-K<K*9*78*7EF$% V*EF$%F$*87<'<9_7$' S7*F (<O*8$9 i:1:1X 0-' T$&$.8.'/:

3.2 Bruchmechanische Analysemethoden

^.6 O*9' +$K*$8$' &$7]<7EF*'$'2 .'& ^'9</$'K<.7 #$%&$' K%.EF5$EF<'*7EF$ ^'<9_7$5$8F-&$' 6N% .'8$%7EF*$&9*EF78$ a#EL $*'/$7$8A8: a*$9 &$% T$%$EF'.'/$' *78 $7J $*' T<.8$*9 6N% $*'$' K$78*55 8$' *'7<8AA#$EL ST$9<78.'/X A. p<9*6*A*$%$': T$*7O*$97#$*7$ 5.77 6N% &*$ &%.EL6NF%$'&$ '57EF9*$,.'/ $*'$% '.L9$<%$' \'$%/*$$%A$./.'/7<'9</$ '<EF/$#*$7$' #$%&$'J &<77 &*$ W'8$/%*8B8 &$% (-5O-'$'8$' 6N% <99$ K$L<''8$' .'& O-78.9*$%8$' M<786B99$ 0-%F<'&$' *78: RN% &*$ p<'8*8<8*0$ T<.8$*9<'<9_7$J &*$ <.6 &*$ T$#$%8.'/ KA#: I-%F$%7</$ &$7 T<.8$*9O$%F<98$'7 <KA*$98J 5N77$' eO%*5$'8$99 $%5*88$98$ b$%L78-66L$''#$%8$ 0$%#$'&$8 #$%&$' .'& &$%$' HK$%8%</K<%L$*8 <.6 &<7 T<.8$*9 /$#BF%9$*78$8 #$%&$': ^.EF *5 c*'K9*EL <.6 &*$ 0$%78B%L8$ *'6NF%.'/ %*7*L--%*$'8*$%8$% HK$%#<EF.'/72 .'& W'78<'&F<98.'/778%<8$/*$' .'& *5 V*''$)L-9-/*7EF .'&)L-'-5*7EF 0$%K$77$%8$% +$7<58K*9<'A$' K$<'7O%.EF.'/7-O8*5*$%8$% (-'78%.L8*-'$' *78 &*$ K%.EF5$EF<'*7EF$ T<.8$*9<'<9_7$.'0$%A*EF8K<%:

Y*$ HK$%8%</K<%L$*8 &$% K%.EF5$EF<'*7EF$' b$%L78-66L$''#$%8$J #$9EF$' K$* &$% T$#$%8.'/ &$7 I$%7</$'7 <'/$%*77$'$% T<.8$*9$ *' 0*9' RB99$' $*'$ VEF9N77$%-99$ A.L-558J #*%& .'8$% T$%NEL7*EF8*/.'/ &$7]$F%<EF7*/L$*87/%<&$7 &$7 VO<''.'/7A.78<'&$7*5 I$%/9$*EF U%-K$k T<.8$*9 '<EF/$#*$7$':

I*$96B98*/$ \'8#*EL9.'/$' &$% 9$8A8$' f<F%$ F<K$' A. $*'$% /%-,$' ^'A<F9 0-' \5O6$F9.'/$'J P*EF89*'*$' .'& D-%5$' A.% \%5*889.'/ .'& ^'#$'&.'/ K%.EF5$EF<'*7EF$% ($''#$%8$ /$6NF%8J #$9EF$ <.6/%.'& 0$%7EF*$&$'$% I-%/F'7#$*7$' .'& I$%$*'6<EF.'/$' 6N% &<7 A. $%#<%8$'&$ T<.8$*9O$%F<98$' .'8$%7EF*$&9*EF K$#$%8$8 #$%&$' 5N77$': Y<K$* #*%& $'87O%$EF$'& &$5 b$%L78-66O$%F<98$' .'8$%7EF*$&$' *' VO%)&K%.EF .'& aBFK%.EF 5*8 h$#$*97 7$O<%<8$' I$%6<F%$' A.% ($''#$%8K$78*55.'/: RN% &$' HK$%/<'/7K$%$*EF A#*7EF$' &*7' K$*2

&$' T$%$*EF$' #.%&$' K'6<997 7O$A*99 I$%6<F%$' $'8#*EL$98: Y5'87O%EF'& 78$F8 F$.8$ $*'$ I*$9A<F9 .'8$%7EF*$&9*EF$% I$%6<F%$' A.% T$78*55.'/ K%.EF5$EF<'*7EF$% ($''#$%8$ A.% I$%6N/.'/J &*$ $'87O%$EF$'& &$% .'8$%7EF*$&9*EF /$#BF98$' I-%/F'7#$*7$'J P<'&K$&*'/.'/$'J +N98*/L$*87/%$'A$' $8E: '<8.%/$5B, <.EF \%/$K'*77$ 5*8 78<%L .'8$%7EF*$&9*EF$% T$&$.8.'/ $%/$K$': Y*$7$ I$%6<F%$' #.%&$' *' 6%NF$%$' R-%7EF.'/70-%F<K$' 0$%*6*A*$%8:

T$*7O*$9F<68 7*'& &*$ R-%7EF.'/7<%K$*8$' *5 T$%$*EF D-8LNF97*5.9<8*-' kV^' d>J +WMd3JVG' dmVG' >>k: Y<K$* #*%& $*' T<.8$*9 .'& 5*8F*' &$% (-'78%.L8*-'7#$%L78-66 $*'$% L-5O9e' 8F$%5*7EF$' .'& 5$EF<'*7EF$' T$<'7O%.EF.'/ .'8$%#-%6$'J &*$ F*'7*EF89*EF &$% K%.EF5$EF<'*7EF$' T$#$%8.'/ F-F$ ^'6-%&$%.'/$' <' &*$ ^'<9_7$ 78$998: a.% HK$%O%N6.'/ &$% HK$%8%</K<%L*8 0-' <' (9$*'O%-K$' $%5*88$98$' K%.EF5$EF<'*7EF$' U<%<5$8$%' <.6 $*' T<.8$*9 #.%&$ $*'$]$8F-&*L $'8#*EL$98J &*$ *'7K$7-'&$%$ &*$ VO<''.'/75$F%<EF7*/L$*8 K$%NEL7*EF8*/8:W' &$' .'8$%7.EF8$' RB99$' #<%$' &*$ K%.EF5$EF<'*7EF$' ($''#$%8$ NK$%8%</K<% .'& &*$7 6N% <99$ %$9$0<'8$' G$5O$%<8.%K$%$*EF$J <97- 7-#-F9 *' &$% aBF*/L$*87F-EF9</$ <97 <.EF *5 HK$%/<'/7K$%$*EF: Y*$7 #.%&$ <' .'8$%7EF*$&9*EF$' b$%L78-66A.78B'&$' .'& R$F9$%/$-5$8%*$' 0$%*6*A*$%8:

a*$9 <L8.$99$% R-%7EF.'/7<%K$*8$'J A:T: kMWY>@k k\'P>IkJ *78 $7J &$']$F%<EF7*/L$*87A.78<'& SZ[DVGP^WDGX *5 HK$%/<'/7K$%$*EF &$% aBF*/L$*8 #$*8$% 7_78$5<8*7EF A. .'8$%7.EF$'J .5 <99/5*' <'#$'&K<%$ ^'<9_7$#$%LA$./$ K$%$*8A.78$99$': Y$% *'69.77 &$7 9-L<9$' VO<''.'/7A.78<'&7 <.6 &*$ T%.EFABF*/L$*8 #.%&$ <' M<K-%O%-K$' 6N% &$' R<99 A.7B8A9*EF$%J *' &$% O-8$'A*$99$' P*77<.7K%$*8.'/7%*EF8.'/ #*%L$'&$' VO<''.'/$'J .'8$%7.EF8 SA:T: k\'P>IkJ kWb]>=kX: c*$%K$* #$%&$' 0$%7EF*$&$'$ U<%<5$8$% A.% o<'8*6*A*$%.'/ &$7 \66$L87 $*'/$7$8A8: [66$' *78 h$&-EF &*$ R%</$ '<EF &$% HK$%8%</K<%L$*8 &$7 \66$L87 <.6 T<.8$*9$ 5*8 5$F%<EF7*/$' T$9<78.'/7A.78B'&$'J #*$ 7*$ $8#< K$* &$% D-8LNF9.'/ &$7 P$<L8-%&%.ELK$FB98$%7 <.68%$8$' L)''$': W5 P<F5$' &$% 9<.6$'&$' ^%K$*8$' A.% L%*8*7EF$' HK$%O%N6.'/ &$7]<78$%L.%0$2^'7<8A$7 *5 c*'K9*EL <.6 &*$ ^'#$'&.'/ K$* &$.87EF$' ($%'L%<68#$%L$' k]U^>I<k kWb]>=k #$%&$' O<%<99$9 A. .56<'/%$*EF$' eO%*5$'8$99$' ''8$%7.EF.'/$' 6-%87EF%*889*EF$ '.5$%*7EF$ T$%$EF'.'/70$%6<F%$' 0$%#$'&$8J .5 &*$ T$#$%8.'/7O%-A$&.% !]<78$%L.%0$; A. K$78B8*/$' -&$% I$%K$77$%.'/70-%7EF9B/$ <KA.9$*8$': ^.EF &*$ ^'#$'&.'/ &*$7$%]$8F-&$ <.6 K$78%<F98$ b$%L78-66A.78B'&$ #<% .'& *78 '<EF #*$ 0-% +$/$'78<'& '<8*-'<9$% .'& *'8$%'<8*-'<9$% R-%7EF.'/7<%K$*8$' SkIW\>IkJk(\W>@kJkT[MdikJkPGY>IkX:

‘’8$%7EF*$&9*EF$ ^’6-%&$%.’/$’ <’ &*$ R$78*/L$*8 -&$% (-%%-7*-’7K$78B’&*/L$*8 0-’ (-5O-’$’8$’ *5 ^’9</$’K<. $%6-%&$%’ &*$ I$%#$’&.’/ 0$%7EF*$&$’$% 5$8<99*7EF$% b$%L78-66$.’& &$%$’ I$%K*’&.’/ &.%EF]*7EF7EF#$*,0$%K*’&.’/$’:]*7EF7EF#$*,2 0$%K*’&.’/$’ S<97]*7EF’BF8$ -&$% <.EF <97 VEF#<%Ak b$*,2I$%K*’&.’/$’ KA*EF’$8X 7*’& *5 ^’9</$’K<.J K$* &$’$’ ’*$&%*/9$/*$%8$ V8BF9$ 5*8 <.78$’*8*7EF$’ V8BF9$’ 0$%7EF#$*,8 #$%&$’J #$*8 0$%K%$*8$8 .’& #$%&$’ <.EF *’ 7*EF$%F$*87%$9$0<’8$’ T$%$*EF$’ $*’/$7$8A8:

]*7EF7EF#$*,0$%K*’&.’/$’ 6*’&$’ 7*EF *’7K$7-’&$%$ K$* P-F%9$*8.’/$’J #-K$* A:T: $*’ 6$%%*8*7EF$7 P-F% 5*8 <.78$’*8*7EF$% W’’$’O9<88*$%.’/ 5*8 $*’$5 <.78$’*8*7EF$’ P-F% 0$%K.’&$’ #*%&: Y<A. #$%&$’ NK9*EF$%#$*7$ U.66$%.’/$’ 5*8 <.78$’*8*7EF$’ b$%L2 78-66$’ -&$% D*EL$9K<7*79$/*$%.’/$’ <.6 &$% 6$%%*8*7EF$’ V$*8$ 0-%/$’-55$’J &*7 7O<’’.’/7<%5/$/9NF8 .’& <’7EF9*$,$’& &*$ I$%K*’&.’/7’<F8 A#*7EF$’ U.66$%.’/ .’& <.78$’*8*7EF$5 P-F% <.7/$6NF%8: *’$ K$L<’’8$ VEF#<EF78$99$ *78 &<K$* &$% +%$’AK$%$*EF $’89<’/ &$% VEF5$9A9*’*$ A#*7EF$’ 6$%%*8*7EF$5 +%.’&#$%L78-66 .’& &$% U.66$%.’/: DK’ .’/N’78*/$’ b$%L78-66A.78B’&$’ *’ &*$7$5 T$%$*EF SA:T: bB%5$$*’69.77A-’$Sb \aX <.6 &$% 6$%%*8*7EF$’ V$*8$X L)’’$’]*L%-%*77K*9&.’/$’*’ &$% b\a &$7 6$%%*8*7EF$’ b$%L78-667 Sc$*,%*77$J P$9<e<8*-’7%*77$X .’& *’ &$% <.78$’*8*7EF$’ U.66$%.’/ Sc$*,%*77$XJ *’7K$7-’&$%$ *’ &$% &*%$L8 <’ &$’ 6$%%*8*7EF$’ b$%L78-66 <’/%$’A$’&$’ $%78$’ M</$ &$% U.66$%.’/J <.68%8’:

Y$%A$*8 9<.6$’&$ ’<8*-’<9$.’& *’8$%’<8*-’<9$ R-%7EF.’/70-%F<K$’ K$6<77$’ 7*EF &$7F<9K 5*8 &$% 6$%8*/.’/7K$&*’/8$’ \’878$F.’/ 0-’ R$F978$99$’ K$*]*7EF7EF#$*,2 0$%K*’&.’/$’J &$’ ^.7#*%L.’/$’ 0-’ <.6/$6.’&$’$’ -&$% A. .’8$%78$99$’&$’ R$F9$%A.78B’&$’ <.6 &*$ P-F%9$*8.’/7*’8$/%*8B8 7-#*$ &$% b$*8$%$’8#*EL9.’/ K%.EF5$EF<’*7EF$% ^’<9_7$5$8F-&$’ A.% W’8$/%*8B87K$#$%8.’/ 0-’]*7EF’BF8$’ Sk]U^ >IKkJk]U^ >IEkJk+PV >@kJkR^W >@kJkWb] >@kX:

W’6-9/$ &$% K$* VEF#$*,0$%K*’&.’/$’ *5 ^99/$5$*’$’ 0-%F<’&$’$’ */$’7O<’’.’/$’ 9*$/8 <.EF *’]*7EF7EF#$*,0$%K*’&.’/$’ $*’ B.,$%78*’F-5-/$’$% a.78<’& 7-#-F9 &$% T$<’7O%.EF.’/ <97 <.EF &$7 b$%L78-66A.78<’&7 0-%: Y*7 W’F-5-/$’*8B8$’ F<K$’ A.%R-9/$J &<77 P*77$ 7*EF *’ $*’$%]*7EF7EF#$*,0$%K*’&.’/ &$.89*EF <’&$%7 0$%F<98$’ L)’’$’J <97 &*$7 0-’ P*77$’ *5 +%.’&#$%L78-66 -&$% K$* /9$*EF<%8*/$’ VEF#$*,0$%K*’&.’/$’ K$L<’’8*78:

^.6/%.’& 6$F9$’&$% Y$8<*9L$’’8’*7 A.5 I$%F<98$’ $*’$% <’/$%*77$’$’ VEF#$*,2 0$%K*’&.’/ $%6-9/8 &*$ T$#$%8.’/ *’ 7-9EF$’ RB99$’ FB.6*/ <.6 &$% T<7*7 &$%

b$%L78-66L$''#$%8$ &$7 +%.'&#$%L78-667 5*8 T$%$EF'.'/75$8F-&$'J &*$ K'6<997 A.'BEF78 6N% F-5-/$'$ b$%L78-66A.78B'&$ $'8#*EL$98 .'& A#*7EF$'A$*89*EF 0$%$*'A$98 <.EF 6N% <%8/9$*EF$ VEF#$*,0$%K*'&.'/$'J *' L$*'$5 R<99 <K$% 6N%]*7EF7EF#$*,20$%K*'&.'/$' 0<9*&*$%8 #.%&$': ^.6 $5O*%*7EF$% T<7*7 #$%&$' F*$%K$* &*$ P<'&K$&*'/.'/$' 7- /$#BF98J &<77*5 <99/$5$*'$' $*'$ /%-,$ (-'7$%0<8*O*8B8 K$78$F8J #*$*' R-%7EF.'/7<%K$*8$' <' [%*/*'<9K<.8$*9$' /A*/8 #$%&$' L-''8$:

V-99$' &*$ -:/: (-'7$%0<8*O*8B8$' /$'<.$% p<'8*6*A*$%8 #$%&$'J *78 $7 $%6-%&$%9*EF &*$ 8<87BEF9*EF$' I$%7</$'7<K9B.6$ &$8<*99*$%8$% A. K$7EF%$*K$': Y*$7 K$8%*668 7-#-F9 &*$ T$78*55./ &$7 +$6N/$7J &$% $%6-%&$%9*EF$' b$%L78-66L$''#$%8$.'& U<%<5$8$% <97 <.EF &*$ A.% T$%$EF'./ F$%<'/$A-/$'$']$8F-&$':

a.% \%5*889./ K%.EF5$EF<'*7EF$% ($''#$%8$ <']*7EF7EF#$*,0$%K*'&.'/$' $e*78*$%$' &$%A$*8 L$*'$ 0$%K*'&9*EF$' D-%5$': I$%7EF*$&$'$ D-%5$' .'& D-%5$'8#N%6$ 6N% VEF#$*,0$%K*'&.'/$' 7*'&*' &$% Y*7L.77*-'C W5 G$*9 3 &$% K%*8*7EF$' D-%5 TV mli #*%& &*$ U%N6.'/ .'& ^.7#$%8.'/ 0-' @ 2U.'L82T*$/$O%-K$' SV\STXX 5*8 P*77$' *' &$% VEF#$*,'<F8 /$%$/$98: Y*7 D-%5 /*98 '.% 6N% K$78*558$]*75<8EF2 I$%FB98'*77$ SR$78*/L*87.'8$%7EF*$&$ A#*7EF$' &$' $*'A$9'$' b$%L78-66K$%$*EF$' &$% VEF#$*,'<F8X .'& D<F8K%$*8$'J '*EF8 <K$% A:T: 6N% P*77$ *' &$% bB%5$$*'69.77A-'$: Y$%A$*8 #*%& &*$7$7 Y-L.5$'8 <.EF <97 T<7*7 6N% $*'$$.%-OB*7EF$ D-%5 &*7L.8*$%8:

T$* &$% K%.EF5$EF<'*7EF$' T$<'7O%.EF.'/7<'<9_7$ *78 &*$ R%</$ '<EF &$% +N98*/L$*8 &$% K%.EF5$EF<'*7EF$' U<%<5$8$%J A:T: &$7 f2W'8$/%<97J A. K$<EF8$'J &< L$*' F-5-/$'$% b$%L78-66A.78<'& 0-%9*$/8 .'& 7-5*8 a.7<8A8$%5$ *' &$% f2W'8$/%<96-%5.9*$%.'/ K$<EF8$8 #$%&$' 5N77$': *'$ /$'<.$ I-%F$%7</$ &$7 P*770$%F<98$'7J .'8$% ‘578B'&$' &.%EF 0$%7EF*$&$'$ +$6N/$K$%$*EF$ 5*8 .'8$%7EF*$&9*EF$' */$'7EF<68$'J *78 <.6 &*$7$% T<7*7 &$%A$*8 '*EF8 5)/9*EF:

Y<%NK$% F*'<.7 L<'' &<7 I$%F<98$' $*'$7 P-F%8$*8.'/77_78$57 5*8 R$F9$% *' $*'$%]*7EF'<F8 h$ '<EF R$F9$%9</$ SA:T: R$F9$% *' &$% I$%K*'&.'/7'<F8 -&$% <5 HK$%/<'/ U.66$%.'/2+%.'&#$%L78-66X 7*/''*6*L<'8$ PNEL#*%L.'/$' <.6 &*$ P*77K$<'7O%.EF.'/ .'& 7-5*8 <.6 &<7 I$%7</$'70$%F<98$' &$%]*7EF7EF#$*,0$%K*'&.'/ F<K$': a.% %EF'%*7EF$' I-%F$%7</$ &$7 78<K*9$' P*77#<EF78.57 L)''$' 7EFB&*/.'/72 5$EF<'*7EF$ ^'7B8A$ <'/$#$'&$8 #$%&$': c*$% L)''$' &*$ 0$%7EF*$&$'$' +$6N/$K$%$*EF$ $*'$%]*7EF7EF#$*,0$%K*'&.'/ 5*8 *F%$' .'8$%7EF*$&9*EF$' */$'7EF<68$' 5-&$99*$%8 #$%&$': Y*$7 $%6-%&$%8 &*$ T$78*55./ &$%

b $%L78-66O<%<5$8$% 6N% h$&$ A. K$%NEL7*EF8*/$'&$ +$6N/$A-'$: Y*$ ^'#$'&.'/ &*$7$%]$8F-&$'<.6]*7EF7EF#$*,0$%K*'&.'/$' *78 &$%A$*8 '-EF '*EF8 0<9*&*$%8:

a.% b$*8$%$'8#*EL9.'/ .'& I$%*6*L<8*-' &$% h$#$*9*/$' T$%$EF'./75-&99 *' T$A./<.6 &$%$' */'./ A.% O%<e*7/$%$EF8$' K%.EF5$EF<'*7EF$' T$#$%8./ 0-']*7EF7EF#$*,0$%K*'&.'/$' *' P-F%9$*8.'/77_78$5$' 7*'& T<.8$*90$%7.EF$.'8$% %$<9*8B87'<F$' T$9<78.'/72 .'& P<'&K$&*'/.'/$' $%6-%&$%9*EF:

3.3 Modellentwicklung zu Werkstoffeigenschaften

''*0$%7$99$ R*'*8$ \9$5$'8$ U%-/%<55$ #*$ ^T^ó VJ ^YWD^ .'& ^DVjV K*8' VEF'*8878$99$'J 5*8 &$'$']-&$99<'7B8A$J &*$ 0-5 ^'#$'&$% $'8#*EL$98 #$%&$'J K$%NEL7*EF8*/8 #$%&$' L)''$': Y<K$* K9$*K8 &$% ^.6#<'& 6N% &*$ U%-/%<55O69$/$ K$/%$'A8 <.6 &*$ */$'$'8#*EL9.'/$': Y*$7$ VEF'*8878$99$' #$%&$' 0-% <99$5 &<A./$'.8A8J 7O$A*$99$ b$%L78-6655-&$99$ A. *5O9$5$'8*$%$'J #*$ 7*$ 6N% &*$ T<.8$*97*5.9<8*-' .'8$% L-5O9e' T$9<78.'/$' .'& P<'&K$&*'/.'/$' .'& A.% &$8<*99*$%8$' T$7EF%$*K.'/ 0-' L-5O9$e$' #$%L78-66OF_7*L<9*7EF$' a.7<55$'FB'/$' SA: T: T$7EF%$*K.'/ &$% \'8#*EL9.'/ 0-' */$'7O<''.'/$' *']*7EF2 7EF#$*,0$%K*'&.'/$'X $%6-%&$%9*EF 7*'&: W' &*$7$5 a.7<55$'F<'/ #.%&$' ''8$%O%-/%<55$A.%]-&$99*$%.'/ &$7 b$%L78-66O$%F<98$'7 $'8#*EL$98J #*$ A: T: A.%

- V*5.9<8*-' &$7 *'$9<78*7EF$' b$%L78-66O$%F<98$'7 .'8$% A_L9*7EF$% T$<'27O%.EF.'/ SP<8EF$8*'/J 7*F A: T: kW b]>>kXJ
- V*5.9<8*-' &$% UF<7$'.5#<'&9.'/ K$* VEF#$*,0-%/B'/$' -&$% bB%5$2K$F<'&9.'/$' 5*8 &$5 VEF#$%O.'L8 <.6 \%5*889.'/ &$% */$'7O<''.'/$'J
- V*5.9<8*-' &$% P*77$'878$F.'/ .'& ?$'8#*EL9.'/ K$* #$EF7$9'&$% T$9<78.'/S\%5N&.'/XJ
- V*5.9<8*-' &$% P*77$'878$F.'/ .'& P*77$'8#*EL9.'/ SP*77#<EF78.5J +$#<98K%.EFX &.%EF 7EFB&*/.'/75$EF<'*7EF$]-&99:

Y*7 Z-&$$'8#*EL9.'/$' L)''$' /$'$%$99 5*8 K$/%$'A8$5 ^.6#<'& 6N% <'&$%$ R\2U%-/%<55$ <'/$O<778 #$%&$'J &< &*$ /%.'&9$/$'&$' L-'8*''..55$EF<'*7EF$' GF$-%*$' &*$7$9K$' 7*'&: \%6-%&$%9*EF 7*'& h$&-EF A.7B8A9*EF$ I$%*6*L<8*-'7<%K$*8$'J &<7*EF &*$ M)7./7<9/-%*8F5$' &$% $*'A$9'$' U%-/%<55$ SV[MI\PX 8$*9#$*7$.'8$%7EF$*&$':

b$*8$%$'8#*EL9.'/$' *' &*7' T$%$*EF$' &$% b$%L78-665-&$99*$%.'/ 7*'& 5)/9*EF .'& *'7K$7-'&$%$.'8$% 6-9/$'&$' +$7*EF8O.'L8$' 6N% &*$ P$<L8-%7*EF$%F$*876-%7EF.'/ 0-' W'8$%77C

- V*5.9<8*-' 0-' VEF#$*,0-%/B'/$' .'& bB%5KF<'&9.'/$' *5 c*'K9*EL <.6 &*$ \'8#*EL9.'/ 0$%K$77$%8$% R$%8*/.'/70$%6<F%$' .'& 5-&*6*A*$%8$% M$/*$%.'/$' A.% [O8*5*$%.'/ &$7 b$%L78-667 .'& &$% VEF#$*,0$%K*'&.'/ F*'7*EF89*EF R$78*/L$*8J I$%6-%5K<%L$*8J (-%%-7*-'70$%F<98$' .7#:J
- \%5*889.'/ &$% P$6$%$'A7O<''.'/ K$* 5$F%<EF7*/$% 7EF#*'/$'&$% T$9<78.'/ A.% T$78*55.'/ &$% ^'%*779<78#$EF7$9A<F9J
- V*5.9<8*-' &$7 \%5N&.'/70$%F<98$'7 SP*77$'878$F.'/ .'& ?$'8#*EL9.'/X .'8$% 5$EF<'*7EF$% .'& 8F$%5-5$EF<'*7EF$% T$9<78.'/ .'8$% I$%#$'&.'/ 5*L%-78%.L8.%5$EF<'*7EF$%]-&99 *5 $9<78*7EF$' .'& NK$%$9<78*7EF$' T$<'7O%.EF.'/7K$%$*EF 7-#*$ &$%$' (-OO9.'/ 5*8 5<L%-7L-O*7EF$' R*'*8$2 \9$5$'8$]-&99'J
- (-OO9.'/ 7EFB&*/.'/75$EF<'*7EF$%]-&99 5*8 PEF'5-&99' *5 D<'-5<,78<K K$* 78<8*7EF$% T$<'7O%.EF.'/ SV*5.9<8*-' &$% P*77$'878$F.'/ .'& P*77$'8#*EL9.'/ <.6 &$% D<'-$K$'$XJ
- V*5.9<8*-' &$7 0*7L-$9<78*7EF$'k0*7L-O9<78*7EF$' I$%F<98$'7 *5 (.%A2 A$*878<'&K$%$*EF: Y*$7 *78 A:T: .'8$% &$5 +$7*EF87O.'L8 &$7 A$*8<KFB'/*/$' I$%6-%5.'/70$%F<98$'7 <' P*777O*8A$' S!(%*$EF69*$,$';X .'& &$% &<5*8 0$%K.'&$'$' VEFB&*/.'/ 0-' VEF.8A7EF*EF8$' *' T$A./ <.6 L-%%-7*-'72 /$78N8A8$7 P*77#<EF78.5 0-' /%-,$% T$&$.8.'/J
- V*5.9<8*-' &$% D$.8%-'$'0$%7O%)&.'/ .'8$% I$%#$'&.'/ 5*L%-78%.L8.%2 5$EF<'*7EF$% .'& <8-5*78*7EF$%]-&99:

DK' &*7' <.6 &$% R*'*8$ \9$5$'8$]$8F-&$ K<7*$%$'&$' \'8#*EL9.'/$' #.%&$' '<'-5$EF<'*7EF K<7*$%8$ V*5.9<8*-'75-&99 A.% T$7EF%$*K.'/ &$% b$%L78-662 0$%B'&$%.'/ 0-' V8BF9$' <.6/%.'& 0-' ^.77EF$*&.'/7K*9&.'/$' $'8#*EL$98 kVZc >Ik: Y<5*8 #<% $7 5)/9*EFJ Z.2^.77EF$*&.'/$' *' V8BF9$' .'& &$%$' ^.7#*%L.'/$' <.6 &*$ R$78*/L$*872 .'& aBF*/L$*87$*/$'7EF<68$' A. 7*5.9*$%$': *'$ b$*8$%$'8#*EL9.'/ &*$7$% T$%$EF'.'/75-&$99$ *78 &.%EF *'K$A*$F.'/ /$%*EF8$8$% Y*66.7*-' S7O<''.'/72 <KFB'/*/X 5)/9*EF: Y<%NK$% F*'<.7 #.%&$' <.EF]-&99 A.% T$7EF%$*K.'/ &$% (-%'/%$'A$'&*66.7*-' 0-' (-F9$'78-66J UF-7OF-% .'& <'&$%$' \9$5$'8$ <'/$#<'&8 .'& #$*8$%$'8#*EL$98: Y*$ I$%L'NO6.'/ 5*8 '<'-5$EF<'*7EF$' T$%$EF'.'/75-&$99$'

A.% V*5.9<8*-' &$7 *'69.77$7 L-'8<5*'*$%8$% (-%'/%$'A$' <.6 &*$ 5$EF<'*7EF$' */$'7EF<68$' #B%$ F*$% 0-' K$7-'&$%$5 W'8$%$77$:

Y*$ A$%78)%.'/76%$*$ ZF<%<L8$%*7*$%.'/ &$% b$%L78-66$*/$'7EF<68$' *78 $*' GF$5< 6N% &*$ P$<L8-%7*EF$%F$*876-%7EF.'/ 7$*8 1dm 5*8 $%78$' T$%*EF8$' A. &$' \%/$K'*77$' *' 1di> Skc\P i>J Y[T i><kX: Y*$ ^%K$*8$' 7*'& /$O%B/8 0-' &$5 a.7<55$'#*%L$' 0-']<8$%*<96-%7EF.'/ .'& &$' I$%6<F%$' A. A$%78)%.'/76%$*$' U%N6O$%6<F%$': Y<A./$F)%$' &*$ b$%L78-66<.7#<F9J &*$ b$%L78-66EF<%<L8$%*7*$%.'/ &.%EF \%5*889.'/ 5$EF<'*7EF28$EF'-9-/*7EF$% ($''#$%8$J &*$ ZF<%<L8$%*7*$%.'/ &$% b$%L78-66A.78B'&$ *5 P<78$%2 .'& G%<'75*77*-'72\9$L8%-'$'5*L%-7L-O .'& &*$]-&$99K$7EF%$*K.'/ <.7 &$']*L%-78%.L8.%O<%<5$8$%' 7-#*$ &*$ I$%6<F%$'7$'8#*EL9.'/: D<EF &$% T$F<'&9.'/ &$% ZF<%<L8$%*7*$%.'/ 0-' 6$78*/L$*8778$*/$%'&$' UFB'-5$'$' #.%&$*' $*'$5 A#$*8$' VEF%*88 <.EF &*$ ZF<%<L8$%*7*$%.'/ 0-' ABF*/L$*87#*%L7<5$']*L%-78%.L8.%O<%<5$8$%' .'8$%7.EF8: Y<K$* #.%&$' <.EF b$%L78-665-&99 <.6 *F%$ +N98*/L$*8 F*' 78.&*$%8J &*$ 7*EF <.6]*L%-78%.L8.%O<%<5$8$% <K78N8A8$' Skc[P @J Y^c i@J VGP i1J Y \W d1kX: Y$%]-&$99<'7<8A 6N% &*$ A$%78)%.'/76%$*$ U%N6.'/J @]^ /$'<''8J K<7*$%8 '*EF8 <.6 OF_7*L<9*7EF$% GF$-%*$ 7-'&$%' #*%& O%</5<8*7EF .'& $5O*%*7EF <.7 P$/%$77*-'7<'7B8A$' .'& G%<*'*'/ 0-' D$.%-'<9$' D$8A$' <K/9*8$8J #-K$* $*'$ I*$9A<F9 0-' A$%78)%.'/76%$* $%5*88$98$' U%N6O<%<5$8$%' /$'.8A8 #*%&J &*$ #7'89*EF <.7 0*$% 5*L%-5</'$8*7EF$' I$%6<F%$' <K/$9$*8$8 #$%&$' SkY[T dikJ ^MU >3kX: Y$% +%.'& 6N% &*$7$' $5O*%*7EF$' ^'7<8A 9*$/8 *' &$% G<87<EF$ K$/%N'&$8J &<77 &*$ 5*L%-5</'$8*7EF$' 8F$-%$8*7EF$' +%.'&9</$' '-EF #$*8/$F$'& '*EF8 $%<%K$*8$8 7*'&:

]-&$99<'7B8A$ A.% ZF<%<L8$%*7*$%.'/ 0-' (%*$EF7EFB&$' 5*8]$8F-&$' &$% '98%<7EF<992 M<.6A$*85$77.'/ #.%&$' <K 1dim0$%6-9/8 kbWM in T<7*$%$'& <. 6 &$% GF$-%*$ 0-' ['&%<E$L k[DYmk A.% T$7EF%$*K.'/ 0-']*7EF.'/7%$/$9' 6N% $9<78*7EF$J 5$F%OF<7*/$]$&*$' SO-%)7$]$&*$'XJ #.%&$' DBF$%.'/$' 6N% &*$ VEF<992 /$7EF#*'&*/L$*8$' &$% Y%.EL2 .'& VEF$%#$99$ 6N% L./$9*/$ U-%$'6-%5 .'& L9$*'$ U-%$'&*EF8$' <K/9*8$8 .'& eO%*5$'8$99 0$%*6*A*$%8: U<%<99$9 #.%&$' &*7 p<7*78<8*7EF$' DBF$%.'/$' &.%EF DBF$%.'/$' K<7*$%$'& <.6 $9<78*7EF$% V8 %$.8F$-%*$ 0-' c*%7$L-%' kcWP dk K$78B8*/8:

Y$% 5*L%-5</'$8*7EF$ @]^2^'7<8A #*%& A#*7EF$'A$*89*EF <.EF <.6 R%</$78$99.'/$' &$% ZF<%<L8$%*7*$%.'/ 0-' 8F$%5*7EF$% ^98$%.'/ k^MU>1kJ &$5 D<EF#$*7 0-' V8%<F9$'0$%7O%)&.'/ .'& &$% R%NF$%L$''.'/ 0-' \%5N&.'/77EFB&$' kY[T>I<kJ kY[T>IKkX<'/$#$'&$8:

3.4 Zerstörungsfreie Werkstoffprüfung

RN% &*$ A$%78)%.'/76%$*$' U%N65$8F-&$' *78 &*$ V*5.9<8*-' &$% b$EF7$9#*%L.'/ 0$%6N/K<%$% OF_7*L<9*7EF$% \'$%/*$6-%5$' SA:T: 9L8%-5</'$8*7EF$ R$9&$% .'& b99'J 5$EF<'*7EF$ I$%A$%%.'/76$9&$% .'& b99'J '98%<7EF<99X 5*8 b$%L78-666$F9$%'J &$5]*L%-/$6N/$ Sb$%L78-66$*/$'7EF<68$'X .'& &$' VO<''.'/$' ST$9<78.'/7A.78<'&J M<782 .'& */$'7O<''.'/$'X 0-' $'87EF$*&$'&$% T$&$.8.'/: W5 P<F5$' &$% P$<L8-%7*EF$%F$*876-%7EF.'/ #.%&$' &<A. 7$*8 &$' i>$% f<F%$' #7'89*EF$ \'8#*EL9.'/7<%K$*8$' &.%EF/$6NF%8J &*$ A.5 /%.'&7B8A9*EF$' I$%78B'&'*7 K$*/$8%</$' F<K$' .'& K$* &$% U9<'.'/ .'& Y.%EF6NF%.'/ &$7 *'7<8A$7 &$% A$%78)%.'/76%$*$' U%N6.'/*' &$% U%<e*7 #$7$'89*EF$ Y*$'78$ 9$*78$':

T$* &$' b$%L78-666$F9$%' #$%&$' &*$7$ b$EF7$9#*%L.'/$' *5 R<99 &$% $9<78*7EF$' b99' S'98%<7EF<99X &.%EF OF_7*L<9*7EF$ UFB'-5$'$ #*$ P69e*-'J T$./.'/ .'& V8%$..'/ K$7EF%*$K$' SkVZ]i@kXQ &$% VO<''.'/7A.78<'& #*%L8 7*EF <.6 &*$ +$7EF#*'&*/L$*8 &$% b$99$' <.7 SkVZD ikX: W5 R<99 &$% b$EF7$9#*%L.'/ 0-' 9L8%-5</'$8*7EF$' R$9&$%' 5*8 $*'$5 R$F9$% SU-8$'A*<97-'&$'O%N6.'/J b*%K$978%-5O%N6.'/X 0$%B'&$%' 7*EF 9L8%*7EF$ U-8$'A*<9$ <' &$% [K$%69BEF$ K$* &$% 9L8%*7EF$' '578%)5.'/ &$7 R$F9$%7 SkY[TimkX .'& &*$ W5O$&<'A$' 0-' b*%K$978%-5O%N67O.9$' SkY[TiikXJ &*$ &$' R$F9$%K$%$*EF <K8<78$': W5 R<99 &$% 5</'$8*7EF$' Y.%EF78%)5.'/ 8%$8$' A.7B8A9*EF$ V8%$.6$9&$% *' &$% R$F9$%.5/$K.'/ <.6 SV8%$.69.770$%6<F%$' kY[Ti>KkX:

Y*$ b$EF7$9#*%L.'/ 9L8%-5</'$8*7EF$% R$9&$% 5*8 &$5]*L%-/$6N/$.'& &$' 5$EF<'*7EF$' T$9<78.'/$' 9B778 7*EF <.6 &$% 5<L%-7L-O*7EF$' VL<9< &.%EF I$%B'&$%.'/$' &$% 9L8%*7EF$' M$*86BF*/L$*8 .'& &$% 5</'$8*7EF$' U$%5$<K*9*8B8 K$7EF%$*K$': ^.6 &$% 5*L%-7L-O*7EF$' VL<9< #$%&$' +*88$%6$F9$%*5]*L%-/$6N/$ SA:T: M$$%78$99$'J a#*7EF$'/*88$%<8-5$J I$%7$8A.'/$'J ^.77EF$*&.'/$'J (-%'/%$'A$'X .'& <' UF<7$'/%$'A$' &<7 '55</'$8*7*$%.'/70$%F<98$' &$% 5</'$8*7EF$' Y-5B'$' S*' *7$'#$%L78-66$' T9-EF#<'&7O%N'/$ 0-' 1i>t2 .'& d>t2T9-EF#B'&$' 7-#*$ Y%$FO%-A$77$X K$$*'69.778: D.% &*$ d>t2T9-EF#B'&$ 7*'& #$/$' *F%$% 5</2 '$8-78%*L8*0$' b*%L.'/ &*%$L8 0-' &$' $9<78*7EF$' VO<''.'/76$9&$%' K$$*'69.778: f$&-EF #$%&$' #$/$' &$% b$EF7$9#*%L.'/ A#*7EF$' 1i>t2 .'& d>t2T9-EF#B'&$' #BF%$'& $*'$7]</'$8*7*$%.'/7A_L9.7*' $*'$% c_78$%$7$7EF9$*6$ <.EF U%N6/%),$'J &*$ O%*5B% &*$ 1i>t2T9-EF#<'&K$#$/.'/ $%6<77$' SA:T: T<%LF<.7$'%<.7EF$'XJ 0-' $9<78*7EF$' VO<''.'/$' $5O6*'&9*EF K$$*'69.778:

Y$% $%%$*EF8$ V8<'& &$7 b*77$'7 .'& &$% G$EF'*L A.% V*5.9<8*-' A$%78)%.'/76%$*$% U%N65$8F-&$' .'& &*$ &<6N% $%<%K$*8$8$' b$%LA$./$ K$A*$F$' 7*EF h$&-EF 6<78 <.77EF9*$,9*EF <.6 &*$ b$EF7$9#*%L.'/ 5*8 5)/9*EF$' b$%L78-66*5O$%6$L8*-'$' SA: T: P*77$J VEF9<EL$'$*'7EF9N77$XJ &*$? #$/$' *F%$7 K$7-'&$%$' *'69.77$7 <.6 V*EF$%F$*87K$8%<EF8.'/$' ?*5 R-L.7 &$% ''8$%7.EF.'/$' .'& \'8#*EL9.'/$' 78<'&$' .'& 78F':

Y$% b$%L78-66$*'69.77 6<'& T$<EF8.'/ A.'BEF78 <99$*' *' 7$*'$% 78)%$'&$' b*%L.'/ <.6 &*$ ^.7K*9&.'/ &$% /$'<''8$' b$EF7$9#*%L.'/$' 5*8 &$' R$F9789$99$': W5 P<F5$' &*$7$% T$8%<EF8.'/$' L-''8$ K$*7O*$9F<68 &*$ b99'<.7K%$*8.'/ 0-' '98%<7EF<99#$99$' *' $9<78*7EF <'*7-8%-O$' b$%L78-66$' .'& *F%$' I$%K*'&.'/$' S^.78$'*8J <.78$'*8*7EF$ VEF#$*,'BF8$J]*7EF'BF8$X #$*8/F'& .56<77$'& $%6-%7EF8 .'& *' V*5.9<8*-'7E-&$7 .5/$7$8A8 #$%&$' SkVZ]>IkJ k]HM>IkX: V-#$*8 +$-5$8%*$$*'69N77$.'& +$6N/NK%/B'/$ S+%.'&#$%L78-66J bB%5$$*'69.77A-'$J VEF#$*,/.8J U9<88*$%.'/X K$F<'&$98 #.%&$'J L-''8$' &.%EF &*$ Y*7L%$8*7*$%.'/$' *5 P<F5$' &$% 0$%#$'&$8$' '.5$%*7EF$']$8F-&$' SR*'*8$ \9$5$'8$J R*'*8$ W'8$/%<8*-'78$EF'*LX <.EF 9-L<9 *'F-5-/$'$ b$%L78-66$ K$F<'&$98 #$%&$': b$EF7$9#*%L.'/79B'/$' 7*'& &<K$* $'87O%$EF$'& &$% U%N6OF_7*L .'& &$% 0$%#$'&$8$' R%$p$'A$'J .'8$% &$% T$<EF8.'/ &$7 7- /$'<''8$' !V<5O9*'/;2GF$-%$57J *' &$% +%),$'-%&'./ 0-' A$F'8$9]*99*5$8$%'J &< $*'$ F)F$%$ [%87<.69)7.'/ &$% I$%6<F%$' *' &$% O%<L8*7EF$' U%N6<.76NF%.'/ K$* $'87O%$EF$'& F-F$' R%p'A$' &.%EF ^K7-O8*-'7OFB'-5$'$ *F%$ T$7EF%B'L.'/ 6*'&$8: ^K7-%O8*-' .'& V8%$..'/*5 O-9_L%*78<99*'$' .'& <'*7-8%-O$' +$6N/$ *78 /%.'&7B8A9*EF K$* &$% T$7EF%$*K.'/ &$% b$99$'<.7K%$*8.'/ *' &*7']*L%-/$6N/$' '-EF '*EF8 K$%NEL7*EF8*/8: \'87O%$EF$'& &$5 A: a: $%%$*EF8$' V8<'& &$% V*5.9<8*-' A$%78)%.'/76%$*$% U%N65$8F-&$' L<'' &<F$% &*$ K$* $*'$% U%N6.'/ <K7-9.8 /$5$77$'$ ^5O9*8.&$ $*'$7 R$F9$%7*/'<97 '*EF8 $e<L8 0-%F$%/$7</8 #$%&$': Y.%EF &*$ *' &$% U%<e*7 NK9*EF$ D-%5*$%.'/ <.6 $*' P$6$%$'A7*/'<9J A: T: &<7 V*/'<9 &$% PNEL#<'&J #*%& &*$7$% D<EF8$*9 h$&-EF #$*8/F'& L-5O$'7*$%8:

W5 R<99$ &$% 9L8%*7EF$' .'& 5</'$8*7EF$' R$F9$%O%N6.'/ SU-8$'A*<97-'&$'O%N6.'/J V8%$.69.77O%N6.'/J V8%-578)%.'/70$%6<F%$'J b*%K$978%-5O%N6.'/X 7*'& V*5.9<8*-'72 #$%LA$./$ <.6 &$% T<7*7 0-' R*'*8$' \9$5$'8$' -&$% W'8$%/<9/9$*EF.'/79)7.'/$' SW8$%<8*0$ M)7.'/ D$.5<''7EF$% P$*F$'X $%<%K$*8$8 #-%&$' SkY[TmkJ T\Z iiJ Y[Ti><kX:

]*8 *'8$/%*$%8$' T$%$EF'.'/70$%6<F%$' &$% T%.EF5$EF<'*L #.%&$ &*$ V8%$..'/ 0-' b$%L78-66L$''#$%8$' .'& &*$ 78<8*78*7EF$ I$%8$*9.'/ 0-' U<%<5$8$%' A.% \%5*889.'/

L%*8*7EF$% R$F9$%/%),$' K$%NEL7*EF8*/8 .'& *F%$ ^.7#*%L.'/$' <.6 T<.8$*9$ K$%$EF'$8 SkVZ] >IkX: Y*$ W'8$%<L8*-' &*$7$% 78<8*78*7EF$' T%.EF5$EF<'*L <.6 T<7*7 $*'$%]-'8$2 Z<%9- V*5.9<8*-' 5*8 &$' A$%78)%.'/76%$*$' U%N6O$%6<F%$' 9*$6$%8 ^.77</$' F*'7*EF89*EF &$% $%6-%&$%9*EF$' +$'<.*/L$*8 &$% $*'A.7$8A$'&$' A$%78)%.'/76%$*$' U%N65$8F-&$' KA#: &$% R789/.'/ 5<,/$K9*EF$% U<%<5$8$%:

+B'A9*EF .'K$<EF8$8 K9*K' K*7F$% #$*8/F'& \'8#*EL9.'/$' 0-' V*5.9<8*-'7#$%LA$./$'J &*$ &*$ b$EF7$9#*%L.'/$' &$% &.%EF &*$ A$%78)%.'/76%$*$' U%N65$8F-&$' $*'/$K%<EF8$ \'$%/*$ 5*8 &$%]*L%-78%.L8.% .'& &$5 T$9<78.'/7A.78<'& <.6 &$% 5$7-7L-O*7EF$' .'& 5*L%-7L-O*7EF$' \K$'$J <97- &$% \K$'$ &$% (-%'78%.L8.%J &$% b$EF7$9#*%L.'/ 5*8 (-%'2 .'& UF<7$'/%$'A$'J 5*8 ^.77EF$*&.'/$' .'& I$%7$8A.'/$' K$7EF%$*K$': Y*$7 *78 *'7K$7-'&$%$ 6N% &<7 I$%78B'&'*7 &$% (-'8%<78$%A$./.'/ &$% U%N6/%),$' K$* &$' 5*L%-5</'$8*7EF$' U%N6O$%6<F%$' 6N% &*$ T$7EF%$*K./ 0-' b$%L78-66$*/$'7EF<68$' 0-' W'8$%$77$J &*$ 7*EF F$.8$ <99$*' <.6 $5O*%*7EF $%A$./8$]-&99 <K78N8A$' S7*F (<O*8$9 !]-&$99$'8#*EL9.'/$' A. b$%L78-66$*/$'7EF<68$';X: T$* p<7*78<8*7EF$%]</'$8*7*$%.'/J &: F: K$* U%N66%$p.$'A$' .'8$%F<9K 0-' $*'*/$' 1>> cAJ 7*'& &*$ b$EF7$9#*%L.'/70-9.5*'< < O%*-%* <.6 &$' -K$%69BEF$''<F$' T$%$*EF K$7EF%B'L8 .'& &*$ \%A*$9.'/ /%-,$% P$*EF#$*8$' ? #*$ 0$%/9$*EF7#$*7$ K$* &$% '98%<7EF<996$F9$%O%N6.'/ ? 7*'& '*EF8 &<7 O%*5B%$ a*$9 &$% U%N6.'/:

Y*$ A$%78)%.'/76%$*$ U%N6.'/ F<8 NK$% f<F%$ F*'#$/ ? .'8$% R)%&$%.'/ A: T: &$% \.%-OB*7EF$' +$5$*'7EF<68 6N% (-F9$.'& V8<F9 ? <.EF eO%*5$'8$99$]$8F-&$' &$% T$7EF%$*K./ &$7 T$9<78.'/7A.78<'&$7J $*'7EF9*$,9*EF &$% T$78*55./ 0-' */$'7O<''./$'J K$F<'&$98: Y*$ &<K$* <.7/$<%K$*8$8$' W'8$%O%$8<8*-'75-&$99$ 78N8A$' 7*EF <99$*' <.6 5<L%-7L-O*7EF$ UFB'-5$'$.'& 5*88$9' 7-/<% NK$% A: T: VEF<999<.6#$/$J #$'' '98%<7EF<99#$99$' A.% ^'#$'&.'/ L-55$' SkVZD ikX: b$*8$%/$F$'&$ T$8%<EF8.'/$'J &.%EF D.8A.'/ 0-' +9$*EF/$#*EF87K$&*'/.'/$' 7-#-F9 6N% &*$ VO<''.'/$' <97 <.EF &*$]-5$'8$J &*$ &*$ /$'<''8$']*88$9.'/7$66$L8$.'& &<5*8]$F%&$.8*/L$*8$' A.5 G$*9 $'87EFB%6$' L)''$'J K9*$K$' K*7F$% .'K$%NEL7*EF8*/8: Y*$7 /*98 K'7- 6N% &*$ b99'<.7K%$*8.'/ *' $9<78*7EF$']$&*$' .'8$% M<78J &$%$' T$7EF%$*K./ $*'$' $%#$*8$%8$' 8F$-%$8*7EF2'.5$%*7EF$' ^'7<8A '-8#$'&*/ 5<EF8:

W5 ^'F<'/ G<K99 1 7*'& &*$ *5 P<F5$' &$% b$*8$%$'8#*EL9.'/ .'& Y.%EF6NF%.'/ A$%78)%.'/76%$*$% U%N65$8F-&$' $*'/$7$8A8$' T$%$EF'.'/72 KA#: V*5.9<8*-'72 O%-/%<55$A.7<55$'/$78$998:

3.5 Qualifizierungsmethoden für Analysewerkzeuge und Benutzer

a.% o<9*6*A*$%.'/ 0-' ^'<9_7$5$8F-&$' A: T: A.% W'8$/%*8B87K$#$%8.'/ 0-' P$<L8-%&%.ELK$FB98$%' F*'7*EF89*EF *F%$% */'.'/ 6N% $*'$' V*EF$%F$*87'<EF#$*7 #*%& &$%A$*8 &<7 b$%LA$./ ó^]\G $'8#*EL$98 S7*F T*9& @ 2=X: Y*$ T<7*7 6N% &<7 $'8#*EL$98$ b$%LA$./ K*9&$' &*$ <LL.5.9*$%8$' ($''8'*77$.'& &*$ \%6<F%.'/ <.7 A<F9%$*EF$' U%-h$L8$' A. L-5O9e' W'8$/%*8B87K$#$%8.'/$' /<98%8$% P$<L2 8-%&%.ELK$FB98$% .'& A. $'87O%$EF$'&$' +%-,0$%7.EF$' 7-#*$ $*'7EF9B/*/$ I$%)66$'89*EF.'/$': Y<7 K*7F$% $'8#*EL$98$ G%<*'*'/75-&.9 $'8FB98 $*'$ *'6NF%.'/ *' &*$ 0$%7EF*$&$'$' ^7O$L8$ A.5 W'8$/%*8B87'<EF#$*7 6N% P$<L8-%&%.ELK$FB98$%: W' $*'$5 M$%'K$*7O*$9 #*%& &$% T$'.8A$% &.%EF &*$ 0$%7EF*$&$'$' ^'<9_7$7EF%*88$ $*'$% PYT2W'8$/%*8B87K$#$%8.'/ /$6NF%8J #-K$* &$% a./%*66 <.6 W'O.8&<8$*$' 7-#*$ \%/$K'*77$ %$<9*7*$%8 #.%&$: W5 ‘'8$%O.'L8 P6%$'A6B99$ 78F' &*$ U%-K9$578$99.'/$' .'& ^'<9_7$$%/$K'*77$ <.7 *'8$%'<8*-'<9$' V8.&*$' A. GF$%5-7EF-EL2+%-,0$%7.EF$' SR^MVWP\C kVW\ dIkJ kVW\ dkkn .'& A. $*'$5 PY T2T$'EF5<%L SPUI2UGV2WZ^VC kVW\ ddKkX A.% I$%6N/.'/: Y<K$* L<'' &$% T$'.8A$% $*/$'$ ^'<9_7$$%/$K'*77$ 5*8 $'87O%$EF$'&$' \%/$K'*77$'<.7 &$' *'8$%'<8*-'<9$' V8.&*$' 0$%/9*EF$':

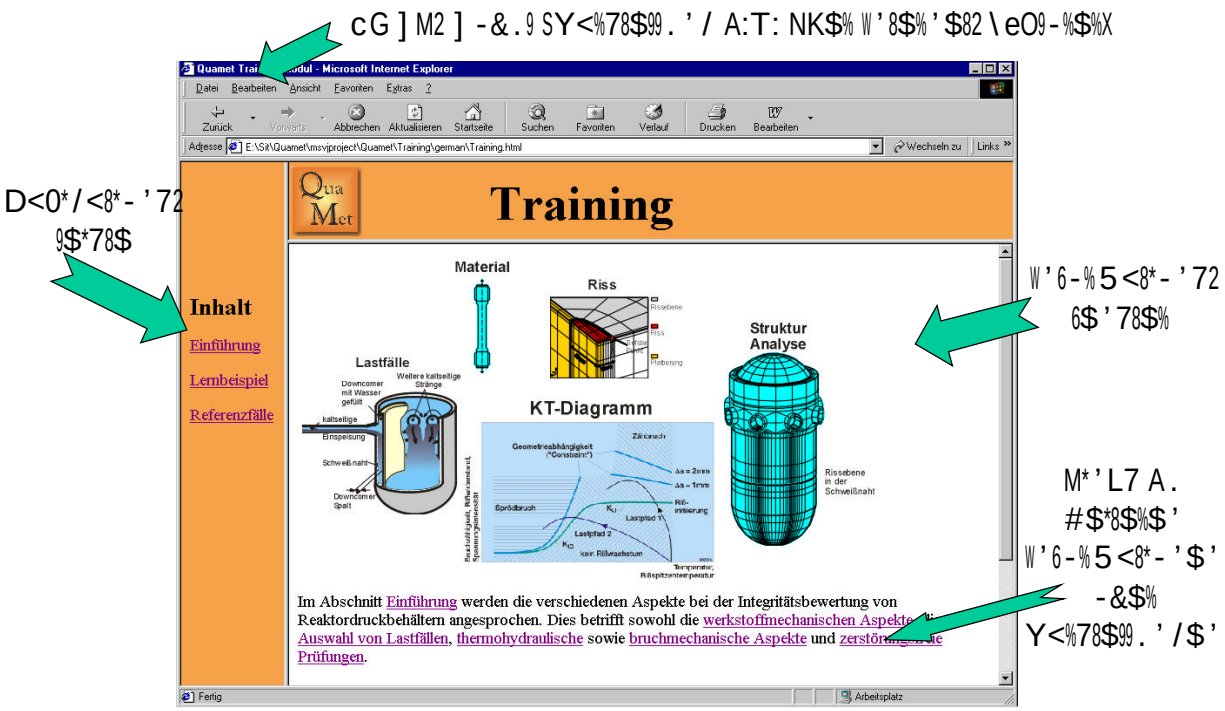


Bild 3-5: T$'.8A$%-K$%69BEF$ A.% o<9*6*A*$%.'/ 0-' ^'<9_7$5$8F-&$' 7-#*$ &$%$' ^'#$'&$%

a.% T$#$%8.'/ 0-' T$'.8A$%$%/$K'*77$' #.%&$' <.7 &$' K$%$*8/$78$998$' \%/$K'*7&<%78$99.'/$' !K$78 $78*5<8$;J <LA$O8<K9$.'& '*EF82<LA$O8<K9$ M)7.'/$' *&$'8*6*A*$%8: \eO$%*5$'8$99$ \%/$K'*77$J !K$782$78*5<8$;2M)7.'/$' -&$%]*88$9#$%872 L.%0$' <.7 <LA$O8<K9$' M)7.'/$' #.%&$' <97 P6%$'AL.%0$' 6$78/$9$/8: ^97 T$#$%8.'/7L%*8$%*.5 #*%& <'/$7$8A8J &<77 T$'.8A$%$%/$K'*77$ <LA$O8<K$9 7*'&J 7-6$%' 7*$ *5 T$%$*EF &$% d= v 2 .'& = v 2o<'8*9$ &$% <'/$O<778$' I$%8$*9.'/76.'L8*-'$' A. &$' 0$%6N/K<%$' <LA$O8<K9$' ^'<9_7$$%/$K'*77$' 9*$/$':

\7 K*$8$8 7*EF <'J &*7]$8F-&*L <.EF <.6 <'&$%$ ^%K$*87/$K*8J *' &$'$' ^'<9_7$5$8F-&$' p<9*6*A*$%8 #$%&$' 7-99$' .'& *' &$'$' I$%7.EF7$%/$K'*77$ $*'7EF9*$,9*EF &.%EF/$6NF%8$% ^'<9_7$' 6N% A.LN'68*/$ ^%K$*8$' KA#: 6N% ^.7K*9&.'/7A#ELA.% I$%6N/.'/ /$78$998 #$%&$' 7-99$'JA. NK$%8%</$':

Y*$ *5 P<F5$' &$% R-%7EF.'/ $'8#*EL$98$' P$EF$'E-&$7 7-#*$]$8F-&$' A.% o<9*6*A*$%.'/ 0-' ^'<9_7$5$8F-&$' 7*'& K'7- T$78<' &8$*9$ &$% K$78F'&$' b*77$'7K<7*7 !(-5O-'$'8$'7*EF$%F$*8 .'& W'8$/%*8B87K$#$%8.'/ &%.EL6NF%$'&$% (-5O-'$'8$'; #*$ T$%*EF8$ 5*8 ^%K$*87$%/$K'*77$'J I$%)66$'89*EF.'/$'J R<EFL-'6$%$'AK$*8%B/$' .'& f<F%$7K$%*EF8$J P$/$9#$%L$J VEF<&$'7K$%*EF8$.'& R$%8*/.'/7&-L.5$'8<8*-'$': Y*$ W'6-%5<8*-'$' 7*'& #$*8/F'& NK$% Y<8$'K<'L$' 9L8%-'*7EF *5 I-998$e8 7.EF6BF*/ 0$%6N/K<%: *'$ a.7<55$'6NF%.'/ &$% 0$%7EF*$&$'$' b*77$'75-&.9$ 5*8 *'8$%&*7A*O9*'B%$' o$%0$%K*'&.'/$' A. $*'$% /5*'7<5$' T$'.8A$%-K$%69BEF$ *78 <97 c*%675*88$9 A.5 b*77$'7$%F<98J A.% ^.72 .'& b$*8$%K*9&.'/ 0-' R<EFO$%7-'<9 .'& A.% \'87EF$*&.'/76*'&.'/ *5 P<F5$' 7*EF$%F$*878$EF'*7EF$% T$#$%8.'/$' 0-' \%$*/'*77$' $%6-%&$%9*EF:

+$'$%$99 /*98J &<77 V*5.9<8*-'7#$%LA$./$ p<9*6*A*$%8 .'& 0<9*&*$%8 #$%&$' 5N77$': Y*$7 /*98 A.5 $*'$' 6N% &*$ 5<8F$5<8*7EF2'.5$%*7EF $%A*$9K<%$ +$'<.*/L$*8: *' b$%LA$./ &<6N% *78 &*$ T$F<'&9.'/ 0-' #-F9&$6*'*$%8$' T$'EF5<%L2U%-K9$5$'J &*$ &$' I$%/9$*EF L-'L.%%*$%$'&$% V-68#<%$ *' &$6*'*$%8$% P$EF'$%F<%&#<%$2'5/$K.'/ $%9<.K8: a.5 <'&$%$' K$&<%6 $7 <.EF &$% I<9*&*$%.'/ &$% *' &*$ 5<8F$5<8*7EF2'.5$%*7EF$ V*5.9<8*-' $*'69*$,$'&$' b$%L78-665-&$99$: Y*$7$7 /$9*'/8 &.%EF I$%/9$*EF 5*8 p<9*6*A*$%8 &.%EF/$6NF%8$' eO%*5$'8$99$' T$#$*76NF%.'/$' SU%-K$'0$%7.EF$J T<.8$*90$%7.EF$X:

a.0$%9B77*/L$*87.'8$%7.EF.'/$' A. &$' A$%78)%.'/76%$*$' U%N60$%6<F%$' 78F' <L8.$99 *5 R-L.7 &$% W'8$%$77$': D.5$%*7EF$ V*5.9<8*-'$' L)''$' &<A. $*'$' $'87EF$*&$'&$' T$*8%</ *5 V*''$ &$% !8$EF'*E<9 h.78*6*E<8*-'; 9$*78$': Y.%EF

U<%<5$8$%0<%*<8*-'$' 7-998$' 7*EF b<F%7EF$*'9*EFL$*8$' 7-#-F9 6N% &<7 %*EF8*/$ \%L$''$' &$7 a*$9$7 &$% U%N6.'/ Sc*8%<8$J U%-K<K*9*8_ [6 Y$8$E8*-'J U[YX <97 <.EF &*$ R<97EF<9<%5%<8$.'& &*$ P<8$ 6N% &<7 HK$%7$F$' 0-' R$F9$%' SU%-K<K*9*8_ [6 D-'2 Y8E8*-'J U[DYX #$*8/$F$'&J *5 I$%/9$*EF 5*8 eO%*5$'8$99$' I$%*6*L<8*-'$'J 78-EF<78*7EF <K/$7*EF$%8 $%5*88$9' 9<77$': Y*$ I<9*&*$%.'/ &$% K*7F$% $%<%K$*8$8$' V*5.9<8*-'7#$%LA$./$ 78$998 $*'$ #$*8$%A.6NF%$'&$ ^.6/<K$ &<%:

3.6 Zusammenfassung zum Forschungsbereich „Komponentensicherheit und Integritätsbewertung“

RN% &*$ V*EF$%F$*87K$#$%8.'/ O<77*0$% (-5O-'$'8$' SP-F%9$*8.'/$'J Y%.ELK$FB98$%J V*EF$%F$*87K$FB98$%X *78 &*$ \'8#*EL9.'/ .'& I<9*&*$%.'/ 0-' ^'<9_7$5$8F-&$' A.% T$78*55.'/ &$% V8%.L8.%A.0$%9B77*/L$*8J &:F: A.% T$%$EF'.'/ 0-' M$EL2 .'& T%.EF#<F%7EF$*'9*EFL$*8$' *'7K$7-'&$%$ *5 P<F5$' 0-' O%-K<K*9*78*7EF$' V*EF$%2 F$*87<'<9_7$' SUV^X 0-' 7*EF$%F$*878$EF'*7EF$% T$&$.8.'/: Y<K$* 7*'& K$#BF%8$ &8%5*'*78*7EF$ ^'<9_7$5$8F-&$' .5 O%-K<K*9*78*7EF$ ^'7B8A$ A. $%#$*8$%': ‘'7*EF$%F$*872.'& V$'7*8*O*8B87<'<9_7$' 7*'&&.%EFA.6NF%$':

(-5O9e T$9<78.'/$' SA:T: 8F$%5*7EF$ VEF*EF8.'/ *' P-F%9$*8.'/$'J (-'&$'2 7<8*-'77EF9</J \%&K$K$'X $%6-%&$%' &*$ V*5.9<8*-' 0-' (-5O-'$'8$' *5 I$%K.'& SA:T: P-F%9$*8.'/$' .'& T$FB98$% *5 U%*5B%2 .'& V$L.'&B%L%$*79<.6X 7-#*$ &*$ PNEL#*%L.'/ 5*8 8F$%5-F_&%<.9*7EF$' U%-A77' SR9.*&2V8%.L8.%2b$EF7$9#*%L.'/X: b*EF8*/ *78 *' &*$7$5 a.7<55$'F<'/ $*'$ $'/$ (--O$%<8*-' 5*8 &$' ^%K$*87/%.OO$' &$% GF$%5-F_&%<.9*LJ .5 T$9<78.'/7%<'&K$&*'/.'/$' %$<9*8B87'<F <KK*9&$' .'& <.7 &$5 I$%F<98$' &$7 /$7<58$' V_78$57 T$9<78.'/7B'&$%.'/$' <K9$*8$' A. L)''$': I-% &*$7$5 c*'8$%/%.'& *78 K$* &$% T$8%<EF8.'/ /$7<58$% V_78$5$ $*'$ 6-%8/$7EF%*88$'$ V*EF$%F$*87<'<9_7$ 5)/9*EF:

o<9*6*A*$%8$ ^'<9_7$5$8F-& $' A.% T$#$%8.'/ &$% W'8$/%*8B8 .'& Y*EF8F$*8 0-' V*EF$%F$*87K$FB98$%' <.7 0-%/$7O<''8$5 V8<F9K$8-' 7*'& $*'$ #*EF8*/$ I-%<.77$8A.'/J .5 ^.77</$' A.% TF%%7EFK<%L$*8 7EF#$%$% ‘'6B99$ *'7K$7-'&$%$ *5 P<F5$' 0-' O%-K<K*9*78*7EF$' V*EF$%F$*87<'<9_7$' A. 8%$66$': Y<F$% *78 &*$ \'8#*EL9.'/ 0-' ^'<9_7$5-&$99$' A.% T$78*55.'/ &$% G%</6BF*/L$*8 0-' V8<F9K$8-'78%.L8.%$' 5*8 .'& -F'$ I-%7O<''.'/ 7-#*$ M$EL)66'.'/$' .'& M$EL</$O6<&$' 7*EF$%F$*878$EF'*7EF %$9$0<'8:

^'/$7*EF87 &$% O-8$'A*$99$' +$6<F% &.%EF 8$%%-%*78*7EF$ ^'/%*66$ SA: T: /$A*$98$% R9./A$./<K78.%AJ VO%$'/78-66X *78 &*$ \'8#*EL9./ .'& I<9*&*$%.'/ 0-' ^'<9_7$5-&99' A.% V*5.9<8*-' F-EF$'$%/$8*7EF$% &_'<5*7EF$% '*EF89*'$<%$% I-%/B'/$ 5*8 $e8%$5$' 5$EF<'*7EF$' .'& 8F$%5*7EF$' T$9<78.'/$' SA: T: ^.6O%<99 &$6-%5*$%K<%$% 69N77*/L$*87/$6N998$% U%-h$L8*9$ <.6 F<%8$ V8%.L8.%$'X 0-' 7*EF$%2 F$*878$EF'*7EF$% T$&$.8.'/:

a.% I<9*&*$%.'/ 78%.L8.%5$EF<'*7EF$% ^'<9_7$5-&99 7*'& I$%7.EF7'<EF%$EF'.'/$' .'& T$'EF5<%L2^L8*0*8B8$' $%6-%&$%9*EF: Y*$ '-8#$'&*/$ o<9*6*A*$%.'/ 0-' ^'<9_7$ 2 #$%LA$./$' .'& &$%$' T$'.8A$% $%6-%&$%8 $*'$ %EF'%/$78N8A8$ b*77$'7K<7*7J*' &$% ^'<9_7$7EF%*88$ &*&<L8*7EF 0-%/A*EF'$8 7*'& .'& *' &$% ^'<9_7$$%/$K'*77$ p<'8*8<8*0 *5 I$%/9$*EF A. P6%$'A9)7./$' .'& eO%*5$'8$99$' Y<8$' K$#$%8$8 #$%&$' L)''$':

*' #$*8$%$% VEF#$%O.'L8 K$* &$% b$*8$%$'8#*EL9./ 0-']$8F-&$' A.% V*5.9<8*-' &$7 T<.8$*90$%F<98$'7 7-998$ &*$ T$%NEL7*EF8*/./ &$%]*L%-78%.L8.% .'& &$7]$&*.57 7$*': Y*$ b$%L78-66O$%B'&$%.'/$' K$* T$78%<F9./ &.%EF $'$%/*$%$*EF$ D$.8%-'$' KA#: K$*5 RN/$' &.%EF VEF#$*,$' -&$% &*$ (-%%-7*-'7$5O6*'&9*EFL$*8 A$*/$' &$' &-5*'<'8$' *'69.77 &$%]*L%-78%.L8.%J &: F: &$% EF$5*7EF$' ^'<9_7$J &$% &<%<.7 %$7.98*$%$'&$' ^.77EF$*&./7A.78B'&$J &$% (-%'/%),$J &$7]$&*.57 .'& '*EF8 A.9$8A8 &$% T<.8$*9K$9<78./: ^.6 &*7% T<7*7 L<'' $7 /$9*'/$'J &*$ c$%78$99K$&*'./'/$' A. 7*5.9*$%$' .'& &$%$' ^.7#*%L./$' <.6 aBF*/L$*8J R$78*/L$*8 .'& (-%%-7*-'70$%F<98$'J A: T: &*$ V$'7*K*9*7*$%./ 0-' ^.78$'*8$' K$*5 VEF#$*,$'J A. p<'8*6*A*$%$':

Y*$ \'8#*EL9./$' A.% \%5*88$9./ &$% a.0$%9B77*/L$*8 A$%78)%.'/76%$*$% U%N65$8F-&$'J #*$ 7*$ *' &$% ($%'8$EF'*L $*'/$7$8A8 #$%&$'J 7*'& 7*EF$%F$*878$EF'*7EF %$9$0<'8: Y*$7 K$8%*668 *' $%78$% M*'*$ &*$ ZF<%<L8$%*7*$%./ 0-' R$F9$%A.78B'&$': W5 V*''$ $*'$% NK$%/$-%&'8' T$#$%8./ &$7 b$%L78-66A.78<'&$7 &.%EF &*$ b$%L78-665$EF<'*LJ 9B778 7*EF 0-' &*7% R%</$78$99./ h$&-EF &*$ R%</$ &$% A$%78)%.'/76%$*$' b$%L78-66EF<%<L8$%*7*$%./ .'& &$% T$7EF%$*K./ &$7]*L%-/$6N/$A.78<'&$7 .'& &$7 T$9<78./7A.78<'&$7 SVO<''.'/$'J VO<''.'/7/%<&*$'8$'X '*EF8 <K8%$''$': ^.7#*%L./$' <.6 &*$ *'8%*'7*7EF$' b$%L78-66L$''/%),$' S$9<78*7EF$J 9L8%-2 5</'$8*7EF$J 5*L%-5</'$8*7EF$X K$&N%6$' &$% \'8#*EL9./ 0-' V*5.9<8*-'75$8F-&$' .'& &*$ I<9*&*$%./ <' /$$*/'8' \eO$%*5$'8$': D.% 7- L<'' $*'$ a.0$%9B77*/L$*87K$.%8$*9./ .56<77$'& /$78<98$8 #$%&$': *'$ <K7-9.8 '$.<%8*/$ R%</$2 78$99./ *78 &*$ V*5.9<8*-' &$%]*L%-5</'$8*L <.6 &$% 5$7-7L-O*7EF$' .'&

5*L%-7L-O*7EF$' VL<9<J &*$ A.5 I$%/9$*EF A.% #$%L78-66L.'&9*EF$' V*5.9<8*-' #N'7EF$'7#$%8 $%7EF$*'8:

*'$ a.7<55$'6NF%.'/ &$% 0$%7EF*$&$'$']-&.9$ &$% b*77$'7K<7*7 A.% (-5O-'$'8$'7*EF$%F$*8 .'& W'8$/%*8B87K$#$%8.'/ &%.EL6NF%$'&$% (-5O-'$'8$' *78 5*8 *'8$%&*7A*O9*'B%$' o$%0$%K*'&.'/$' .'8$% $*'$% /5*'7<5$' T$'.8A$%-K$%69BEF$ <97 c*9675*88$9 A.5 b*77$'7$%F<98J A.% ^.72 .'& b$*8$%K*9&.'/ 0-' R<EFO$%7-'<9 .'& A.% \'87EF$*&.'/76*'&.'/ *5 P<F5$' 7*EF$%F$*878$EF'*7EF$% T$#$%8.'/$' 0-' \%$*/2 '*77$' $%6-%&$%9*EF:

Y*$ NK$% 0*$9$ f<F%$ <.6/$K<.8$ (-5O8'A A.% V*5.9<8*-' &$7 78%.L8.%5$EF<'*7EF$' I$%F<98$'7 O<77*0$% (-5O-'$'8$' *78 A. $%F<98$' .'& K$AN/9*EF '$.$% R%</$78$99.'/$' <.7A.K<.$': Y*$ L-5O8'8$ ^K&$EL.'/ &$7 F8%-/$'$' ^.6/<K$'2 .'& Z-&$7O$L8%.57 $%6-%&$%8 K$* &$' K8*9*/8$' W'78*8.8*-'$' $'87O%$EF$'&$ (<O<A*8B8$': W' &*$7$5 a.7<55$'F<'/ #*%& <.6 &$' T$%*EF8 k([ ] >@k 0$%#*$7$':

3.7 Literatur zum Forschungsbereich „Komponentensicherheit und Integritätsbewertung“

k^MU >1k ^98O8%J W:Q Y-K5<''J +:Q (<8$%K<.J (:2c:Q VEF*ELJ]:Q T*'L9J U:Q (*A9$%J U:Q VEF5<.&$%J V:C Z-OO$% O%$E*O*8<8$7 *' 1= D*Z.]-DK = S b T @Xm78$$9J 5<8$%*<9 O%-O$%8*$7 <'& 5*E%-78%.E8.%$J <8-5*78*E 7*5.9<8*-' <'& 5*E%-25</'$8*E DY\ 8$EF'*p$7J *'C D.E9$<% \'/*'$$%*'/ <'& Y$7*/' 3>n$3>>1XJ O: @@n 2@=>

k^MU >3k W: ^98O8%J P: TEL%J +: Y-K5<''J P: ($%'J b: GF$*'$% <'& ^: j<7F<'Q P-K.78 7-9.8*-'7 -6*'0$%7$ O%-K9$57*' 9E8%-5</'$8*E '-'2&$78%.E8*0$ $0<9.<8*-'J W'0$%7$ U%-K9$57 1i S3>>3X 121=J W'78*8.8$ -6 UF_7*E7 U.K9*7F*'/

k^MG >@k ^9878<&8J \: <'& c:2+: b*997EFN8A S3>>@<XC VEF5$9A$%NELF<98.'/*5 PYT '<EF I$%9</$%.'/ 0-' Z-%*.5 *' &<7 .'8$%$ U9$'.5 b*77$'7EF<689*EF2G$EF'*7EF$ T$%*EF8$ k R-%7EF.'/7A$'8%.5 P-77$'&-%6Q RaP2@nJ WVVD 1l@n 2@33x] B%A 3>>@

kT^Z idk T<EF5<''J +%.'$%J (.'8A$J VEF.9AJ *K9J VEF9N8$%C
I$%7</$'7<'<9_7$ $*'$7 V8<F9K$8-'E-'8<*' 5$'87 5*8 M*'$%*5]<,78<K 1Cm
.'8$% c-EF&%.ELK$9<78.'/ ST$%$EF'.'/$' '<EF I$%7.EF7&.%EF6NF%.'/XJ
+PV2^21=@in1did

kT\Z iik TEL%J P:Q T$8A-9&J (:Q Y-K5<''J +:Q c)99$%J U:Q
U%-/%$77*' &$6$E8 &$8$E8*-' <'& EF<%<E8$%*A<8*-' #*8F 5.98*26%p'E_ 2
$&&_2E.%%$'8 <'& E.%%$'8 O$%8.%K<8*-' 8$78*'/ SW'8$%'<8*-'<9 Z-'6$%$'E$ -'
D-'2&$78%.E8*0$ \0<9.<8*-'*' 8F$ D.E9$<%W'&.78%_J 1diiJG-L_-X
*'C ^5$%*E<' V-E*$8_6-%]$8<97 2^V]2J]$8<97 U<%Lk[F*-C d8F W'8$%'<8*-'<9
Z-'6$%$'E$ -' D-'2&$78%.E8*0$ \0<9.<8*-'*' 8F$ D.E9$<%W'&.78%_ÿi:
U%-E$$&*'/7J 1diiJO:@=n2@n

kT\P dik M:T$%'<AC
\8.&$ &. 8%<'76$%8 &$ EF<9$.%z2< 6%-'8*{$ 7.O{*$.%$ &|.'K<*' 69.*&$ <0$E
&*77*O<8*-'0-9.5*p$ &$ O.*77<'E$: Y*77$%8<8*-'JM|'*0$%7*8$ f-7$OF
R-.%*$% Y$ +%$'-K9$J 1ddi

kT[M dik T-98-'JZF:$8 <9:C
P$9<8*-'K$8#$$' &*66$%$'8 5$<7.%$7 -6 $eO-7.%$2*'&.E$& 7F*687*' &.E8*9$
8-K%*889$ 8%<'7*8*-' 8$5O$%<8.%$JP\R\P\\J \.%-O$<' Z-5*77*-'6-.%8F
6%<5$#-%L O%-/%<5 5$J 1ddl 2 1ddi

kT'W dik T.*J I:^:S1ddiXC
UF$'-5$'-9-/*E<9<'&]$EF<'*78*E]-&$99*'/ -6]$982V8%.E8.%$2b<8$%
W'8$%<E8*-'7*' <M*/F8 b<8$% P$<E8-%V$0$%$ ^EE*&$'8:Y-E8-%<9 GF$7*7 <8
P-_<9W'78*8.8$ -6 G$EF'-9-/_JV8-ELF-95 1ddi

kZc' ddk ZF.JG:j:JU*9EFJ]:]:JT$'8AJ f:c:JM.&#*/7$'J f:V:JM.J b:j:Jc.5OF%*$7J
M:M:S1dddXC
;M-#$% c$<& R<*9.%$ \eO$%*5$'87<'& ^'<9_7$7;J P$O-%8J D'P\+kZP2
==i3J V^DYdi23>lnV<'&*<D <8*-'<9M<K-%<8-%*$7J ^9K.p$%p$JD]J
'V^:

kY^c i@k b:Y<F9Q b:^'8-'Q
b$%L78-66L.'&$ *7$' .'& V8<F9:G$*9WC +%.'&9</$' &$% R$78*/L$*8J &$%
aBF*/L$*8 .'& &$7 T%.EF7J b:Y<F9J \&:SI$%9</ V8<F9$*7$']:T:c:J
YN77$9&-%6J 1di@X

kY\W d1k U:Y$*5$9J \:V<889$%Q
a.7<5 5$'F<'/A#*7EF$' +%),$.'& Y*EF8$ &$% '*EF85$8<99*7EF$'
'7EF9N77$.'& &$5 f2W'8$/%<9K$* P*77$'9$*8.'/Q
1n]U^2V$5*'<%J 1>:?11:[L8-K$% 1dd1JV8.88/<%8

kYWD dkn Y*'FJ G:D:J P:P: D-.%/<9*$0 S1ddXC

G.%K.9$'E$ 5-&$99*'/ 6-% 9<%/$ 0-9.5$8%*E<99_ F$<8$& 9*p*& O--97

D'ZM\^P \D+WD\\PWD+ ^DY Y\VW+DJ 0-9 1dhJ OO 1@1 21=>J 1ddn

kY[T mk Y-K5<''J +:Q

R*'*8$ \9$5$'8$2DBF$%.'/ A.% T$78*5 5.'/ 0-' U-8$'8*<90$%8$*9.'/$' 6N%

$*' 9L8%*7EF$7 Y.%EF78%) 5.'/70$%6<F%$'*' &$% A$%78)%.'/76%$*$'

b$%L78-66O%N6.'/J*'C (9$*'F$.K<EF$% T$%*EF8$ 31 S1dmXJ V: d 21lX

kY[T i><k +: Y-K5<''J b: GF$*'$%J (: +-KK97J c: (<O*8A<Q

a$%78)%.'/76%$*$ ^'<9_7$ &$% +$6N/$ 5*8 '98%<7EF<992 .'& \9$L8%-2

5</'$8*7EF$']$8F-&$'J m]U^2V$5*'<%J >d:21>: [L8-K$% 1di>J

T$*8%</=J V8.88/<%8

kY[T i>Kk Y-K5<''J +:Q c)99$%J U:Q

UF_7*E<9 <'<9_7*7 5$8F-&7 -6 5</'$8*E 69.e 9$<L</$J*'C VF<%O$J P:V:C

P7<%EF G$EF'*p$7 *' D-'2&$78%.E8*0$ G$78*'/J I-9.5$ lJ M-'&-'C

^E<&$5*E U%$77J 1di>J O: @d2dn

kY[T dik +: Y-K5<'' $8 <9:Q

T<%LF<.7$' '-*7$ 5$<7.%$5$'87 <'& %$9<8$& 5$<7.%5'8*' 6$%%-2

5</'$8*E 5<8$%*<97J*'C Yh-%&h$0*EJ T:T:Q Y-7 P$*7J c:Q G-O*E7 -' '-'2

&$78%.E8*0$ $0<9.<8*-' 7$%*$7J I-9.5$ 1J 7$'7*'/ 6-% 5<8$%*<97

EF<%<E8$%*A<8*-'J O%-E$77*'/J <'& 5<'.6<E8.%*'/ ST*%'K<.5J +:Q ^.9&J T:^:Q

8$EF'*E<9 $&*8-%7XJ GF$ ^5$%*E<' V-E*$8_ 6-% D-'2&$78%.E8*0$ G$78*'/J

WVTD 12=1n 2>m 2jh1ddiJ O: 3@@ 23=3

kY[T >l<k +: Y-K5<''J]: (-OOQ

\9$E8%-5</'$8*E EF<%<E8$%*A<8*-' -6 5<8$%*<9 &$/%<&<8*-' &.$ 8- '$.8%-'

%%<&<8*-'J Wf^\] I-9 1dJ D.5K$%7 12lJ 3>>lJ OO: @n 2m

kY[T >lKk +: Y-K5<''Q

DY\ 6-%]<8$%*<9 ZF<%<E8$%*A<8*-' -6 ^/$*'/ &.$ 8- GF$%5<9 \5K%*889$5$'8J

R<8*/.$ <'& D$.8%-' Y$/%<&<8*-'Q U%-E$$&*'/7 -6 8F$ R*''*7F2+$%5<'2

f<O<'7 f-*'8 W'8$%'<8*-'<9 V$5*'<% ?]$EF<'*E<9 <'&]$8<99.%/*E<9

^OO%-<EF$7 8- D$# f-*'*'/ U%-E$77$7J F$9& <8 8F$ ^#<h* j.5$K.8<*

W'8$%'<8*-'<9 Z-'6$%$'E$ E$'8$%J ^#<h* W79<'&J c_-/-J f<K<'J

3>231 f.9*J 3>>l

k\WV >@k *7$%8J T<EF5<''J V*$0$%7C

b$*8$%$'8#*EL9.'/ &$% 78%.L8.%5$EF<'*7EF$' ^'<9_7$5$8F-&*L A.%

T$78*5 5.'/ &$7 (%*$EF0$%F<98$'7 0-' (-5O-'$'8$'J +PV2^2@1>lJ 3>>@

k\ ‘ P >Ik G%<’76$%<K*9*8_ -6 R%<E8.%$ G-./F’$77 Y<8< 6-%W’8$/%*8_ -6 R$%%*8*E V8$$$9
Z-5O-’$’87: V$5*’<% U%-E$&&*’/7J fPZ U$88$’J
Y-E.5$’8D-: \ ‘P 31Id1 \DJ3>:13:3>>I

kR^W>@k R<*&_$8 <9C
GF$ ^YW] \b S^77$775$’8 -6 ^/$& U*O*’/ Y*77*5*9<%]$8<9 b$9& W’8$/%*8_X
U%-h$E8J U%-E$$&*’/7 RWV^ Z-’6$%$’E$ 3>>@

kRWP >>k R*%’F<K$%J V*$0$%7J VEF#*’/$7C
T$%$EF’./ &$7 5$EF<’*7EF$’ I$%F<98$’7 .’& &$% M$EL%<8$ $*’$7
VO<’’K$8-’2]-&$99E-’8<*’5$’87 .’8$% 7EF#$%$’ V8)%6<99K$&*’/.’/$’J
^K7EF9.77K$%*EF8A.5 I-%F<K$’ PV 1>d@J +PV2^23i3iJ f.9* 3>>>

k+WM d3k R-%7EF.’/70-%F<K$’ T]RG2R(a 1=>> mn\eO$%*5$’8$99$.’&
’.5$%*7EF$ ‘’8$%7.EF.’/$’ A.5 I$%F<98$’ $*’$7 ’*$&%*/ABF$’
T$FB98$%#$%L78-667 K$* P*77$*’9$*8.’/J*’78<K*9$% P*77<.7K%$*8.’/ .’&
P*7778-OO K$* NK$%9</$%8$’ 5$EF<’*7EF$’ .’& 8F$%5*7EF$’
T$<’7O%.EF.’/$’:
^K7EF9.77K$%*EF8J]U^ V8.88/<%8J Y$A$5K$% 1dd3

k+P\ d3k +%$K’$%J c)69$%C
\%#$*8$%.’/ ABFK%.EF5$EF<’*7EF$% ^’<9_7$’ A.% T$78*5 5.’/ &$%
M$EL/%),$ K$* &*EL#<’&*/$’ P-F%9$*8.’/$’: ^K7EF9.77K$%*EF8A.5
I-%F<K$’ PV dmn+PV 2^21dlm1dd3

k+P\ ddk +%$K’$%J]N99$%J V*$0$%7C
b$*8$%$’8#*EL9.’/ &$% ^’<9_7$8$EF’*L .’& /$’$%*7EF$ ^’<9_7$’ A.5
(-5O-’$’8$’0$%F<98$’ *5 I$%K.’& 6N% <.79$/.’/7NK$%7EF%$*8$’&$
V8)%6B99$J ^K7EF9.77K$%*EF8A.5 I-%F<K$’ PV 1>@dJ +PV2^23mJ 1ddd

k+PV d>k +$7$997EF<68 6N% ^’9</$’2 .’& P$<L8-%7*EF$%F$*8C
Y$.87EF$ P*7*L-78.&*$ ($%’L%<68#$%L$ UF<7$ TJ I$%9</ GH I PF$*’9<’&J
1dd>

k+PV >@k b$*8$%$’8#*EL9.’/ &$% ^’<9_7$5$8F-&$ A.% T$#$%8.’/ &$7 G%</0$%F<98$’7
0-’]*7EF’BF8$’J +PV2I-%F<K$’ PV 11=@ S3>>@ ?3>>=X

kc\P i>k (: c$%AJ Y: (.OO9$%J U: Y$*5$9JQ
(-%%$9<8*-’0-’ 5$EF<’*7EF$’ .’& 5</’$8*7EF$’ +%),$’ 5*8
9L8%-’$’5*L%-7L-O*7EF .’8$%7.EF8$’]*L%-78%.L8.%$’0-’ Y%.ELK$FB92
8$%78BF9$’Q m]U^ 2V$5*’<%J >d:21>: [L8-K$% 1di>J T$*8%</ =^J V8.88/<%8

kcWP dk V: c*%7$L-%’Q
WaRU2T$%*EF8D%: d>31i 2GbJ V<<%K%NEL$’ 1dd

kc [\ dkm c)69$%J +%$K'$%J M*.J VEF*5O6L$J T$9*EA$_J V*0%7C
D.5$%*7EF$ V*5.9<8*-' &$7 78%.L8.%5$EF<'*7EF$' I$%F<98$'7 &$%
(-5O-'$'8$' $*'$% Y b P2(NF9L%$*79<.67EF9$*6$.'8$%<.,$%/$#)F'9*EF$'
T$9<78.'/$': ^K7EF9.77K$%*EF8A.5 I-%F<K$' PV dI>J +PV2^23@==J 1ddm
kc [\ dkn c)69$%J +%.'$%J ^A-&*J *7$%8J T$9*EA$_C
V*EF$%F$*87<'<9_8*7EF$ ‘ '8$%7.EF.'/$' A. 7EF#$%$' V8)%6B99$' *' V b PJ
^K7EF'*88 =C V8%.L8.%5$EF<'*7EF$ ^'<9_7$'J +PV2^K7EF9.77K$%*EF8 &$7
I-%F<K$'7 PV dnJ 1ddn
kc [P @k \: c-%'K-/$'Q Y$.8.'/ &$% V8%$EL/%$'A$ $*'$7 5*L%-9$/*$%8$' T<.78<F97J
V8<F9.'& *7$' d@J i33J S1d@X
kc ‘] >3k c.5OF%*$7J M:M: $8<9:C
[\ZY M-#$% c$<& R<*9.%$ U%-h$E8 R*'<9 P$O-%8J
V<'&*< D<8*-'<9 M<K-%<8-%*$7J ^9K.p$%p$J D] J ‘V^Q
[\ZYkD\^kZVDWkPS3>>3X3jn 3>>3
kW([ddk WL-'$'J (:S1dddXC
;Z%$$O]-&$9 R*88*'/ Y$%*0$& 6%-5 P\IWV^ Z%$$OJ G$'7*9$ <'& P$9<e<8*-'
]$<7.%$5$'87;J G$EF'*E<9 P$O-%8] [V\V2IkddJ IGG2\'$%/_J \7O--J
R*'9<'&
kW b] >>k R-%7EF.'/70-%F<K$' T] b ^2R(a 1=>>d1C
\%6<77.'/ .'& T$#$%8.'/ 0-' VEFB&*/.'/75$EF<'*75$' *' <.78$'*8*7EF$'
(%<68#$%L7L-5O-'$'8$' .'8$% 5$EF<'*7EF$% .'& 8F$%5-A_L9*7EF$%
T$9<78.'/: ^K7EF9.77K$%*EF8 G 13k3>>>J Y$A: 3>>>
kW b] >@k (9B%.'/ &$7 T$8%*$K70$%F<98$'7 0-' VEF#$*,0$%K*'&.'/$' A#*7EF$'
5<%8$'7*8*7EF$' .'& <.78$'*8*7EF$' P-F%$' K$*G$5O$%<8.%$' K*7 n> fZ
.'8$%L-5K*'*$%8$% 8F$%5*7EF$% .'& 5$EF<'*7EF$% T$9<78.'/:
^K7EF9.77K$%*EF8A.5 R-%7EF.'/70-%F<K$' !] ^PZ([2VEF#$*,'<F8;J
T] b ^2R)%&$%L$''A$*EF$' >@3n=>J ^IWR ($''A$*EF$' ^ 1>d.'& ^ 1nJ
W b]2T$%*EF8 b Ik3>>@J R%$*K.%/J 3>>@
kW b] >=k R-%7EF.'70-%F<K$' T] b ^2R(a 1=>13@dC
(%*8*7EF$ HK$%O%N6.'/ &$7]<78$%E.%0$2^'7<8A$7*5 c*'K9*EL <.6 &*$
^'#$'&.'/ K$* &$.87EF$' ($%'L%<68#$%L$':
^K7EF9.77K$%*EF8 Vik3>>IJ >d:>@:3>>=
k(\W >@k ($*5J \:$8<9C
\%5*889.'/0-' T%.EF5$EF<'*LL$''#$%8$' <'0-%K$78%<F98$' U%-K$' 6N% &*$
&$.87EF$' Y b P2T<.9*'*$' Z^PWV] ^J T] b ^2R I 1=>1 3i IJ
R%<5<8-5$ ^DUJ 3>>@ K*7 3>>n

k([ ] >@k (- 5 O8 ' A0$%K . ' & ($% ' 8$EF ' *LJ GF$ 5 $ ' &$% ' . L9$<%$ ' V*EF$%F$*872 . ' &
\ ' &9</$%6 - %7EF . ' / *' Y$. 87EF9<' & 3>>323>>im
P$<L8 - %7*EF$%F$*876 - %7EF . ' / J f . 9* 3>>@
kM^D i=k (: f: M<' /$ ' K$%/J I : VEF 5 *8AQ
+$ ' $%<9*A$& G - 5 - /%<OF_ <7 < . ' *6*$& <OO% - <EF 8 - 9*' $<% *' 0$%7$ 7E<88$%*' /
? 8F$ - %_ <' & eO%* 5 $ ' 8Q *' T$%LF - . 8J ^: f: Q P*&&$%J f: Q 0<' &$% b <9J
M: R: Q ^E - . 78*E<9 W 5 </*' / J I - 9: 1 I J D$# j - %LJ U9$ ' . 5 U%$77J 1d i=
kMWY >@k M*&K . %_J Y: U: + : $8 <9: C
I <9*&<8*- ' -6 E - ' 78%<*' 8 K<7$& 5 $8F - &- 9 - / _ *' 78% . E8 . %<9 *' 8$/%*8_
S I [Z^MWVGXJ RWV^ 3>>@J 1>21@ D - 0$ 5 K$% 3>>@J \ Z M . e$ 5 K - . %/:
k] [D >>k] - ' /<K . %$J UF: S3>>>XC Z%$$O 8$787 - ' McR <' & [McR V^=@@T1 78$$9:
P<OO - %8 D - : V \ ] GkMWVDkPGk>>2>mi^J Z \ ^ V<E9<_ ? Y] V3J
YE 5 K$% 3>>>
k] U^ >I<k R - %7EF . ' /70 - %F<K$ ' T] b ^2R (a 1=>1 3 I >C
(%*8*7EF$ HK$%O%N6 . ' / &$7] <78$%L . %0$2^ ' 7<8A$7 *5 c*' K9*EL <. 6 &*$
^ ' #$ ' &. ' / K$* &$. 87EF$ ' ($% ' L%<68#$%L$ ': ^K7EF9 . 77K$%*EF8J] U^
V8 . 88/<%8J *' ^%K$*8
k] U^ >IKk \: P - - 7J b : T . %%J f: R) F9J U: (*A9$%J G: VEFN88J \: V - OO<J M: V8 . 5 O6% - ELJ
Y: b *99$%C
' ' 8$%7 . EF . ' /$ ' A . % 6$%8*/ . ' /7K$&*' /8$ ' \ ' 878$F . ' / 0 - ' R$F978$99$ ' K$*
] *7EF7EF#$*, 0$%K*' &. ' /$ ':] <8$%*<9O%N6 . ' /7<' 78<98 S] U^X ' ' *0$%7*8B8
V8 . 88/<%8J ^K7EF9 . 77K$%*EF8J P$<L8 - %7*EF$%F$*876 - %7EF . ' / ? I - %F<K$ ' 2D%:
1=>1 3 I =J 3>>I :
k] U^ >IEk \: P - - 7J G: VEFN88J M: V8 . 5 O6% - ELC
T%. EF 5 $EF<' *7EF$ ' ' 8$%7 . EF . ' /$ ' A .] *7EF7EF#$*, 0$%K*' &. ' /$ ':
] <8$%*<9O%N6 . ' /7<' 78<98 S] U^X ' ' *0$%7*8B8 V8 . 88/<%8J
P$<L8 - %7*EF$%F$*876 - %7EF . ' / ? I - %F<K$ ' 2D%: 1=> 13 imi&$%A$*8 *' ^%K$*8:
k] U^ ddk] <8$%*<9O%N6 . ' /7<' 78<98 ' ' *0$%7*8B8 V8 . 88/<%8C
\ %5*889 . ' / . ' &] - &$99*$%. ' / &$7 b $%L78 - 660$%F<98$ ' 7 0 - ' P$<L8 - %K<. 78BF2
9$ ' . ' 8$% 5 $F%<EF7*<9$% T$<' 7O%. EF . ' / 6N% &$ ' <. 79$/. ' /7NK$%7EF%$*8$ ' 2
&$ ' G$ 5 O$%<8 . %K$%$*EF 0 - ' I >> fZ K*7 1>>> fZJ
P$<L8 - %7*EF$%F$*870 - %F<K$ ' D%: 1=1>1>J ^K7EF9 . 77K$%*EF8 0 - 5 f . '* 1ddd
k] HM >Ik b :] N99$%J c: U<. 9Q
' 98%<7EF<99<' <9_7$O%N6 . ' / <' $*' $%] *7EF' <F8 . ' & $*' $% <. 78$ ' *8*7EF$ '
VEF#$*, ' <F8 <5 +%- , K$FB98$% &$%] U^Q P$<L8 - %7*EF$%F$*876 - %7EF . ' / ?
I - %F<K$ ' D%: 1=> 13mi a#*7EF$ ' K$%*EF8J WaRU 2T$%*EF8 D%: >I >13>2 \ J
V<<%K%NEL$ ' 3>>I

k[TV idk [K78J Y:J]<*9$J (:S1didXC

I$%7.EF$ A.% VEF<66.'/ $*'$% Y<8$'78%.L8.%6N% &*$*'$9<78*7EF$ T$%$EF2

'.'/0-' (%*$EF0-%/B'/$'*' 8F$%5*7EF K$9<78$8$' (-5O-'$'8$':

R-%7EF.'/7K$%*EF8]U^2V8.88/<%8 D%: im> >> >>>J ^O%*9 1did

k[DY mk +: ['&%<E$LQ

a:6: b$%L78-668$EF'*L d S1dmXJ @1 2@m

kPGY >lk U%$&*E8*-' -6*%%<&*<8*-' 66E87*' %$<E8-%E-5O-'$'87J Y+2PGYC

\'P^G[ ] RUm'8$/%<8$& O%-h$E8J 3>>l ?3>>=

kV^Wdik V<*'8$ Z<8F$%*'$J Z:S1ddiXJ

G$'7*9$ <'& E%$$O 8$787 5<8$%*<9 ZF<%<E8$%*A<8*-' -6O%$77.%$ 0$77$9 78$$9

S1mhDY=X <8 F*/F 8$5O$%<8.% $7:P<OO-%8 V\ ]GkMWVDkPGkdi2>>dk^J

Z\^J R%<'E$

kV^'d>k R-%7EF.'/70-%F<K$' T]RG2RT 1=>> fmiC

\eO$%*5$'8$99$.'& 8F$-%$8*7EF$ T%.EF<'<9_7$ 5*8 '.5$%*7EF$']$8F-&$'

A.% T$F<'&9.'/ $*'$% W''$'&%.ELK$9<78.'/ 5*8 NK$%9</$%8$% GF$%5-2

7EF-ELK$<'7O%.EF.'/ <5 P$<L8-%&%.ELK$FB98$%:

^K7EF9.77K$%*EF8J]U^ V8.88/<%8J f<'.<% 1dd>

kVZ^ ddk VEF<<6J V*0%7J]N99$%C

\'8#*EL9.'/ .'& I$%*6*L<8*-' 0-']-&$99$' A.% T$7EF%$*K.'/ &$%

b$EF7$9#*%L.'/ Y$K%*72P$<L8-%&%.ELK$FB98$%#<'&J +PV2^23mdJ 1ddd

kVZc >lk VEF5<.&$%J V:J (*A9$%J U:J T*'L9J U:J (-F9$%J Z:,

^'#$'&.'/7-%*$'8*$%8$ \'8#*EL9.'/ &$% '<'-5$EF<'*7EF K<7*$%8$'

V*5.9<8*-' 0-' s&$%.'/$' &$7 b$%L78-66O$%F<98$'7 0-' V8BF9$' <.6/%.'&

0-' ^.77EF$*&.'/$'J I-%F<K$' 1=>133iJ]U^ V8.88/<%8J f.'*3>>l

kVZ] i@k I:VEF5*8AJ (:f:M<'/$'K$%/J f:f<EL7-'J c:bN78$'K$%/Q

W5O%-0$& 5$8F-&76-% .98%<7-'*E &6E8 E9<77*6E<8*-'J %$E-'78%.E8*-' <'&

%$9*<K*9*8_Qo<'8*8<8*0$ DY*' D.E9$<%W'&.78%_J

^V]J]$8<97 U<%L [c 1di@J OO:@m 2@m

kVZ] >lk I:VEF5*8AJ b:]N99$%J]:]<*79J V:+-'&%-5J (:f:M<'/$'K$%/J f:]*<-J

P:]<%L9$*'J (:]<*$%J \:P--7J U:f.9*7EFJ xVEF.9$%Q

+%.'&9</$' 6N% $*'$K$<'7O%.EF.'/7-%*$'8*$%8$ A$%78)%.'/76%$*$ U%N6.'/

0-' &%.EL6NF%$'&$' (-5O-'$'8$'Q P$<L8-%7*EF$%F$*876-%7EF.'/?

I-%F<K$' D%: 1=>133>J ^K7EF9.77K$%*EF8J WaRU2T$%*EF8 D%: >l>3>n2G b J

V<<%K%NEL$' 3>>l

kVZD ihn \:VEF'$*&$%J P:c$%A$%Q

^.8-5<8*7*$%8$ VO<''.'/7<'<9_7$ 5*8 '98%<7EF<99J 1@:]U^2V$5*'<%J

>i:?>d:[L8-K$% 1dihV8.88/<%8

kV\ c ddk V$F/<9J T:P:J D-.%/<9*$0J P:P:J Y*'FJ G:D:J (<%K-h*<'J ^.,

*FOREVER experimental program on reactor pressure vessel creep behaviour and core debris retention*J U%-E$$&*'/7 -6 8F$ 1=28F W'8$%'<8*-'<9 Z-'6$%$'E$ -' V8%.E8.%<9] $EF<'*E7 *' P$<E8-% G$EF'-9-/_ SV] *PG21=XJ V$-.9J (-%$<J ^./.78 1=23>J 1ddd

kVW\ dlk V*0%7J VEF.9AJ T<77J U./FJ ($$'$_C R%<E8.%$ ^'<9_7$7 -6 M<%/$ VE<9$ W'8$%'<8*-'<9 P$6$%$'E$ \eO$%*5$'87 SR^MVWP\X UF<7$ W: +PV21>iJ 1ddl

kVW\ dkm V*0%7J VEF.9AJ T<77J U./FJ ($$'$_C R%<E8.%$ ^'<9_7$7 -6 M<%/$ VE<9$ W'8$%'<8*-'<9 P$6$%$'E$ \eO$%*5$'87 SR^MVWP\X UF<7$ WWJ +PV21@>J 1ddm

kVW\ dd<k V*0%7J T<EF5<''J VEF*5O6L$J f$'&%*EFJ (%A_L<EA2c<.75<''J V-''$'K.%/J VEF$.$%$%C V$'7*8*0*8B87<'<9_7$' A.% \%5*889.'/ &$% ''7*EF$%F$*8$' K$* &$% T$7EF%$*K.'/ &$7 P*770$%F<98$'7*'6-9/$ 8F$%5-25$EF<'*7EF 8%<'7*$'8$% T$9<78.'/ .'8$% *'K$A*$F.'/ eO%*5$'8$99$% \%/$K'*77$J ^K7EF9.77K$%*EF8 A.5 I-%F<K$' PV 1>@im+PV 2^23im1ddd

kVW\ ddKk V*0%7J VEF.9AJ T<77J U./FC R*'<9 %$O-%8 -' 8F$ W'8$%'<8*-'<9 Z-5O<%<8*0$ ^77$775$'8 V8.&_ -6 U%$77.%*A$& GF$%5<92VF-EL *' P$<E8-% U%$77.%$ I$77$97 SPUI UGV WZ^VXJ D\^kZVDWkPSddX @J +PV21=3J 1ddd

kVGP i1k c:V8%-OO$Q \%5*889.'/ &$% T%.EFABF*/L$*8 &.L8*9$% b$%L78-66$ <.7 U<%<5$8$%' &$%]*L%-78%.L8.% .'& &$% R9*$,L.%0$J D$.$ cN88$ 3mlIim$1di1X

kVG' dkm R-%7EF.'/70-%F<K$' T] TR2R(a 1=>> dlCm ''8$%7.EF.'/$' A. &$' ^.7#*%L.'/$' 0-' D*$&$%&%.EL8%<'7*$'8$' K$* 7*5.9*$%8$' b$%L78-66A.78B'&$': ^K7EF9.77K$%*EF8J] U^ V8.88/<%8J YA5K$% 1ddm

kVG' >>k R-%7EF.'/70-%F<K$' T] b*2R(a 1=>1 >mC ''8$%7.EF.'/$' A.% ^.7#*%L.'/ &$% U9<88*$%.'/ <.6 &<7 I$%F<98$' 0-' L9$*'$' R$F9$%'*5 +%.'&#$%L78-66 K$* /$L-OO98% 8F$%5*7EF$% .'& 5$EF<'*7EF$% T$9<78.'/: ^K7EF9.77K$%*EF8J] U^ V8.88/<%8J YA5K$% 3>>>:

kIW\ >lk I*$F%*/J c:b:C ^'#$'&.'/ &$7]<78$%2Z.%0$2(-'A$O8$7 A.% ZF<%<L8$%*7*$%.'/ &$% aBF*/L$*8 '$.8%-'$'K$78%<F98$% P$<L8-%&%.ELK$FB98$%78BF9$J T] b^2R-%7EF.'/70-%F<K$' 1=>1 3inRaP P-77$'&-%6J 3>>l K*7 3>>=

kbWMih c:b*99$57Q

R%NF$%L$''./0-'(%*$EF7EFB&*/./ 5*88$97 ‘98%<7EF<99O$%6<F%$'J

1@:]U^2V$5*'<%J>i:?>d:[L8-K$% 1dihV8.88/<%8

4 Reaktorphysik

Y*$ %$<L8-%OF_7*L<9*7EF$' T$%$EF'.'/75$8F-&$' F<K$' $*'$' F-F$' \'8#*EL9.'/778<'& $%%$*EF8: +9$*EFA$*8*/ 78$998 &*$ 6-%89<.6$'&$ [O8*5*$%.'/ &$% T%$''$9$5$'8$*'7<8A78%<8$/*$' .'& &$% ($%'K$9<&.'/$' h$&-EF '$.$ 0$%B'&$%8$ ^'6-%&$%.'/$' .'& &*$ 7*EF$%F$*878$EF'*7EF$ T$#$%8.'/ 0$%9<'/8 '<EF $%F)F8$% PEF'/$'<.*/L$*8 .'& ^.77</$7*EF$%F$*8:

Y*$ I$%B'&$%.'/$' *5 T%$''78-66$*'7<8A*' M$*EF8#<77$%%$<L8-%$' SMbPX $%/$K$' 7*EF <.7 &$% /$O9<'8$' 7EF%*88#$*7$' \%F)F.'/ &$7 ^KK%<'&$7 <.6 ph 2i>]b&kL/J &$% <'/$78%$K8$' \%F)F.'/ &$% '%<'2^'%$*EF$%.'/ <.6 K*7 A. =v &$5 &<5*8 0$%K.'&$'$' $%F)F8$' *'7<8A 0-' <KK%$''K<%$' ^K7-%K$%' .'& &$5]*7EF-e*& S][xX2*'7<8A*5 '56<'/ 0-' @> K*7 =>vA.7< 55$' 5*8 '%<'2T%$''$9$5$'8$': W' <99/5*'$' V8.&*$' A.5 T%$''78-66$*'7<8A #$%&$' I-992][x2($%'K$9<&.'/$' K$8%<EF8$8 .'& ^98$%'<8*0$' #*$ &*$ ^L8*'*&$'K$78%<F9.'/ A.% I$%%*'/$%.'/ &$% 9<'/9$K*/$' P<&*-8-e*A*8B8 &.%EF ^YV S^EE9%<8-% Y%*0$' V_78$57X -&$% &.%EF &$' *'7<8A0-'*'$%8$' T%$''78-66$' .'8$%7.EF8:

RN% ($%'K$%$EF'.'/$' 0-' MbP F<8 7*EF $*'$ V8<'&<%&6-9/$ 0-' PEF'7EF%*88$' F$%<.7/$K*9&$8J &*$ <.7 6-9/$'&$' G$*97EF%*88$' K78F8C

- Y*$ T$%$*878$99.'/ 0-' '.L9$<%$' T<7*7&<8$' .'& &$%$' ^.6K$%$*8.'/ 6N% '<EF6-9/$'&$ T$%$EF'.'/$'J

- &*$ P$<L8*0*8B872 .'&D.L9*&*'0$'8<%K$%$EF'.'/0-' T%$''$9$5$'8$'J

- &*$ @Y2($%'K$%$EF'.'/$' A.% T$78*55.'/ &$7 P$<L8*0*8B87A.78<'&$7 .'& &$% %B.59*EF$' M$*78.'/70$%8$*9.'/J

- &*$ V8)%6<99<'<9_7$' &.%EF 8%<'7*$'8$ @Y2($%'K$%$EF'.'/$' -&$% &.%EF /$L-OO98 T$%$EF'.'/$' 5*8 V_78$5E-&$.'&*'8$/%*$%8$5 @Y2($%'5-&$99:

W' \%/B'A.'/ &<A. #$%&$']-'8$2Z<%9-2T$%$EF'.'/$' .'& &8%5*'*78*7EF$ D$.8%-'$'8%<'7O-%8K$%$EF'.'/$' 6N% L%*8*7EF$ VO<9878-667_78$5$J <97- L%*8*7EF$ \eO$%*5$'8$J T%$''$9$5$'8$.'& ($%'<'-%&'.'/$'J &.%EF/$6NF%8: Y*$7$ U%-/%<55$ #$%&$' <.EF 6N% V-'&$%6%</$' #*$ &*$ T$78%<F9.'/ &$7 P$<L8-%&%.ELK$FB98$%7 -&$% ^K7EF*%5O%-K9$5$$*'/$7$8A8:

RN% <'&$%$ P$<L8-%8_O$' #*$ A: T: ^YV #$%&$' &*$ /$'<''8$' PEF'7EF%*88$ 8$*9#$*7$ 5-&*6*A*$%8J 7-&<77 ($%'K$%$EF'.'/$' *' $'/$%$% I$%K*'&.'/ 5*8 &$% T$%$*878$99.'/ &$% '.L9$<%$' Y<8$' &.%EF/$6NF%8 #$%&$': Y*$ T$7EF%$*K.'/ &$7 $%%$*EF8$' \'8#*EL9.'/778<'&$7 .'& &*$ Y*7L.77*-' &$% $%6-%&$%9*EF$' b$*8$%$'8#*EL9.'/ *' &$' '<EF6-9/$'&$' (<O*8$9' 6-9/$' h$&-EF &$% +9*$&$%.'/J &*$ &.%EF &*$ PEF'7EF%*88$ 6N% M b P /$/$K$' *78:

4.1 Nukleare Basisdatenbibliotheken und ihre Aufbereitung für nukleare Berechnungen

4.1.1 Stand der nuklearen Basisdatenbibliotheken

a.% T$%$EF'.'/ %$<L8-%OF_7*L<9*7EF$% +%),$' 6N% ($%'%$<L8-%$' .'& L%*8*7EF$ ^'-%&'.'/$' 7*'& *'8$/%<9$.'& &*66$%$'8*99 b*%L.'/7p$%7EF'*88$ $%6-%&$%9*EFJ #$9EF$ &*$ P$<L8*-'$' 0-' D$.8%-'$' 5*8 &$' ^8-5L$%'$' SVO<982 KA#: T%.878-66$J V8%.L8.%5<8$%*<9*$'J VO<98O%-&.L8$J ^K7-%K$%J]-&$%<8-%X K$7EF%$*K$': a.7B8A9*EF 7*'& '.L9$<%$ Y<8$' $%6-%&$%9*EF A.5 a$%6<99 0-' ($%'$' .'& A. &$' ^.7K$.8$' &$% VO<98O%-&.L8$ K$* &$% ($%'7O<98.'/: Y*$7$ T<7*7&<8$' #$%&$' *'8$%'<8*-'<9 <.7/$<%K$*8$8 .'& 7*'& A.5 /%-,$' G$*9 6%$* 0$%6N/K<%: *'$ HK$%7*EF8 NK$% &*$ '.L9$<%$' Y<8$'K<7$'J G--97 .'& ^%K$*87/%.OO$' A.% I$%<%K$*8.'/ .'& D.8A.'/ '.L9$<%$% Y<8$' /*K8 T*9& I21:

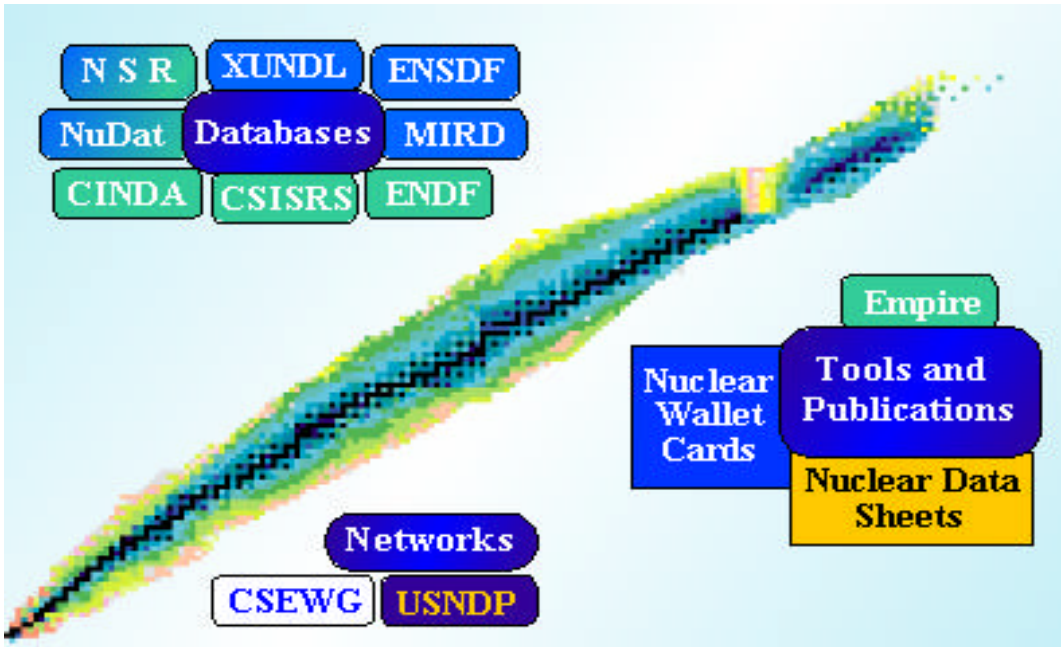


Bild 4-1C I$%6N/K<%$ W'6-%5<8*-'$' .'& Y<8$' K$AN/9*EF '.L9$<%$% P$<L8*-'$'

Y<K$* K$&$.8$'C

ZWDY^C Z-5O.8$% W'&$e -6 D$.8%-' Y<8<J 5*8 P$6$%$'A$' A.]$77.'/$'J T$%$EF'.'/$'J T$#$%8.'/$' .'& \0<9.*$%.'/$' 0-' D$.8%-'$'2 p$%7EF'*88$' 7 -#*$ P6%$'A$' A. T*K9*-8FL' 5*8 '.5$%*7EF$' D$.8%-'$'&<8$' 0-' 0*$% D$.8%-'$'&<8$'2a$'8%$' kZWDkJ

D.Y<8:C D.E9$<% Y<8< R*9$J $%5)/9*EF8 *'8$%<L8*0$ V.EF$.'& Y<%78$99.'/$' 0-' a$%6<997&<8$' .'& '.L9$<%$' V8%.L8.%$'J

DVPC D.E9$<% VE*$'E$ P6%$'E$7J U.K9*L<8*-'$' KA#:($%'OF_7*L6-%7EF.'/

x DYMC \eO$%*5$'8<9 ''$0<9.<8$& D.E9$<% Y<8< M*78J$'8FB98 eO%*5$'8$99$ Y<8$'J

\DVYRC \0<9.<8$& D.E9$<% V8%.E8.%$ Y<8< R*9$J $'8FB98 ($%'78%.L8.%2 .'& a$%6<997&<8$' 6N% NK$% 3d>> D.L9*&$J

]WPYC D.E9$<% Y<8<*' 8F$]WPY R-%5<8J$'8FB98 ($%'78%.L8.%2 .'& a$%6<997&<8$' *5]$&*E<9 W'8$%'<9 P<&*<8*-' Y-7$ R-%5<8 S<.7 \DVYRXJ

\DYRC \0<9.<8$& D.E9$<% Y<8< R*9$J R-%5<8K$7EF%$*K.'/ &$% Y<8$'K*K9*-8F$L$'JA.% VO$*EF$%.'/ .'& ^K%.6 0-' '.L9$<%$' Y<8$' A.% ^'#$'&.'/ *' &$% ($%'8$EF'*L:+$/$'#B%8*/$ I$%7*-'C \DYR2m\DY kJ

ZV\b+C Z%-77 V$E8*-' \0<9.<8*-' b-%L*'/ +%-.OJ

'VDYUC ':V:D.E9$<% Y<8< U%-/%<5:

^97 $0<9.*$%8$ T<7*7&<8$'J &*$ *'7K$7-'&$%$ 6N% &*$ T$%$EF'.'/ 0-' VO<98%$<L8-%$' /$$*/'$8 7*'&J 7*'&6-9/$'&$ Y<8$*$' A./B'/9*EFC

f\R23:3C f-*'8 S\.%-O$<'X \0<9.<8$& R*9$J /$/$'#B%8*/ 6%$*/$/$K$'$ I$%7*-' 3:3J

f\RR2@:>C f-*'8 \0<9.<8$& R*77*-'<'&R.7*-' R*9$ $%7EF$*'$' kf\R21JD[PkJ

\DYRkT2IW:iC \0<9.<8$& D.E9$<% Y<8< R*9$ S‘V^XJ 5*8 I$%7*-’ IW:i <K/$7EF9-77$’ kbU\kJ &*$ I$%7*-’C \DYRkT2IWW*78*’ I-%K$%$*8.’/J

f\DYM2@:@C f<O<’7 \0<9.<8$& D.E9$<% Y<8< R*9$J I$%7*-’ @:@ kf\DkJ f\DYM2I:> *’ I-%K$%$*8.’/J

TP[DY23:3C \0<9.*$%8$7 Y<8$’6*9$ $%78$998*’ P.779<’&kTP[kJ

Z\DYM2@:>C \0<9.*$%8$7 Y<8$’6*9$ $%78$998*’ ZF*’<kZDYkJ

\^R23>>@C \.%-O$<’ ^E8*0<8*-’ R*9$Jo$%7EF’*887&<8$* .’& a$%6<997&<8$’ kR[P21k:

*’ #7’89*EF$% VEF%*88 A.% D.8A.’/ &$% ’.L9$<%$’ T<7*7&<8$’K*K9*-8F$L$’ 6N% %$<L8-%OF_7*L<9*7EF$ T$%$EF’.’/$’ *78 &*$ ($%’&<8$’<.6K$%$*8.’/: Y<%.’8$% 0$%78$F8 5<’ &*$ G%<’76-%5<8*-’ &$% *5 7O$A*99’ \DYR2m2R-%5<8 <K/$7O$*EF$%8$’ W’6-%5<8*-’$’ K$AN/9*EF &$% b*%L.’/7p$%7EF’*88$*’ R.’L8*-’70$%9B.6$ KA#:G<K99’J #$9EF$ &*$ \’$%/*$<KFB’/*/L$*8 $eO9*A*8 &<%78$99$’: V-9EF$ Y<8$’ #$%&$’ <97 U.’L8&<8$’ KA*EF’$8J &< 7*$ &$’ R.’L8*-’70$%9<.6 &$% o$%7EF’*88$*’ ^KFB’/*/L$*8 &$% \’$%/*$ &$8<*99*$%8 *’ $*’$% &*EF8$’ R-9/$ 0-’ U.’L8$’ &<%78$99$’J #-K$* *’7K$7-’&$%$ &*$ P$7-’<’A$’ &$8<*99*$%8 <K/$K*9&$8 #$%&$’:

RN% &*$ P$L-’78%.L8*-’ &*$7$% U.’L8&<8$’ <.7 &$’ *5 \DYR2m2R-%5<8 /$7O$*EF$%8$’ ’.L9*&7O$A*6*7EF$’ U<%<5$8$%’ .’& G<K$99$’ #*%& *’8$%’<8*-’<9 <5 FB.6*/78$’ &<7 U%-/%<557_78$5 Df[j kR^Pk $*’/$7$8A8: Y*$7$7 U%-/%<557_78$5 $’8FB98]-&.9$ A.% P$L-’78%.L8*-’ 0-’ U.’L8&<8$’ SP\Z[DPXJ G$5O$%<8.%0$%K%$*8$%.’/ STP[^YPJ T$%NEL7*EF8*/.’/ &$7 Y-OO9$%2\66$L87XJ R-%5<8*$%.’/ 6N% ^’#$’&.’/7E-&$7 S^Z\P 6N%]-’8$ Z<%9- U%-/%<55$ 5*8 U.’L8&<8$’J A:T: &$5]-’8$ Z<%9- U%-/%<55]ZDU kR[P23kX .’& A.% \%78$99.’/ 0-’ 7-/:].98*/%.OO$’&<8$*$’J #-K$* &$% \’$%/*K%$*EF*’ +%.OO$’ .’8$%8$*98 #*%& .’& &*$ 5*889$%$’ b*%L.’/7p$%7EF’*88$ &$% +%.OO$’ NK$% $*’ b*EF8.’/77O$L8%.5 K$%$EF’$8S]-&.9 +P[‘UPX #$%&$’:

DK’ &$’ ($%’%$<L8*-’$’ 6N% 7EF’99 .’& $O*28F$%5*7EF$ D$.8%-’$’ 7*’& 6N% &*$ V8%$..’/ 8F$%5*7EF$% D$.8%-’$’ V8%$./$7$8A$ A. K$%NEL7*EF8*/$’J #$9EF$ &*$ b$EF7$9#*%L.’/$’ 0-’ D$.8%-’$’ 5*8 9$*EF8$’ ($%’$’ .’8$% T$<EF8.’/ &$% 8$5O$%<8.%<KFB’/*/$’ T$#$/.’/75-&* &$% *’]-9$LN9$’ -&$% *’ +*88$%’ /$K.’&$’$’ V8%$.$%J A:T: c2 -&$% Y2^8-5L%’$J K$7EF%$*K$’ kf\R23k: c*$%K$* L<’’ $7 7*EF .5

==

L-FB%$'8$ -&$% *'L-FB%$'8$ $9<78*7EF$ -&$% *'$9<78*7EF$ V8%$../ F<'&$9': Y*7 V8%$./$7$8A$ #$%&$' *' &$% P$/$9 <.7]$77.'/$' -&$% &.%EF 5-9$L.9<%&_'<5*7EF$ P$EF'./$' K$78*55 8: Y*$ T$%NEL7*EF8*/./ &*$7$% V8%$./$7$8A$ *78 #7'89*EF 6N% &*$ %$<9*78*7EF$ T$%$EF'./ 8F$%5*7EF$% D$.8%-'$'7O$L8%$':

[K#-F9 K$%$*87 F$.8$ $*'$ /.8$ o<9*8B8 &$% T<7*7&<8$' 6N% 7$F% 0*$9$ D.L9*&$ 6$78/$78$998 #$%&$' L<''J 7*'& O<%8*$99$ I$%K$77$%.'/$' '-8#$'&*/J .5 5*8 &$' T<7*7&<8$' V_78$5$ 5*8 .'8$%7EF*$&9*EF$' VO$L8%$' .'& T%$''78-662 A.7<55$'7$8A.'/$' 5*8 &$% 6N% &*$ T$#$%8./ &$% V*EF$%F$*8 $%6-%&$%9*EF$' +$'<.*/L$*8 K$%EF'' A. L)''$': Y*$7 K$8%*668 0-% <99$5 T%$''78-66 5*8 F-F$5 ^KK%<'& -&$% 5*8 F-F$% (-'A$'8%<8*-' 0-' ^L8*'*&$' -K$%F<9K 0-' U9.8-'*.5 KA#: <KK%$''K<%$' D$.8%-'$'/*68$': W'7K$7-'&$%$ 6N% ''8$%7.EF./$' 0-' T%$''78-6678%<8$/*$' -&$% &$' \'8#.%6 0-' V_78$5$' A.% P$&.L8*-' KA#: G%<'72 5.8<8*-' 0-' 9<'/9$K*/$' ^L8*'*&$' K$L-55 8 &*$ +$'<.*/L$*8 0-' o$%7EF'*88$' .'& D.L9$<%&<8$' F)F$%$% ^L8*'*&$ #*$ ^52 .'& Z52W7-8-O$ $*'$ #7'89*EF /%),$%$ T$&$.8./ <97 K$* V8<'&<%&2M b P2T%$''78-66: Y$7F<9K 7*'& *' 5$F%$%$' M<K-%7 S+$$9 *' T$9/*$'J M-7 ^9<5-7 D<8*-'<9 M<K-%<8-%_ SM^DMX *' 'V^J f<O<'J P.779<'&X]$77.'/$' /$O9<'8 KA#: K$%$*87 *5 +<'/$J .5 6N% &*7 D.L9*&$ <.EF *5 F)F$%$' \'$%/*$K$%$*EF 0$%K$77$%8$ Y<8$' A.% I$%6N/./ A. 78$99$':

Y*$ /$6-%&$%8$' KA#: /$O9<'8$']$77.'/$' 7*'& *' &$% 7-/: D\^ c*/F U%*-%*8_ D.E9$<% Y<8< P$p$78 M*78 &-L.5$'8*$%8 : D$.$%9*EF$ ^L8*0*B8$' 7*'& *' &*$7$5 P<F5$' <K$% <.EF I$%K77%.'/$' K$* '23@= .'& '23@iJ &*$ $%F$K9*EF$' *'69.77 <.6 &*$ +$'<.*/L$*8 0-' (%*8*L<9*8B87%$EF'./$' 6N% '*$&%*/ <'/$%$*EF$%8$.'& .'8$%5-&$%*$%8$ Mb P2+*88$% F<K$': Y*$7 L-''8$ &.%EF D<EF%$EF'./ 0-' T$'EF5<%L7 6N% '*$&%*/ <'/$%$*EF$%8$ '[32+*88$% S7*$F$ W'8: c<'&K--L -6 Z%*8*E<9*8_ \eO$%*5$'87 kD\^23kX /A*/8 #$%&$':

Y*$ 6N% Mb P %$9$0<'8$' 0$%K77%8$' '.L9$<%$' Y<8$' 7-998$' '<EF R%$*/<K$ &.%EF &*$ *'8$%'<8*-'<9$' Y<8$'$0<9.*$%.'/7/%.OO$' '<EF $*'$% .56<77$'&$' I<9*&*$%./ SD<EF%$EF'./ 0-' \eO$%*5$'8$' .'& T$'EF5<%L7X 6N% 7*EF$%F$*87%$9$0<'8$ %$<L8-%OF_7*L<9*7EF$ T$%$EF'./$' $*'/$7$8A8 #$%&$'J &< 7*$ #$*8/$F$'& <97 0-' &$% h$#$*9*/$' U%-K9$578$99./ .'<KFB'/*/ <'/$7F' #$%&$' L)''$'J &:F: 6N% <99$]-&$%<8*-'7/%<&$ /$$*/'$8 7*'&:

4.1.2 Validierung der nuklearen Basisdaten

Y*$ b*%L.'/7p$%7EF'*887&<8$*$' #*$ f\R 23:3 -&$% \DYRkT2IW 9<77$' 7*EF '*EF8 .'5*88$9K<% NK$%O%N6$'J 7-'&$%' '.% &*$ <.7 &*7' Y<8$*$' $%A$./8$' U.'L82 -&$%].98*/%.OO$'&<8$': DK' $*'$5 &*%$L8$' I$%/9$*EF &$% $%A$./8$' o$%7EF'*887&<8$' 5*8 /$5$77$'$' 8-8<9$' -&$% &*66$%$'8*$99$' o$%7EF'*88$'J S A:T:A.7<55$'/$78$998 *' &$% \R[P 2Y<8$'K<'LkXJ 7*'& 0-% <99$5 &*$ T$%$EF'./ 0-' eO%*5$'8$99$' ^'-%&'.'/$' .'& &*$ ^.7#$%8.'/ 0-' T$8%*$K7$%/$K'*77$' 9<.6$'&$% MbP2^'9</$' T<7*7 &$% I<9*&*$%.'/: V$F% 0*9 \eO$%*5$'8$ 5*8 MbP28_O*7EF$' T%$''78-662]-&$%<8-%2^'-%&'.'/$' 7*'& *5 W'8$%'<8*-'<9$' c<'&K.EF (%*8*7EF$% \eO$%*5$'8$ kD\^23kA.7<55$'/$78$998:

Y*$ I<9*&*$%.'/ K$78$F8 &<%*'J &<77 $*'$ /%-,$ ^'A<F9 0-' \eO$%*5$'8$' 7-#-F9 5*8 &$' U.'L8&<8$' <97 <.EF 5*8 +%.OO$'&<8$' '<EF/$%EF'8 #$%&$': W' &$' 0$%/<'/$'$' f<F%$' #.%&$' &<F$%*' Y$.87EF9<'& 7-9EF$ T$%$EF'.'/$' &.%EF/$6NF%8 kT\P21kJ kab\kJ kT\P23kJ #-K$* 0-% <99$5 &<7 U.'L8&<8$'2]-'8$2Z<%9-2U%-/%<55]ZDU .'& &<7].98*/%.OO$'2]-'8$2Z<%9-2U%-/%<55 (\D[2I< KA#: (\D[2IW kc[Mk $*'/$7$8A8 #.%&$': Y*$].98*/%.OO$'&<8$'2^.6K$%$*8.'/ #.%&$ 5*8 &$5 U%-/%<55 P\V][Y k+]^k &.%EF/$6NF%8: Y*$7$ ^.6K$%$*8.'/ *78 $%6-%&$%9*EFJ &< *'].98*/%.OO$'&<8$*$' SK$* E<: @>> +%.OO$'X &*$ +%.OO$'p$%7EF'*88$ *5 <.6/$9)78$' P$7-'<'AK$%$*EF 78<%L 0-5 b*EF8.'/77O$L8%.5 <KFB'/$'J &<7 6N% h$&$ ^'-%&'.'/ *'&*0*&.$99 K$78*558 #$%&$' 5.77J A:T:&.%EF $*'$ R$*'78/%.OO$'2 KA#: U.'L8&<8$'2 M)7.'/: Y*$ T$%$EF'.'/ &*$7$7 b*EF8.'/77O$L8%.57 *78 &<5*8 6N%].98*/%.OO$'9)7.'/$' $*' #*EF8*/$% *'69.776<L8-%J *'7K$7-'&$%$ K$* L-5O9$e$' ^'-%&'.'/$': T$* %$/.9B%$' +*88$%' #*$ A:T:K$* YbP 7*'& $*'&*5$'7*-'<9$ T$%$EF'.'/$' &$7 D$.8%-'$'7O$L8%.57 *5 P$7-'<'AK$%$*EF *' &$% P$/$9 <.7%$*EF$'&J &:F:F*$% 7*'&]ZDU .'& P\V][Yk(\D[2M)7.'/$' K$* /9$*EF$% '.L9$<%$% Y<8$'K<7*7 '<F$A. *&$'8*7EF: Y*$7 /*98 <.EF 6N% &8%5*'*78*7EF$].98*/%.OO$'9)7.'/$' 5*8 V_D2G%<'7O-%8O%-/%<55$' kPc[kJ kT\P2@k:

‘5 &*$].98*/%.OO$'O%-/%<55$ <.EF 6N% L-5O9e%$ U%-K9$5$ '-EF /$'<.$% A. 5<EF$'J #$%&$' 6-9/$'&$ b$*8$%$'8#*EL9.'/$' 0-%/$7EF9</$'C

- \%#$*8$%.'/ &$% VO$L8%<9%$EF'.'/ 6N% &$' P$7-'<'AK$%$*EF 6N% L-5O9$e$%$ +$-5$8%*$'J

- Y.%EF6NF%.'/ &$% VO$L8%<9%$EF'.'/ 6N% &$' P$7-'<'AK$%$*EF 5*8]ZDU .'& T$%$EF'.'/ &$% /$#*EF8$8$'].98*/%.OO$'&<8$' *5 P$7-'<'AK$%$*EF 5*88$97 &*$7$7 VO$L8%.57:

Y<5*8 #B%$ &*$ Y.%EF6NF%.'/ 0-' /$'<.$' T$%$EF'.'/$' 5*88$97 K$#BF%8$%].98*/%.OO$'2]-'8$2Z<%9-2U%-/%<55$.'& &8%5*'*78*7EF$% G%<'7O-%8O%-/%<55$ /$#BF%9$*78$8:

4.1.3 Sensitivitätsanalysen für die nuklearen Basisdaten

DK' &$% D<EF%$EF'.'/ 0-' \eO$%*5$'8$'J &*$ ^.67EF9.77 NK$% &*$ +$'<.*/L$*8 &$7 T$%$EF'.'/70$%6<F%$'7 .'& &$% '.L9$<%$' Y<8$' /$K$'J #$%&$' 5$F% .'& 5$F% V$'7*8*O*8B87<'<9_7$' &.%EF/$6NF%8J .5 &$' *'69.77 &$% ''/$'<.*/L$*8$' *' &$' '.L9$<%$' Y<8$' <.6 &*$ A.K$%$EF'$'&$' \%/$K'*77$<KA.7EFB8A$':

Y<A.7*'& V$'7*8*O*8B87%$EF'.'/$' &.%EFA.6NF%$'J 5*88$97 #$9EF$% &$% *'69.77 0-' &*66$%$'8*99' Y<8$'.'/$'<.*/L$*8$' <.6 &*$ A. K$78*55$'&$' U<%<5$8$% SV$'7*8*O*8B87L-$66*A*$'8$'X K$7EF%*K' #$%&$' L<'': Y$% V$'7*8*O*8B87L-$66*A*$'8 K$7EF%$*K8 &*$ %$9<8*0$ ś&$%.'/ &$% P$<L8*-'7%<8$ PJ K$A-/$' <.6 &*$ %$9<8*0$ ś&$%.'/ &$7 5*L% -7L-O*7EF$' b*%L.'/7p$%7EF'*887 &$% ($%'%$<L8*-' x*' &$% \'$%/*$/%.OO$ /:

Y*$ ''7*EF$%F$*8 &$% A.K$%EF''&$' P$<L8*-'7%<8$ P 6N% ^K7-%O8*-' -&$% VO<98.'/ KA#: &$7].98*O9*L<8*-'76<L8-%7 L<'' 5*88$97 &$% V$'7*0*8B872 .'& (-0<%*<'A2 (-$66*A*$'8$' K$78*558 #$%&$': Y*$ (-0<%*<'AL-$66*A*$'8$' K$7EF%$*K$' &*$ Y<8$'.'7*EF$%F$*8 $*'$7 b*%L.'/7p$%7EF'*887 6N% &*$ P$<L8*-' x .'& \'$%/*$/%.OO$ /*' ^KFB'/*/L$*8 0-' $*'$% <'&$%$' P$<L8*-' k.'& \'$%/*$/%.OO$ /| k([Y21k:

Y<7 \%78$99$' &$7 V$'7*8*O*8B87O%-6*97 .'& &*$ T$%$EF'.'/ &$% ''7*EF$%F$*8$' $%6-%&$%' *' &$% P$/$9 &*$ M)7.'/ &$% 1Y2@Y2G%<'7O-%8/9$*EF.'/: Y*$ \%78$99.'/ $*'$7 V$'7*8*O*8B87O%-6*97 #N%&$ $*'$ /%-,$ a<F9 0-' *'A$99)7.'/$' 5*8 0<%**$%8$' o$%7EF'*88$' &$% P$<L8*-' x*' +%.OO$ / S*' &$% P$/$9 #$%&$' &*$ V$'7* 2 8*O*8B87%$EF'.'/$' 6N% $*'$ '*EF8 A.6$*'$ \'$%/*$/%.OO$'$*'8$*9.'/ &.%EF/$6NF%8X $%6-%&$%': '5 &*$7 A..5/$F$'J K$&*$'8 5<' 7*EF &$% 7-/: V8)%.'/78F$-%*$J &*$ <.6 &$% M)7.'/ &$% G%<'7O-%8/9$*EF.'/ .'& *F%$% <&h.'/*$%8$' R-%5 K<7*$%8: Y*$7$ M)7.'/$' L)''$' 5*8 &8%5*'*78*7EF$' G%<'7O-%8 SV_D2U%-/%<55$X -&$% 5*8]-'8$2

Z<%9-2I$%6<F%$' SA: T: 5*8 Z-%%$9<8$& V<5O9*'/ V8)%.'/$' $%78$% .'& A#$*8$% [%&'.'/X K$78*558 #$%&$': Y*$ I$%<%K$*8.'/ &$% M)7.'/$' A. V$'7*8*0*8B87O%-6*9$' .'& &$% T$%$EF'.'/$' &$% ''7*EF$%F$*8$' L)''$' A: T: 5*8 6-9/$'&$' Z-&$7 &.%EF/$6NF%8 #$%&$'C

- V'VY@Y S12@Y V_D M)7.'/$'J T$%$EF'.'/ 0-' V$'7*8*0*8B87O%-6*9$' .'& ''7*EF$%F$*8$'Xk([Y23kJ
- GV'D^]WSVZ^M\2=XJ1Y2V_DJ@Y]-'8$ Z<%9-kTP[kJ
-]ZDUIZ S&*66$%$'8*<9 -O$%<8-%O$%8.%K<8*-'7 5$8F-&XkP\^k:

(-0<%*<'A2Y<8$' #$%&$' &$%A$*8 6N% #*EF8*/$ D.L9*&$ K$* <99$' '$.$%$' Y<8$'$0<9.<8*-'$' \DYRkT2IJf\RR2@:>J \DYRkT2IW:hf\DYM 2@:@ 5*8<'/$/$K$': V*$ L)''$' <.7]$77.'/$' .'& P$EF'.'/$' 5*8 ($%'5-&99' K$78*558 #$%&$': W''$%F<9K &$% $0<9.*$%8$' D.L9$<%&<8$*$' #$%&$' 7*$ *' 6$78/$9$/8$' R-%5<8$' <K/$7O$*EF$%8 .'& L)''$' 5*8 &$' I$%<%K$*8.'/7E-&$7 SA: T: Df[jJ \PP[P2fX 0$%<%K$*8$8 #$%&$': G$*9#$*7$ 7*'& h$&-EF '-EF $%F$K9*EF$ I$%K$77$%.'/$' .'& Y<8$'6-%5<82\%#$*8$%.'/$' $%6-%&$%9*EFJ .5 &*$ (-0<%*<'A2Y<8$' .56<77$'& A.% V$'7*8*0*8B87<'<9_7$ $*'7$8A$' A. L)''$':

4.1.4 Weiterverarbeitung der nuklearen Daten für Brennelement- und Kernberechnungen

RN% &*$ Y.%EF6NF%.'/ 0-' T%$''$9$5$'82 .'& ($%'K$%$EF'.'/$' *78 $*'$ b$*8$%0$%<%K$*8.'/ &$% T<7*7&<8$' $%6-%&$%9*EF: Y*7 $%6-9/8 6N% V8<'&<%&2M b P2 T$%$EF'.'/$' &.%EF &*$ \%78$99.'/ 0-'].98*/%.OO$'&<8$'K*K9*-8F$L$'J &*$ *'7K$7-'&$%$ &.%EF &*$ ^'A<F9 &$% \'$%/*$/%.OO$' .'& &$' '56<'/ &$% D.L9*&$ EF<%<L8$%*7*$%8 7*'&: R<997 .'8$%7EF*$&9*EF$ P$<L8-%<'-%&'.'/$' 5*8 0<%*<K9$5 \'$%/*$7O$L8%.5J #*$ A: T: 7EF'99 P$<L8-%7_78$55$-&$% F-EF L-'0$%8*$%$'&$ M b P 5*8][x*'7<8AJ K$%$EF'$8 #$%&$' 7-99$'J 7*'& 7O$A*99$ I$%<%K$*8.'/77_78$55$ $%6-%&$%9*EF:

^' &$% T$%$*878$99.'/ 0-' '.L9$<%$' Y<8$' #*%&*' Y$.87EF9<'& 7$*8 9<'/$5 /$<%K$*8$8: a.'BEF78 #.%&$' +%.OO$'L-'78<'8$'2T*K9*-8FL' .'& PEF'O%-/%<555$ 6N% VEF'99 P$<L8-%$' $'8#*EL$98: ^5 ^'6<'/ <.7/F'& 0-' $*'$% $*/$'$' T<7*7K*K9*-8F$L S(\Y^(XJ 7OB8$% .'8$% I$%#$'&.'/ &$% *'8$%'<8*-'<9$' Y<8$'6*9$7

\DYRkTJ f\RSRX .'& f\DYM #.%&$' 5$F%$%$ +%.OO$'L-'78<'8$'2T*K9*-8FL' K$%$*8/$78$998: a.'BEF78 #.%&$' T*K9*-8F$L$' 5*8 &$% 3m2+%.OO$'78%.L8.% &$7 %.77*7EF$' ^TD2V<8A$7J #*$ A:T: &$% (R(WDP2V<8A k(W\kJ .'& &<7 A./$F)%*/$ PEF'O%-/%<55 +P'Z^M kb[Mk $'8#*EL$98: W5 P<F5$' &$% ^%K$*8$' 6N% F-EFL-'0$%8*$%$'&$ MbP 5*8][xT%$''78-66 #.%&$' T*K9*-8FL' 5*8 &$% bW]V 2dh2 \'$%/*$/%.OO$'2V8%.L8.% K$%$*8/$78$998 .'& &<7 U%-/%<55 +P'Z^M 6N% ^.6#B%8778%$..'/ $%#$*8$%8: Y<K$* #.%&$ *5 P<F5$' &$7 5-&.9<%$' U%-/%<557_78$57 (^UP[V &<7 PEF'O%-/%<55 (^PT'V $'8#*EL$98J &<7 <.7/F'& 0-' &*7' T*K9*-8FL' .'& .'8$% I$%#$'&./' &$7 U%-/%<557 +P'Z^M P$<L8-%7_78$5$ 5*8 8F$%5*7EF$'J $O*8F$%5*7EF$' .'& 7EF'$99$' \'$%/*$7O$L8%$' <&Bp<8 K$7EF%$*K$' L<'':W' $*'$% 7O$A*$99$' T*K9*-8F$L 70$%7*-' 7*'& '$K$' D$.8%-'$'#*%L.'/7p$%7EF'*88$'<.EF +<55< 2Y<8$' 0$%6N/K<%J &*$*' $*'$% 7O$A*$99$' ^'#$'&.'/ &$7 G%<'7O-%8O%-/%<557 Y^DGVjV kRWVk 0$%#$'&$8 #$%&$' L)''$': c$.8$ #$%&$' &*7 I$%6<F%$' 5*8 (^UP[Vk(^PT'V #$*8$% $'8#*EL$98 .'& <'/$#<'&8: a.7B8A9*EF A. &$' K$%$*87 0<9*&*$%8$' PEF'0$%6<F%$' 6N% YbPJ RYbP .'& VTP 7*'& U%-A$&.%$' 0-%F<'&$' 6N% &*$ T$%$EF'./ 0-' YbP 5*8 (NF9./ &.%EF b<77$% K$* 7.O$%L%*8*7EF$' 8F$%5-&_'<5*7EF$' T$&*'/.'/$' .'& 0-' K$7EF9$.'*/$%/$8%*K'$' ^'9</$' 5*8 T9$*2 .'& T9$*kb*75.82(NF9./:a.%A$*8 #$%&$' T*K9*-8F$L$' 6N% &*$ 7O$A*$99$' ^'6-%&$%.'/$' &$7 GPW+^ T%$''78-667 *5 U%-h$L8 GP^Y\ $'8#*EL$98 S^.6#B%8778%$..'/ &.%EF &*$ T*'&.'/ 0-' b<77$%78-66 *' a*%E-'*.5F_&%*&:W' &$% <L8.$99$' ^%K$*87.5/$K.'/ <.6 $*'$5 9$*78.'/76BF*/$' MWD'x Z9.78$% 7*'& '$K$' &$' .%7O%N'/9*EF$' 3m2+%.OO$'2T*K9*-8FL' (R(WDP .'& (R(WDP3 p<9*6*A*$%8$ Y<8$'K* K9*-8F$L$' 5*8 &$% dh2+%.OO$' V8%.L8.% <.7 bW]VJ K<7*$%$'& <.6 f\R3:3J f\RR@:> .'& \DYRkT2IW:=J 0$%6N/K<% .'& %-.8*'$5B,*/ *5 *'7<8A: RN% R$*'/.OO$'2VO$L8%<9%$EF'.'/$' 7*'& @@I2+%.OO$'2T*K9*-8FL' K<7*$%$'& <.6 \DYRkT2IW .'& f\R3:3 0$%6N/K<%: RN% G%<'7*$'8$'%$EF'.'/$' 7*'& &*$7$].98*/%.OO$'78%.L8.%$' 5*8 3mk*7 @@I +%.OO$' -68 '-EF A. %EF'*'8$'7*0: RN% &*7 RB99$ $%5)/9*EF8 &<7 (^UP[V2]-&.9 Z[MMWT 5*8 c*96$ 0-' %$O%B7$'8<8*0$' b*EF8.'/77O$L8%$' &*$ \%A$./.'/ 0-' 7_78$5<KFB'/*/$' b$'*//%.OO$'2T*K9*-8F$L$' 5*8 &$' /9$*EF$' V8%.L8.%$' #*$ &*$ ^.7/<'/7K*K9*-8FL': Y*$7$7 I$%6<F%$' L-''8$ $%6-9/%$*EF <'/$#<'&8 #$%&$' 6N% /$L-OO98 D$.8%-'$'OF_7*LkGF$%5-F_&%<.9*L P$EF'./$' 6N% &*$ 78<8*7EF$ ^.79$/.'/ 0-' cUMbP ($%'$ 5*8 &$% (^UP[V U%-A$&.% P=UP[Z kTP[2Ik .'& 6N% G%<'7*$'8$' ''8$%7.EF.'/$' 6N% $*'$' T9$*kb*75.8 /$LNF98$' ^YV kY^+k: b$*8$%$ *'A$9F$*8$' L)''$' *' kTP[21kJ kTP[23k /$6.'&$' #$%&$':

]*8 c*%6$ 0-' SZ!UXJ $*'$5 ZZZZ].98*/%.OO$'2Y<8$'2U%-E$77*'/7_78$5 #*%& &*$ b*%L.'/7p$%7EF'*887/$'$%*$%.'/ &.%EF/$6NF%8: Y<7 Y<8$'6- %5<8 ZZZZ #.%&$ 0-5 Z-55*88$$ -6 Z-50.8$% Z-&$ Z--%&*'<8*-' &$6*'*$%8:

Y*$ D.L9$<%&<8$' #$%&$' &<K$* $'8#$&$% 0-' $*'$% $%#$*8$%8$' Df[j2I$%7*-' -&$% NK$% $*'$']-&.9 &$7 Z-&$2V_78$57 \P^D[V $%78$998: ^97 ^.7/<'/7K<7*7 &*$'$' &*$ T*K9*-8FL' \DYRkT2IW:iJ f\R23:3J f\RR2@:>J f\DYM2@:3 7-#*$ f\DYM2@:@: f$&$ &$% T*K9*-8F$L$' K$*'F<98$8 $8#< @@> D.L9*&$ *5 $%#$*8$%8$' ZZZZ2 R-%5<8 ST$%NEL7*EF8*/.'/ &$% 8F$%5*7EF$' D$.8%-'$'78%$..'/X: Y*$ Y<8$' #$%&$' *5 A.$%78 /$'<''8$' I$%6<F%$' A. $*'$%]<78$%K*K9*-8F$L 0-' =I= \'$%/*$/%.OO$' S‘'8$%K*K9*-8F$L $*'$7 1dmn+%.OO$'7<8A$7X 5*8 d G$5O$%<8.%78N8AO.'L8$' S@>> K*7 mm>> (XJ 1m‘'8$%/%.'&p$%7EF'*88$' 7-#*$ K*7 A. mb*'L$95-5$'8$' 0$%<%K$*8$8: Y*7 [O8*-' K*$8$8 &*$])/9*EFL$*8 &$% I<9*&*$%.'/ &8%5*'*78*7EF$%]$8F-&$' &.%EF 5*8]-'8$2Z<%9- I$%6<F%$' $%A*$98$ \%/$K'*77$J &*$ <.6 &$'7$9K$' '.L9$<%$' Y<8$' K<7*$%$':

T$* &$% A#$*8$' [O8*-' #*%& &*$ \P^MWT T*K9*-8F$L*5 Z-&$7_78$5 \P^D[V K$'.8A8J &*$ 1dmn+%.OO$' 6N% #*EF8*/$ D.L9*&$ S‘J U. W7-8-O$X .'& 1dn +%.OO$' 6N% &*$ NK%*/$' D.L9*&$ $'8FB98: Y$% 1dn 2+%.OO$'7<8A *78 &<K$* $*' ‘'8$%/%.OO$'7<8A &$% 1dmn2 KA#: =I=2VB8A$: Y*$ 1dmn2+%.OO$'7B8A$ #$%&$' #$/$' *F%$% +%),$ '.% 6N% 7O$A*$99$ T$'EF5<%L<'<9_7$' $*'/$7$8A8: Y<'$K$' 78$F8 '-EF $*' 112+%.OO$'7<8A SZZZZ R-%5<8J K<7*$%$'&<.6 &$5 (R(WDP2+%.OO$'7<8AX A.% I$%6N/.'/:

Y*$ 1dn 2+%.OO$'78%.L8.%*78 &*$ P6%$'A78%.L8.% &$7 L-55$%A*$99$' bW]V2V_78$57J &<7 *' +%-,K%*8<''*$' $'8#*EL$98 #*%&: 98$%$ I$%7*-'$' K$7EF%B'L8$' 7*EF <.6 dh +%.OO$': Y<7 6%<'A)7*7EF$ ^U[MM[2V_78$5 /%$*68 K'7- <.6 1dn +%.OO$' A.%NEL: Y*$ 6N% &$' MbP2T$%$*EF <.7%$*EF$'&$ +%.OO$'A<F9 5.77 6N% <'&$%$ ^'6-%&$%.'/$' $%#$*8$%8 #$%&$':

Y$% =I=2+%.OO$'7<8A *78 $*'$ ‘'8$%5$'/$ &$7 1dmn2+%.OO$'7<8A$7: a<F9%$*EF$ T$'EF5<%L<'<9_7$' A$*/$'J &<77 5*8 c*%6$ &*$7$7 +%.OO$'7<8A$7 A#*7EF$' &$8$%5*'*78*7EF$' .'& 5*8]-'8$2Z<%9-]$8F-&$' SU.'L8&<8$'X /$#-''$'$' \%/$K'*77$' $*'$ 7$F% /.8$ HK$%$*'78*55.'/ $%A*$98 #$%&$' L<'': Y$% 112 +%.OO$'7<8A *78 &<K$* K$/%$'A8 <.6 &*$ ^'#$'&.'/ K$* P$<L8-%$' 5*8 7EF'$99$5 D$.8%-'$'7O$L8%.5:

Y*$ PEF'A$*8$' .'& &$% VO$*EF$%K$&<%6 6N% &8%5*'*78*7EF$ ^'<9_7$' 7*'& K$* T$'.8A.'/ &$% I*$9/%.OO$'K*K9*-8FL' 7$F% F-EF:]*8 c*96$ &$7 Z'U V_78$57 L)''$' &<F$% 6N% &*$ 0$%7EF*$&$'$' ^'#$'&.'/7A#$EL$J A: T: 6N% G%<'7*$'8$'E-&$7J b$'*/2 /%.OO$'K*K9*-8FL' $%78$998 #$%&$': Y<6N% #*%& A.$%78 $*' 6N% &$' h$#$*9*/$' R<99 %$9$0<'8$7 R$*'/%.OO$'7O$L8%.5 K$%EF'8:]*8 &*$7$5 #*%& &<'' $*' 6N% &*$ 7O$A*$99$ ^'#$'&.'/ A./$7EF'*88$'$% b$'*//%.OO$'7<8A SA: T: @> +%.OO$'X $%78$998:]*8 c*96$ &$% $e8$'&$& O%-K<K*9*8_ 8<K9 $}]$8F-&$ L)''$' ZZZZ 2Y<8$' 6N% W7-8-O$'2 5*7EF.'/$' /$'$%*$%8 #$%&$'J #<7 A. $*'$% P$&.L9*-' &$% A. K$%$EF'$'&$' D.L9*&$ 6NF%8:

Y*$ *5 *'7<8A K$6*'&9*EF$' G%<'7O-%8E-&$7 Y^DGVjV kY^Dk .'& I^PW^DGk(WD@Y kP^Tk L)''$' <.6 Z'U A./%$*6$': V- L)''$' A: T: a$99%$EF'.'/$' 5*8 Y^DGVjV 6N% $*' MbP2V_78$5 &.%EF/$6NF%8 #$%&$' -&$% A$*8<KFB'/*/$ &%$*&*5$'7*-'<9$ G%<'7O-%8%$EF'.'/$' 5*8 I^PW^DGk(WD@Y: \K$'7- L)''$' 6N% &<7 ^KK%<'&O%-/%<55 ([PW+\D kbW\k &*$ '-8#$'&*/$' *'/%.OO$'p$%7EF'*88$ -&$% b*%L.'/7 2 p$%7EF'*887K* K9*-8FL' 6N% &<7 VW]]\P2WWWkVW]]\P2WI V8)%6<992Z-&$2V_78$5 k]^Vk $%78$998 #$%&$':

4.1.5 Anforderungen für ADS-Systeme

W' K$7EF9$.'*/$%/$8%*K'$' .'8$%L%*8*7EF$' ^'9</$' S^YVX A.% I$%'*EF8.'/ 0-' 9<'/9$K*/$' W7-8-O$' *5 '.L9$<%$' ^K6<99 8%8' D$.8%-'$' 5*8 7$F% 0*$9 F)F$%$' \'$%/*$' <97*' VO<98%$<L8-%$' <.6: Y*$ OF_7*L<9*7EF$' U%-A$77$ K$* F)F$%$' \'$%/*$' *' $*'$5 ^YV #$%&$' 5*8]-'8$2Z<%9-2U%-/%<55$' K$F<'&$98: a.'BEF78 #.%&$' &<A. 7O$A*99 c-EF$'$%/*$2Z-&$7 #*$ c\GZ .'& M^c\G 5*8 &$5 V8<'&<%&]-'8$ Z<%9-U%-/%<55]ZDU -&$% 5*8].98*2+%.OO$' I$%6<F%$' 6N% VO<98%$<L8-%$' /$L-OO$98: Y<7 &$%A$*8 5$*78<'/$#<'&8$ U%-/%<55 6N% ^YV P$EF'.'/$' *78 &<7 <.7 &$% (-OO9.'/ 0-' M^c\G .'&]ZDU $'878<'&$'$ U%-/%<55]ZDUx I-% <99$5 *5 c*'K9*EL <.6 &$8<*99*$%8$ M<'/A$*.'8$%7.EF.'/$' *78 $*'$ \%#$*8$%.'/ &$% dh+%.OO$' T*K9*-8F$L <.6 m +%.OO$' 5*8 \'$%/*$' K*7 1=>]$I*' \'8#*EL9.'/k [T\k:

4.1.6 Zusammenfassung zum Forschungsbereich „Nukleare Basisdatenbibiotheken“

Y*$ '.L9$<%$' Y<8$'K<7$' 6N% '.L9$<%$ T$%$EF'.'/$' #$*7$' K$%$*87 $*'$' F-F$' V8<'&<%& <.6: Y<77$9K$ /*98 6N% &<7 ($%'&<8$'2U%-E$77*'/ .'& &*$ T$%$EF'.'/72

5$8F-&$': b$*8$%$'8#*EL9.'/$' .'& I$%K$77$%.'/$' 7*'& $%6-%&$%9*EF <.6 &$' +$K*8'C

- Y<8$'$0<9.*$%.'/ .'& I$%*6*L<8*-' 0-' ^L8*'*&$' -K$%F<9K 0-' U9.8-'*.5J
- (-0<%*<'A&<8$' 6N% #*EF8*/$ D.L9*&$J
-]$8F-&$' A.% T$%$*878$99.'/ 66L8*0$% b*%L.'/7p$%7EF'*88$ 6N% &8% 2 5*'*78*7EF$ G%<'7O-%8%$EF'.'/$' 6N% L-5O9e ^'-%&'.'/$'J
- \66$L8*0$ ^'#$'&.'/$' .'& I<9*&*$%.'/7%$EF'.'/$' 6N%]-'8$2Z<%9- .'& &8%5*'*78*7EF$ G%<'7O-%8E-&$7:

Y*$ <.7 *'8$%'<8*-'<9$' U%-h$L8$' K$%$*8/$78$998$' \%/$K'*77$ A.% \0<9.*$%.'/$' .'& '$.$]$77#$%8$ *'7K$7-'&$%$ &$% ^L8*'*&$' -K$%F<9K 0-' U9.8-'*.5 7-998$' A. I<9*&*$%.'/ &$% 6N% 7*EF$%F$*87%$9$0<'8$ T$%$EF'.'/$' $*'/$7$8A8$']$8F-&$' .'& Y<8$'K<7$' 0$%#$'&$8 #$%&$':

R$%'$% 7-998$ &.%EF <L8*0$]*8<%K$*8 *' &$' \0<9.*$%.'/7/%.OO$' $*' *'8$'7*0$% \%6<F%.'/7<.78<.7EF /$O69$/8 #$%&$'J .5 //6: NK$% R-%7EF.'/7O%-/%<55$ A.% I$%K$77$%.'/ &$% Y<8$' 6N% A.LN'68*/$ ^.6/<K$'78$99.'/$' 5*8K$78*55$' A. L)''$':

4.2 Reaktivitäts- und Nuklidinventarberechnungen

W' &$% $'8#*EL$98$' V8<'&<%&5$8F-&*L 6N% '.L9$<%$ T$%$EF'.'/$' 78$99$' &*$ T%$''$9$5$'8K$%$EF'.'/$' &$' HK$%/<'/ 0-' &$']$F%/%.OO$'&<8$'K*K9*-8F$L$' A. &$' ($%'K$%$EF'.'/$' &<%: Y*$ T%$''$9$5$'8K$%$EF'.'/$' &*$'$' A.% P$<L8*0*8B872 .'& D.L9*&*'0$'8<%K$%$EF'.'/ 7-#*$ A.% T$%$*878$99.'/ 0-' b$'*//%.OO$'&<8$' 6N% &*$ ($%'K$%$EF'.'/$'J 6N% MbP *: ^99/: 0-' A#$* \'$%/*$/%.OO$': W5 *'7<8A F*$%6N% 7*'& L-55$%A*99 Z-&$7 #*$ Z^V] [-&$% c\MW[V 7-#*$ b$*8$%$'8#*EL9.'/$'J*' &$'$']-'8$ Z<%9- Z-&$7 #*$ (\D[-&$%]ZDU 5*8 &$8<*99*$%8$' ^KK%<'&5-&99' /$L-OO$98 #.%&$': Y$% V8<'& &$% 0$%6N/K<%$' P$EF$'5-&$99$ #*%& '<EF6-9/$'& K$7EF%*K':

4.2.1 CASMO

Z^V] [2 l kVG ‘ k *78 $*’ A#$*&*5$’7*-’<9$7] .98*/%.OO$’2U%-/%<5 5 A.% M)7.’/ &$% D$.8%-’$’8%<’7O-%8/9$*EF.’/ .’& A.% Y.%EF6NF%.’/ 0-’ ^KK%<’&%$EF’.’/$’ 6N% Y b P2 .’& V b P2TN’&$9 7-#*$ 6N% $*’A$9’$ T%$’’78<KA$99$’: Y$% Z-&$ K$F<’&$98 +$-5$8%*$’ <.7 A_9*’&%*7EF$’ T%$’’78<KA$99$’J &*$ <KK%$’’K<%$ ^K7-%K$%J b<77$%78BK$ KA#: b<77$%L<’B9$.’& ^K7-%K$%$9$5$’8$ 6N% Y b P2 -&$% V b P2TN’&$9 $’8F<98$’ L)’’$’: ^.6 &$% T<7*7 0-’ ’.L9$<%$’ Y<8$’K*K9*-8F$L$’ 5*8 l> KA#: ɒ \’$%/*$/%.OO$’ K$%$EF’$8 &<7 U%-/%<5 5 5<L%-7L-O*7EF$ b*%L.’/7p$%7EF’*88$.’& Y*7L-’8*’.*8B876<L8-%$’ *’ A#$* \’$%/*$/%.OO$’ A.% b$*8$%0$%#$’&.’/ *’ U%-/%<5 5$’ A.% ’.L9$<%$’ ($%’<.79$/.’/:

Y<A. #$%&$’ A.’BEF78 &*$ 66L8*0$’ b*%L.’/7p$%7EF’*88$ *5 P$7-’<’AK$%$*EF 5*8 $*’$5 ɒ*0<9$’A8F$-%$5 K$%$EF’$8J &<7 8<K$99*$%8$ 66L8*0$ P$7-’<’A*’8$/%<9$ 6N% h$&$’ P$7-’<’A<K7-%K$% *’ h$&$% P$7-’<’A/%.OO$ &$5 0-%9*$/$’&$’ F8%-/$’$’ U%-K9$5 A.-%&’$8: Y*$ /$/$’7$*8*/$ ^K7EF*%5.’/ 0-’ T%$’’78BK$’ #*%& &.%EF 0-’ Z^V] [2 l K$%$EF’8 Y<’E-662R<L8-%$’ K$%NEL7*EF8*/8:

^97 P$7-’<’AK$%$*EF *78 &$% \’$%/*$K$%$*EF A#*7EF$’ l $l .’& d11i $l &$6*’*$%8: Y*$ 12$l?P$7-’<’A*’ 3l>U. 7-#*$ #$*8$%$ P$7-’<’A$’ *5 D*$&%*/$’$%/*$2T$%$*EF #$%&$’ &.%EF /$$*/’8 (-’A$’8%<8*-’ 0-’ 8F$%5*7EF$’ \’$%/*$/%.OO$’ *’ &$% ‘5/$K.’/ &*7% P$7-’<’A$’ <K/$&$EL8 .’& &<F$% 0-’ &$% 7O$A*$99$’ P$7-’<’AK$F<’&9.’/ <.7/$7EF9-77$’:

W’ $*’$% P$*F$ 0-’]*L%-/%.OO$’2P$EF’.’/$’ #$%&$’ 6N% h$&$’ T%$’’78<K8_O *5 TN’&$9 *’&*0*&.$99$ D$.8%-’$’7O$L8%$’ A.% (-’&$’7<8*-’ .’& c-5-/$’*7*$%.’/ &$% b*%L.’/7p$%7EF’*88$ $%5*88$98: RN% ^K7-%K$%78BK$ #$%&$’ &<A. NK9*EF$%#$*7$ A$F’ P*’/A-’$’ <’/$’-55$’J &*$ 0-’ $*’$% (NF95*88$9A-’$.’& $*’$% &*$ K$’<EFK<%8$’ T%$’’78BK$ $’8F<98$’&$’ U.66$%A-’$ .5/K’ 7*’&:]*8 &$’ &$%<%8 F-5-/$’*7*$%8$’ T%$’’78<KA99’ #*%& 6N% &<7 /$7<58$ TN’&$9 $*’$ 3Y2]<L%-/%.OO$’%$EF’.’/ *’ 8_O*7EF$%#$*7$ l> \’$%/*$/%.OO$’ &.%EF/$6NF%8:

Y*$ &<K$* $%F<98$’$’ \%/$K’*77$ #$%&$’ 6N% &*$ 3Y2G%<’7O-%8%$EF’.’/ 0$%#$’&$8J &*$ <.6 &$%]$8F-&$ &$% ZF<%<L8$%*78*L$’ K$%.F8 .’&*’ NK9*EF$%#$*7$ i D$.8%-’$’/%.OO$’ &.%EF/$6NF%8 #*%&: V*$ 9*6%8 &$’ */$’#$%8 .’& &*$ D$.8%-’$’69.770$%8$*9.’/ 6N% &*$.’8$%7.EF8$ ^’-%&’.’/: *’$ <K7EF9*$,$’&$!6.’&<5$’8<9 5-&$;?P$EF’.’/ &*$’8 &$% T$%NEL7*EF8*/.’/ 0-’ M$EL</$2\66$L8$’:

Y*$ D.L9*&L-'A$'8%<8*-'$' <97 R.'L8*-' &$7 ^KK%<'&$7 #$%&$' 6N% h$&$' T%$''78<K KA#: K$* <KK%$''K<%$' ^K7-%K$%' 6N% h$&$ T%$''78-66%*'/A-'$ K$%$EF'$8: a.% ^KK%<'&K$%$EF'.'/ #*%& $*'$ U%B&*L8-%2(-%%$L8-%2]$8F-&$ 0$%#$'&$8J &:F: &*$ D.L9*&L-'A$'8%<8*-'$' #$%&$' A#$*5<9 K$%EF'8C A.'BEF78 5*8 &$5 A. T$/*'' $*'$7 ^KK%<'&7EF%*88$7 0-%F<'&$'$' D$.8%-'$'7O$L8%.5J &<'<EF 5*8 &$5 VO$L8%.5 <5 \'&$ &$7 ^KK%<'&7EF%*88$7: ^.7 K$*&$' PEF'7EF%*88$' #$%&$' &*$ 5*889$%$' G$*9EF$'A<F9&*EF8$' #$*8$%0$%#$'&$8:

Z^V][2I $'8FB98 $*']-&.9 A.% T$%$EF'.'/ O%-5O8$% .'& 0$%A)/$%8$% +<55<2 o$99$' .'& A.% M)7.'/ &$7 +<55< 2G%<'7O-%8O%-K9$57*' 1i +<55</%.OO$': Y<5*8 L)''$' V*/'<9$0-' +<55<2$5O6*'&9*EF$' Y8L8-%$' $%5*88$98 #$%&$':

Y*$ 78<'&<%&5B,*/ 0$%#$'&8 '.L9$<%$ Y<8$'K*K9*-8F$L K<7*$%8 <.6 \DYRkT2WI: ^.7 \DYRkT2I 78<55$' Y<8$' 6N% ^/J +&J \% .'& G5 7-#*$ &*$ VO<98<.7K$.8$' 6N% 1@=$.'& &*$ VO<9870$L8%$' 6N% 3@=‘ .'& 3@dU.: Y<8$' 6N% 3l1U. 7*'& f\DYM23 $'8'-55$': P$7-'<'A&<8$' 6N% +&2W7-8-O$.'& 3@m‘ K<7*$%$' <.6 f\R23:1:

Y*$ Y<8$' 6N% &*$ +<55<2G%<'7O-%8%$EF'.'/ 78<55$' <.7 &$% ZM[V\‘U T*K9*-8F$L &$7 P$'77$99<$% U-9_8$EF'*EW'78*8.8$J &*$ *F%$%7$*87 <.6 \DYRkT2WI2Y<8$' A.%NEL/$F8:

a.% I<9*&*$%.'/ &$7 U%-/%<557 #$%&$' 0-% <99$5 I$%/9$*EF$ 0-' L%*8*7EF$' */$'#$%8$'J VO<98%<8$'0$%8$*9.'/$' .'&W7-8-O$'L-'A$'8%<8*-'$' 0-%/$'-55$': a.5 I$%/9$*EF #$%&$' A:T: L%*8*7EF$ \eO$%*5$'8$ S(PWGaXJ]-'8$2Z<%9-2P$EF'.'/$' S]ZDUX .'&W7-8-O$'<'<9_7$' S^PW^D\XF$%<'/$A-/$' SO/9:k]WVkX:

W' R-%87$8A.'/ &$7 ^PW^D\2U%-/%<55$7 9<.6$' &$%A$*8 &*$ U%-/%<55$ +\P[DW][Sded VbP2][x2T%$''78-66 K*7 E<: n]b&kL/X .'& G[U 2+‘D S\%#$*8$%.'/ 0-' +\P[DW][<.6 ^KK%B'&$K*7E<: i>]b&kL/X:

4.2.2 HELIOS

c\MW[V*78 $*' a$992 .'& ^KK%<'&O%-/%<557_78$5J &<7 0-' &$% R*%5<VE<'&O-#$% A.% T$%$EF'.'/ 0-' b$'*//%.OO$'2Y<8$' 6N% P$<L8-%2T%$''$9$5$'8$ $'8#*EL$98 #.%&$: c\MW[V 9)78 &*$ I*$9/%.OO$'2D$.8%-'$'2 KA#: +<55<2G%<'7O-%82+9$*EF.'/ *' &$% *'8$/%<9$' S#*'L$9*'8$/%*$%8$'X R-%5: Y*$ /%.'&9$/$'&$ c\MW[V2($%'&<8$'K*K9*-8F$L Sc\MW[V2*'/<K$X K78F8 <.7 Y<8$' 6N% 1d> D$.8%-'$'2+%.OO$' .'& Ii +<55<2 +%.OO$': Y*$7$ Y<8$'K*K9*-8F$L K<7*$%8 0-%%<'/*/J <K$% '*EF8 <.77EF9*$,9*EFJ <.6 &$%

T*K9*-8F$L \DYRkT2IW S1dd>XJ *' &$% Y<8$' 6N% E<: 31>> D.L9*&$ $'8F<98$' 7*'&: Y*$ c\MW[V2($%'&<8$'K*K9*-8F$L #*%& *5 b$7$'89*EF$' 5*8 c*96$ &$% U%-/%<55$ Df[jJ P^TTM\ .'& c\T\ <.7 &$' T<7*72($%'&<8$' \DYRkT2IW $%A$./8: Df[j #*%& A.% T$%$EF'./ &$% \'$%/*$/%.OO$'2Y<8$' <.7 &$' 6N% \'$%/*$O.'L8$ 0-%9*$/$'&$' T<7*72 ($%'&<8$' 0$%#$'&$8: Y*$ T$%$EF'./ $%6-9/8 .'8$% &$% *&$<9*7*$%$'&$' ^''<F5$J &<77 &<7 K$8%$66$'&$ D.L9*& *' 7$F% L9$*'$% (-'A$'8%<8*-' S!.'$'&9*EF$ I$%&N''./;X *5]<8$%*<9 0-%9*$/8: Y*$ K$* %$<9$% D.L9*&L-'A$'8%<8*-' 0-%F<'&$'$ P$7-'<'A2 V$9K78<K7EF*%5./J #$9EF$ &*$ D$.8%-'$'L*'$8*L *5 P$<L8-% #7'89*EF K$$*'69.778J #*%& 5*8 &$5 U%-/%<55 P^TTM\ '<EF &$% V8-,#<F%7EF$*'9*EFL$*872]$8F-&$ 5-&$99*$%8:

W' c\MW[V #*%& &*$ 32&*5$'7*-'<9$ G%<'7O-%8/9$*EF./ *''$%F<9K 0-' P<.52 KA#: R9BEF$'2\9$5$'8$' 5*8 c*96$ &$% V8-,#<F%7EF$*'9*EFL$*872]$8F-&$ /$9)78: Y*$ P<.5$9$5$'8$ #$%&$' &.%EF &*$ 7-/$'<''8$ V8%-5L-OO9.'/ 5*8$*'<'&$% 0$%K.'&$': Y<K$* #*%& &$% D$.8%-'$'78%-5J &$% &.%EF $*' V$/5$'8 &$% P<.5$9$5$'8/%$'A$ 8%*88J <97 %B.59*EF L-'78<'8 <'/$'-55$': Y$% c<9K%<.5 6N% &*$ D$.8%-'$'%*EF8./ #*%& *' $*'$ ^'A<F9 0-' V$L8-%$' .'8$%8$*98J *' &$'$' &*$ b*'L$9<KFB'/*/L$*8 <97 L-'78<'8 <'/$'-55$' #*%& S!E-7*'$ E.%%$'8;X: Y*$7 *78 7$F% #-F9 $*'$ DBF$%./ A.% T$7EF%$*K./ &$% L-5O9*A*$%8$' I$%8$*9./ &$7 #*'L$9<KFB'/*/$' D$.8%-'$'69.77$7: Y*$ DBF$%./ *78 h$&-EF <.7%$*EF$'& A.% T$%$EF'./ 0-' b$'*/2+%.OO$'2Y<8$' 6N% P$<L8-%2T%$''$9$5$'8$*' .'$'&9*EF O$%*-&*7EF$% ^.7&$F'./:

T$*5 HK$%/<'/ A.''*EF825.98*O9*A*$%$'&$']$&*$'J &: F: <5 P<'& &$7 P$<L8-%L$%'$7 S%<&*<9$% P69L8-%X -&$% <' &$' II\P2II>27O$A*6*7EF$' V8$.$%$9$5$'8$'J *78 &*$ DBF$%./ &$% V8%-5L-OO9./ A. .'/$'<.: a.% T$%$EF'./ &$% b$'*//%.OO$'2 o$%7EF'*88$J $*'7EF9*$,9*EF Y*7L-'8*'.*8B876<L8-%$' 6N% &*$7$ P$<L8-%/$K*8 L<'' &<7 U%-/%<55]^PW([0$%#$'&$8 #$%&$':]^PW([K<7*$%8 <.6 &$% ZF<%<L8$%*78*L$'2]$8F-&$.'& 0$%5$*&$8 &*$ -: /: DBF$%.'/J -F'$ A. .'<LA$O8<K9$' PEF'A$*8$' A. 6NF%$'J #-K$* A: a: c\MW[V2/$'$%*$%8$ 3@2+%.OO$'&<8$' $*'/$/K' #$%&$':

T$AN/9*EF &$% +$-5$8%*$L-'A$O8*-'J &*$ 7*EF &.%EF F-F$ R9$e*K*9*8B8 <.7A$*EF'$8J *78 c\MW[V /.8 /$$*/'$8 6N% R-%7EF./7<%K$*8$' <.6 &$5 +$K*$8 LN'68*/$% ($%'%$<L8-%$'J #$'' a$99$' -&$% T%$''$9$5$'8$ K$%$EF'$8 #$%&$' 7-99$'J &*$ 7*EF *' *F%$% +$-5$8%*$ 0-' F$.8*/$' P$<L8-%$' .'8$%7EF$*&$': Y*$ R9$e*K*9*8B8 #*%& <99$%&*'/7 &.%EF $*'$' %$9<8*0 F-F$' ^.6#<'& K$* &$% *'/<K$ &$% +$-5$8%*$&<8$' $%L<.68:

4.2.3 KENOREST

Y<7 PEF'O%-/%<5 5 (\D[P\VG kc\Vk #.%&$ A.% T$%$EF'./ &$7 P$<L8*0*8B870$%F<98$'7 .'& &$7 D.L9*&*'0$'8<%$7 0-' p<&%<8*7EF$' .'& F$e</-'<9$' T%$''$9$5$'8$' $'8#*EL$98: \7 K78F8 <.7 &$% (-OO9./ &$7 @Y]-'8$ Z<%9-U%-/%<5 5$7 (\D[2I< KA#: (\D[2IW .'& &$5 1Y ^KK%<'&O%-/%<5 5 [P\VG: Y*$ 1Y ^KK%<'&%$EF'./ 6N% h$&$' $*'A$9'$' T%$''78<K #*%& &.%EF &*$!R9.e \p*0<9$'8 Z$99 SR\ZX;2]$8F-&$ <' &*$ \%/$K'*77$ &$% T%$''$9$5$'8%$EF'./ 5*8 (\D[<'/$O<778: Y<7 U%-/%<557_78$5 [P\VG #.%&$ NK$% 9<'/$ a$*8 <97 ^KK%<'&O%-/%<5 5 $*'/$7$8A8 .'& K$78$F8 <.7 &$5 1Y2VO$L8%<9E-&$ c^]]\P .'& &$5 ^KK%<'&5-&$99 [PW+\D: Y*$ i@ +%.OO$'K*K9*-8F$L$' 6N% &*$ (\D[T$%$EF'./$' #.%&$' 0-' &$% 3d3 +%.OO$'K*K9*-8F$L <.6 &$% T<7*7 0-' f\R 3:3 <K/9*8$8: Y*$ '.L9$<%$' Y<8$' *' [PW+\D #.%&$' 6N% &$' '$.78' Y<8$'78<'& <'/$O<778:

Y*$ I<9*&*$%./ $%6-9/8$ &.%EF D<EF%$EF'./ 0-' 0$%6N/K<%$']$77&<8$' 0-' D.L9*&*'0$'8<%$' .'& &$' I$%/9$*EF 5*8 A<F9%$*EF$' *'8$%'<8*-'<9$' T$'EF5<%LO%-K9$5$' 6N% T%$''$9$5$'8K$%$EF'./$' <.EF *5 a.7<55$'F<'/ 5*8 R%</$' A.5 T.%'2.O Z%$&*8:

Y<7 U%-/%<55 (\D[P\VG #*%& &$%A$*8 $%#$*8$%8 &.%EF &$' *'K<. $*'$7 %<&*<9$']$F%A-'$'5-&$997 6N% &<7 T%$''78-66O$99$8J .5 &*$ ^KK%<'&%$EF'./$' 6N% <KK%$''K<%$ +*68$.'& &*$ U9.8-'*.52 .'& ^L8*'*&$'O%-&.L8*-' 6N% F-F$ ^KK%B'&$ A.0$%K$77$%': ^.EF &*$ T*K9*-8FL' &$7 D.L9*&*'0$'8<%E-&$7 [PW+\D #$%&$' 6N% &*$ VO<98./ &$% ^L8*'*&$' .'& &*$ 0-9978B'&*/$ T$7EF%$*K./ &$% P$<L8*-'7L<'B9$ $%/B'A8:

4.2.4 KORIGEN und CALOR

([PW+\D kYWVkJ &$% <.6 &$% T<7*7 0-' [PW+\D $'8#*EL$98$ ^KK%<'&2 .'& a$%6<997E-&$J &*$'8 A.% I$%6-9/./ &$% D.L9*&0$%B'&$%.'/$' .'& &$% D$.8%-'$'5.98*O9*L<8*-' #BF%$'& &$7 P$<L8-%K$8%*$K7 .'& A.% ^'<9_7$ &$% '.L9$<%$' W'0$'8<%$S]<77$'JP<&*-<L8*0*8BJa$%6<9979$*78.'/JP<&*-8-e*A*8B8$'X7-#*$ ~2V8%<F9.'/J '2V8%<F9./ <.7 VO-'8<'7O<98./ .'& SJ'X 2P$<L8*-'$' *5 F-EF<L8*0$' ^K6<99:]*8 ^'7EF9.77O%-/%<55$' L<'' 5*8 ([PW+\D &$% 7*EF <LL.5.9*$%$'&$ D.L9$<%<K6<99 <.7 &$5 T$8%*$K 0-' M$*78.'/7%$<L8-%$' K$78*558 #$%&$': Y*$ /$/$'#B%8*/$ Y<8$'K<7*7 .56<778 &*$ 6-9/$'&$' OF_7*L<9*7EF$' +%),$'C D$.8%-'$'#*%L.'/7p$%7EF'*88$

K<7*$%$'& <.6 f\R 3:3 .'& \^RJ VO<98O%-&.L8<.7K$.8$'C 1d VO<98'.L9*&$ f\R 3:3J a$%6<997&<8$'C D'G^TdhVO-'8<'7O<98 2VO<98O%-&.L8<.7K$.8$' Z53I3J Z53III Z63=3 SI$%6-9/.'/ &$% VO<98O%-&.L8K*9&.'/ *5 F-EF<L8*0$' ^K6<99XJ &*$ Y-7*7K$%$EF'.'/ K$%.F8<.6WZPUm

W' &$% I$%/<'/$'F$*8 #.%&$' %$<L8-%7O$A*6*7EF$ D$.8%-'$'2b*%L.'/7p$%7EF'*88$ 6N% YbP .'& VbP 5*8 (^PT'V $%78$998J &*$ &<'' *' ([PW+\D2o$%7EF'*887&<8$*$' $*'/$K$88$8 #.%&$': (^PT'V #*%& '.' &.%EF &<7 Z'UkY^DGVjV U%-/%<557_78$5 $%7$8A8:

RN% $*'$ *'8$%<L8*0$ \%78$99.'/ &$% ([PW+\D *'/<K$ L<'' &$% *'8$/%*$%8$ *'/<K$2 U%$O%-E$77-% U[(W K$'.8A8 #$%&$': Y*$ /%<6*7EF$ Y<%78$99.'/ &$% ([PW+\D2 \%/$K'*77$ $%6-9/8 5*8 (-%]-8J #-K$* &*$ A$*89*EF$' D.L9*&0$%B'&$%.'/$' *' R-%5 0-' (.%0$'J T<9L$'&*</%<55$' -&$% D.L9*&L<%8$' S]<77$' $8E:X <97 R*95 &<%/$78$998 #$%&$'L)''$':

Z^M[P *78 $*' Z-&$ A.% V8<'&<%&K$%$EF'.'/ SYWDX &$% a$%6<997$*78.'/ SD<EF#B%5$X 0-' YbP][x2T%$''78-66 K*7 @3 f<F%$ '<EF T%$''78-66$'89<&.'/ .'8$% T$%NEL2 7*EF8*/.'/ &$% ^L8*'*&$''.L9*&$ 0-' '3@I K*7 Z53III &$% O%*5B% $%A$./8$' VO<98O%-&.L8$ 5*8 a$%6<997$*78.'/7O.976.'L8*-'$' S<'/$O<778 <']$77.'/$'X .'& &$% 7$L.'&B% NK$% S'J*-2P$<L8*-'$' /$K*9&8' VO<98O%-&.L8$ SZ71@I $8E:X: P$<L8-%7O$A*6*7EF$ D$.8%-'$'#*%L.'/7p$%7EF'*88$ #.%&$' 6N% $*'$' &*$ F$.8*/$' \%6-%&$%'*77$ <K&EL'&$' T$%$*EF 5*8 [P\VG $%78$998:

4.2.5 KAPROS/KARBUS und Kopplung mit KORIGEN

Y*$ (^UP[V2U%-A$&.% (^PT'V kTP[21kJ kTP[2>3k $%5)/9*EF8 ^KK%<'&%$EF'.'/$' 6N% *'F$*87A99' .'& 6N% $*'2 K*7 &%$*2&*5$'7*-'<9$ P$<L8-%5-&$99$J #$9EF$ 5*8 Y*66.7*-'72 -&$% G%<'7O-%82DBF$%.'/$' K$%EF'8 #$%&$': Y*$ $*/$'89*EF$' ^KK%<'&%$EF'.'/$' #$%&$' *5]-&.9 T'PD'U kVG\kJ $'8#*EL$98 <.7 &$5 ([PW+\D ^KK%<'&2Z-&$ kRWVkJ &.%EF/$6NF%8: Y*$ K$')8*/8$' *'/%.OO$'p$%7EF'*88$ L)''$' 5*8 !K$782$78*5<8$; b*EF8.'/77O$L8%$' <.7 <K/$7EF*%58$'].98*/%.OO$'&<8$' /$#-''$' #$%&$'J 6<997 7-9EF$ Y<8$' 0$%6N/K<% 7*'&: Y*$ b*EF8.'/77O$L8%$' L)''$' <.7 &$8$%5*'*7EF$'].98*2/%.OO$'2 -&$% <.EF <.7]-'8$2Z<%9-2P$EF'.'/$' /$#-''$' #$%&$': R<997 L$*'$].98*/%.OO$'2b*%L.'/7p$%7EF'*88$ 0$%6N/K<% 7*'&J #$%&$' *'/%.OO$'2Y<8$'J #*$ <.EF &*$ 0-5 VO$L8%.5 .'<KFB'/*/$' a$%6<997&<8$' 0-' T'PD'U $*/$'$' T*K9*-8F$L$' /$9$7$': Y*$ T*K9*-8FL' 6N% ([PW+\D .'& T'PD'U

7*'& '*EF8 &*%$L8 L-5O<8*K$9J &< &*$ P$*F$'6-9/$ &$% /$7O$*EF$%8$' W7-8-O$ 6N% T‘PD‘U -O8*5*$%8 #.%&$ kVG\k: *' G%<'76-%5<8*-'7O%-/%<55 [PR[PY 7-%/8 <K$% &<6N%J &<77 K$*&$ Z-&$7 L-'7*78$'8$ T*K9*-8F$L7*'F<98$ 0$%#$'&$' L)''$': Y$%]-&.9 T‘PD‘U$'8FB98 '*EF8 &*%$L8 &*$ 0*$%B98*/$' ^.7#$%8$-O8*-'$' 0-' ([PW+\DJ7-'&$%' $7 L<'' *' (^UP[V 5*8 &$5]-&.9 ([PWDG <.8-5<8*7EF $*'$ *'/<K$ 5*8 <KK%<'&7O$A*6*7EF$' T%$''78-66A.7<55$'7$8A.'/$' 6N% ([PW+\D $%A$./8 #$%&$'J .5 5*8 &*$7$5 Z-&$ &*$ /$#N'7EF8$' ^'<9_7$' &.%EFA.6NF%$': Y$% (^UP[V2]-&.9 VW+3\I $%5)/9*EF8 &*$ \%A$./.'/ 0-' 7_78$5<KFB'/*/$' *'/%.OO$'2Y<8$'6*9$7 6N% ([PW+\D kRWVk: Y*7 [O8*-' #.%&$ *' &$% I$%/<'/$'F$*8 FB.6*/ 6N% V-'&$%.'8$%7.EF.'/$' K$'.8A8: Y*$ o<9*6*A*$%.'/ &*$7$% P$EF$'O%-/%<55$ 5*8 A./$F)%*/$' T*K9*-8FL' 6N% &<7 ^KK%<'&0$%F<98$' 0-' MbP $%6-9/8$.:<: &.%EF D<EF%$EF'./$' &$7 WZ\ \eO$%*5$'87 *5 ($%'L%<68#$%L [K%*/F$*5 k([Zk .'& &.%EF T8*9*/./<' 5$F%$%$' *'8$%'<8*-'<9$' 8F$-%$8*7EF$' T$'EF5<%L7J #*$ A: T: 6N%][x2 PA_L9*%./*' MbP*' a.7<55$'<%K$*8 5*8 \YR.'& [\ZYkD\^:

4.2.6 MCNP mit Abbrandmodul

U%-/%<55$ A.% M)7./ &$% G%<'7O-%8/9$*EF./ 5*8 &$%]-'8$2Z<%9-]$8F-&$ <.6 &$% T<7*7 0-' *5 \'$%/*K%$*EF L-'8*'.*$%9*EF &<%/$78$998$' b*%L./7p$%7EF'*887 2 R.'L8*-'$' 7*'& <97 ^98$%'<8*0$ A. &$'].98*/%.OO$'0$%6<F%$' $'8#*EL$98 #-%&$' .'& /$#*''$' 5$F% .'& 5$F% <' T$&$.8./J &< &*$ b*%L./7p$%7EF'*88$ &*%$L8 -F'$ 0-%F$%*/$ b*EF8./ NK$% $*' O%-K9$5<KFB'/*/$7 D$.8%-'$'7O$L8%.5 $*'/$7$8A8 #$%&$' L)''$': T$*7O*$9$ 6N% 7-9EF$ U%-/%<55$ 7*'&]ZDU2Ik= .'&]ZDUx SM^DM2‘V^X kTP[2>@kJ][D(S‘(XJ GPWU[MW SRPX -&$%]IU Sf<O<'X: Y< &*$7$]-'8$2Z<%9-2U%-/%<55$ L-5O9e @2&*5$'7*-'<9$ +$-5$8%*$' K$7EF%$*K$' L)''$'J 7*'& 7*$ 6N% 0*9 U%-K9$578$99./$' *5 T$%$*EF &$% P$<L8-%OF_7*L /$$*/'$8 .'& L)''$' <97 P6%$'A5$8F-&$ <'/7F$' #$%&$'J *'7K$7-'&$%$ 6N% 78<8*-'B%$ T$%$EF'.'/$': T$* M$*78./7%$<L8-%$' *78 '$K$' &$% /$-5$8%*7EF$' T$7EF%$*K./ &$% ^'-%&'./ &*$ <KK%<'&K$&*'/8$ D.L9*&A.7<55$'7$8A./ 0-' T$&$.8./J &< 7*$ 78<%L -%87<KFB'/*/ *78 .'& 6N% 7*EF$%F$*87%$9$0<'8$ T$%$EF'.'/$' &$8<*99*$%8 K$%NEL7*EF8*/8 #$%&$' 5.77: *'$ [O8*-' *78 F*$%J &*$ D.L9*&A.7<55$'7$8A.'/ 5*88$97 &$8$%5*'*78*7EF$% U%-/%<55$ A. K$%$EF'$' .'& *5]-'8$2Z<%9- U%-/%<55 -%87<KFB'/*/ $*'A.7$8A$': Y*$7 K$&$.8$8 h$&-EFJ &<77 &*$ D.L9*&A.7<55$'7$8A.'/ 5*88$97 $*'$7 I$%6<F%$'7 $%5*88$98 #.%&$J &<7 *' &$% P$/$9 <.6 DBF$%.'/$' K$AN/9*EF &$% G%<'7O-%89)7./ K$%.F8 SA: T: +%.OO$''BF$%.'/J 0$%$*'6<EF8$ P$7-'<'A2 K$F<'&9.'/J $8E:X: ‘5 $*' L-'7*78$'8$7 I$%6<F%$' A.% M)7./ &$% G%<'7O-%8/9$*EF./

.'& &$% ^KK%<'&/9$*EF.'/$' A. F<K$'J #.%&$' &$7F<9K /$L-OO$98$]-'8$2Z<%9-2 ^KK%<'&2U%-/%<55$ $'8#*EL$98J 5*8 #$9EF$' &*$ D.L9*&0$%8$*9.'/$' 6N% &*$ *5]-'8$2 Z<%9-2U%-/%<55 &$6*'*$%8$' a-'$' &*%$L8 K$78*5 58 #$%&$' L)''$': Y*$ A.%M)7.'/ &$% ^KK%<'&/9$*EF.'/$' $%6-%&$%9*EF$' 66L8*0$' b*%L.'/7p$%7EF'*88$ #$%&$' &<K$* <.7 &$% M)7.'/ &$% G%<'7O-%8/9$*EF.'/ K$78*5 58: c*$%K$* $e*78*$%8 K$%$*87 $*'$ P$*F$ 0-' !VL%*O8$';J &*$ $*'$ (-OO9.'/ 0-']-'8$2Z<%9-2U%-/%<55$' .'& ^KK%<'&O%-/%<55$' %$<9*7*$%$'C

-]Z2P\T‘VS]ZDUkP\T‘VJ^DMXJ
- [ZG[U‘VS]ZDUkRWVU^ZGJ\ZD DP+XJ
-]ZTS]ZDUkZ.78-5J PWG VEF#$&$'XJ
-]-'8$T.%'7S]ZDUk[PW+\D3 -&$% ZWDY\Pd>J M^DMXJ
-]ZDUkZWDY\Pd>W'8$%6<E$ SM^DMX J
-]ZDUk^TTP^DYS]ZDUk^TTP^DY -&$% [PW+\D3JW(\XJ
-]IU2T‘PDS]IU2T.%'.OJ f<O<'X:

Y*$ (-OO9.'/ 0-']ZDU .'& $*'$5 ^KK%<'&E-&$ *78 *5 U%*'A*O '*EF8 L-5O9*A*$%8J &<&.%EF K$78*5 58$ *'/<K$7O$A*6*L<8*-'$' &*$ -%872 .'& '.L9*&7O$A*6*7EF$' P$<L8*-'7%<8$' 0-']ZDU K$%$EF'$8 .'& NK$% $*' %$9<8*0 $*'6<EF$7 W'8$%6<E$ <' &<7 ^KK%<'&O%-/%<55 NK$%/$K$' #$%&$' L)''$': *'*/$ &$% $%#BF'8$' U%-/%<55$ F<K$' K$%$*87 VEF'*8878$99$'J &*$ K$AN/9*EF &$% T$7EF%$*K.'/ &$7 ^KK%<'&O%-K9$57 %$9<8*0 L-56-%8<K$9 7*'& SA:T:]ZDUkZWDY\Pd>X: Y*$]ZDU 2 .'& &*$ ^KK%<'&K$%$EF'.'/ #*%& <99$%&*'/7 K$* A.'$F5$'&$% a-'$'A<F9 .'& K$* a-'$' 5*8 L9$*'$5 I-9.5$' O%-K9$5<8*7EFJ &< &$% VO$*EF$%O9<8AK$&<%6 .'& &*$ PEF'A$*8 5*8 &$% a-'$'A<F9 78<%L <'#<EF7$' .'& K$* L9$*'$' I-9.5*'< &$% 78<8*78*7EF$ R$F9$% 7$F% /%-, #$%&$' L<''J #<7 6N% &*$ T$%$EF'.'/ &$% 66L8*0$' o$%7EF'*88$ &*7% a-'$' '<EF8$*9*/ *78: R$%'$% *78 A.% T$7EF%$*K.'/ 0-' +$-5$8%*$' 5*8 $*'$% I*$9A<F9 0-' ^KK%<'&A-'$' Sa-'$' .'8$%7EF*$&9*EF$%]<8$%*<9A.7<55$'7$8A.'/X 5*8]ZDUSk$*' $%F$K9*EF$% ^.6#<'& K$* &$% +$-5$8%*$$*'/<K$ $%6-%&$%9*EFQ &*$ K$* &*$7$5 U%-/%<55 0-%F<'&$'$' [O8*-'$' A.% T$7EF%$*K.'/ #*$&$%F-98$% V8%.L8.%$' S#*$: A:T: K%$''78<K#$*7$ T%$''$9$5$'82^'-%&'.'/$'X L)''$' '*EF8 5$F% 66L8*0 /$'.8A8

#$%&$': \7 L-''8$ h$&-EF /$A$*/8 #$%&$'J &<77 5*88$97 $*'$7 U%-/%<5 52W'8$%6<E$7 &*$ *'8$%'$ a.-%&'./ 0-' <KK%<'&K$&*'/8$' D.L9*&A.7<5 5$'7$8A.'/$' A. /$-5$8%*7EF$' a-'$' %$/.9B%$% V8%.L8.%$'J #*$ 7*$ K$* MbP S.'& <.EF K$* R-%7EF.'/7%$<L8-%$'X NK9*EF 7*'&J -F'$ <.6#B'&*/$ +$-5$8%*$$*'/<K$ %$<9*7*$%8 #$%&$' L<'': R$%'$% L-''8$ /A*/8 #$%&$'J &<77 &.%EF I$%#$'&.'/ L-5O<L8$% o$ %7EF'*8877 8%.L8.%$' 6N% 0*$9$ VO<98O%-&.L8$.'& F)F$%$ ^L8*'*&$' &$% VO$*EF$%2 .'& PEF'<.6#<'& K$* /9$*EF$% +$'<.*/L$*8 $%F$K9*EF %$&.A*$%8 #$%&$' L<'': Y<5*8 7*'& '.' <.EF /$L-OO$98$ ^KK%<'&%$EF'./$' '*EF8 '.% 6N% T%$''$9$5$'8$ #*$ K$* &$' F$.8$ 0$%6N/K<%$' T%$''$9$5$'82^.79$/./7O%-/%<5 5$' #*$ A: T: Z^V][.'& c\MW[VJ 7-'&$%' <.EF 6N% P$<L8-%$' 5)/9*EF: W'7K$7-'&$%$ 6N% R-%7EF.'/7%$<L8-%$' L-''8$ &*$7 5*8 $*'$% Y<%78$99./ 0-' NK$% I>:>>> a-'$' $%6-9/%$*EF &$5-'78%*$%8 #$%&$': D<EF8$*9*/ K$* &$5 I$%6<F%$' *78 &*$ F-F$ PEF'A$*8J &*$ &*$]-'8$2Z<%9-2 P$EF'./ K$')8*/8: ‘5 F*$% '<EF <LA$O8<K9$% a$*8 PEF'$%/$K'*77$ A. $%F<98$'J 7-998$' U<%<99$9%EF'% $*'/$7$8A8 #$%&$': Y*$ U%-/%<5 5$]ZDUx.'&]ZDU=7*' & F*$% K$%$*87 6N% &$' *'7<8A <.6 U<%<99$9%EF'%' '<EF &$5]$77</$ U<77*'/W'8$%6<E$ S]UWX (-'A$O8 O%-/%<5 5*$%8 .'& <.6 0*9' PEF'%<%EF*8$L8.%$'J *'7K$7-'&$%$ <.EF <.6 &$' M*'.e2Z9.78$%' 9<.66BF*/: Y*$ b$*8$%$'8#*EL9./ &*$7$%]$8F-&$ 7-998$ 0-%<'/$8%*$K$' #$%&$'J .5 A.7B8A9*EF A. &$' ^.79$/.'/7O%-/%<5 5$' $*'$ 66L8*0$J .'<KFB'/*/$.'& /$'<.$]$8F-&$ A.% T$%$EF'.'/ 7*EF$%F$*87%$9$0<'8$% %$<L8-%OF_7*L<9*7EF$% U<%<5$8$% A.% I$%6N/.'/ A. F<K$':

*'$ (-OO9./ A#*7EF$']ZDUSx .'& (^UP[Vk(^PT‘V #.%&$ 6N% ^YV2 ^'#$'&.'/$' %$<9*7*$%8 .'& A: T: 6N% ^YV2T$'EF5<%L2‘'8$%7.EF.'/$' .'&]\+^UW\2 G<%/$82^'<9_7$' <'/$#<'&8: Y<K$* #$%&$' 5*8]ZDUSx b*EF8.'/77O$L8%$' 5*8 &$% \'$%/*$78%.L8.% $*'$%].98*/%.OO$']<78$%K*K9*-8F$L SA.%A$*8 5$*78$'7 dh +%.OO$'X $%5*88$98 .'& A.% *'/%.OO$'L-'&$'7<8*-' &$%]<78$%K*K9*-8F$L7&<8$' 0$%#$'&$8: Y*$7$ *'/%.OO$'2Y<8$' /F' &<'' *' (^UP[Vk(^PT‘V2^KK%<'&%$EF'./$' $*': Y*$!<K/$K%<''8$'; Y<8$' 6N% &*$ P$<L8-%A-'$' 9*6%' &<'' <.8-5<8*7*$%8 '$.$ *'/<K$&<8$' 6N%]ZDUSx P$EF'./$'J # -5*8 &$% T%$EF'./7A_L9.7 #*$&$%F-98 #$%&$' L<'':

4.2.7 Zusammenfassung zum Forschungsbereich „Reaktivitäts- und Nuklidinventarberechnung“

RN% &$' O%<L8*7EF$' *'7<8A &$% T%$''$9$5$'8K$%$EF'./$' 6N% MbP 78F' L-55$%A*$99$ Z-&$7 #*$ Z^V][.'& c\MW[V A.% I$%6N/.'/:]*8 &$5 U%-/%<55

(\D[P\VG #.%&$ $*' K$AN/9*EF PEF'5$8F-&*L .'& &$% 0$%#$'&8' Y<8$'K<7*7 .'<KFB'/*/$7 P$<L8*0*8B872 .'& D.L9*&*'0$'8<%O%-/%<55 $%78$998: *'$ (-OO9.'/ &$7]-'8$ Z<%9- U%-/%<557]ZDU 5*8 ^KK%<'&5-&99' #.%&$ $'8#*EL$98: Y<5*8 7*'& &*$])/9*EFL$*8$' /$/K'J &*$ +$'<.*/L$*8 &$% 0$%6N/K<%$' P$EF$'5$8F-&*L A. NK$%O%N6$': Y*$7 *78 $%6-%&$%9*EF 6N% &$' T$%$*EF F-F$% ^KK%B'&$J &$' *'7<8A 0-'][x2T%$''78-66 .'& 6N% <98$%'<8*0$ T%$''78-6678%<8$/*$' #*$ ^L8*'*&$'0$%K%$''./ .'& *'$%8$ T%$''78-665<8%*e: \7 7-998$ &<7 a*$9 0$%6-9/8 #$%&$'J $*' U%-/%<55 A. $%78$99$'J &<7 '*EF8 '.% &$' ^'#$'&.'/7K$%$*EF .'& &*$ R.'L8*-'$' &$% L-55$%A*$99$' Z-&$7 <K&$EL8J 7-'&$%' 5*8 &$5 6N% $*'$' /%),$%$' ^'#$'&.'/7K$%$*EF &*$ T$%$EF'.'/$' 5*8 0$%K77%8$% +$'<.*/L$*8J /9$*EF$5 P$EF$'<.6#<'& .'& $*'$% $*'6<EF$'J <'#$'&.'/76%$.'&9*EF$' Y<8$'$*'/<K$ &.%EF/$6NF%8 #$%&$' L)''$':

4.3 3D-Kernberechnungen

4.3.1 Modellumfang

RN% &*$ 78<8*-'B%$ '.L9$<%$ ($%'<.79$/.'/ #*$ <.EF 6N% V8)%6<99K$%$EF'.'/$' 7*'& @Y2 ($%'K$%$EF'.'/$' 0-' /%),8$% 7*EF$%F$*878$EF'*7EF$% T$&$.8.'/: Y$%]-&$99.56<'/ 0-' @Y2($%'K$%$EF'.'/$' 6N% MbP .56<778 &*$ T$%$EF'./ &$% D$.8%-'$'69.772 .'& M$*78.'/7&*EF8$0$%8$*9.'/ &.%EF &*$ M)7.'/ &$% D$.8%-'$'&*66.7*-'7/9$*EF.'/$'J 6N% MbP NK9*EF$%#$*7$ 5*8 A#$* \'$%/*$/%.OO$'J &*$ T$%$EF'./ &$% (NF95*88$9A.78B'&$ 6N% $*'2 .'& A#$*OF<7*/$ V8)5.'/ &.%EF M)7.'/ &$% \%F<98.'/7/9$*EF.'/$' 0-']<77$J \'$%/*$.'& W5O.97 7-#*$ &*$ T$%$EF'./ &$% T%$''78<K8$5O$%<8.%$' &.%EF M)7.'/ &$% bB%5$9$*8.'/7/9$*EF.'/$' *' $*'$5 %<&*<9$' T%$''78<K5-&$99: Y*$ (NF95*88$978%)5.'/ #*%& *5 ^99/$5$*'$' &.%EF $*' U<%<99$9L<'<95-&$99 K$7EF%*K'J $7 #$%&$' h$&-EF <.EF 8F$%5-F_&%<.9*7EF$ ''8$%L<'<95-&$99$ #*$ A:T: Z[TP^ 5*8 T$%NEL7*EF8*/.'/ 0-' o$%78%)5.'/$' $*'/$7$8A8: RN% &*$ T$%$EF'./ &$7 ($%'0$%F<98$'7 #$%&$' &*$ P<'&K$&*'/.'/$' 6N% U%*5B%&%.ELJ T-%L-'A$'8%<8*-' *5 YbPJ]<77$'78%-52.'& G$5O$%<8.%0$%8$*9.'/<5 ($%'$*'8%*88 $e8$%' 0-%/$/$K$': Y*$ '.L9$<%$' */$'7EF<68$' &$% T%$''$9$5$'8$ #$%&$' &.%EF /$5*88$98$ a#$*2 \'$%/*$/%.OO$'2b*%L.'/7p$%7E F'*88$ K$7EF%*$K$'J &*$ 0-%<K *' T%$''$9$5$'82 <KK%<'&%$EF'.'/$' K$78*558 #$%&$': W' &*$7$' b*%L.'/7p$%7EF'*887K*K9*-8FL' #$%&$' <.EF &*$ P$<L8*0*8B87%NEL#*%L.'/$' 0-' (NF95*88$9&*EF8$.'& ?8$5O$%<28.%B'&$%.'/$' 7-#*$ 0-' T%$''78-668$5O$%<8.%2 .'& T-%L-'A$'8%<8*-'7B'&$%.'/$' K$7EF%*$K$': Y*$ @Y2($%'5-&$99$ L)''$' NK9*EF$%#$*7$ b*%L.'/7p$ %7EF'*887&<8$'

0-' .'8$%7EF*$&9*EF$' T%$''$9$5$'8<KK%<'&O%-/%<55$' '.8A$'J /$/K'$'6<997 7*'& &*$ VEF'*8878$99$' A. &$' b*%L.'/7p$%7EF'*887K*K9*-8FL' <'A .O<77$':

4.3.2 Entwicklung der nodalen Verfahren

a.% $66*A*$'8$' M)7.'/ &$% D$.8%-'$'&*66.7*-'7/9$*EF.'/$' #.%&$' 7$*8 &$' n$% f<F%$' '-&<9$ I$%6<F%$' -&$% +%-K/*88$%0$%6<F%$' $'8#*EL$98J 5*8 &$'$' $*'$ F-F$ +$'<.*/L$*8 6N% &*$ T$%$EF.'/ &$% D$.8%-'$'69N77$.'& &$% M$*78.'/ *' &$' I-9.5$'$9$5$'8$' -&$% D-&$7 &$7 P$EF$'/*88$%7 5)/9*EF *78: W5 ($%'p$%7EF'*88 $'87O%$EF$' &*$ D-&$7 &$% T%$''$9$5$'878%.L8.%J*' a2P*EF8.'/ 7*'& +*88$%#$*8$' 0-' 3> ? @> E5 #BF9K<%: Y*$ PEF'A$*8 6N% &*$7$ +%-K/*88$%0$%6<F%$' *78 <.EF 6N% /%-,$ ($%'<'-%&'.'/$' /$%*'/J 7-&<77 &*$ I-%<.77$8A.'/$' 6N% &$' %-.8*'$5B,*/$' O%<L8*7EF$' *'7<8A /$/$K$' 7*'&:

W5 *'A$9'$' .'8$%7EF$*&$' 7*EF &*$ PEF'5-&99 *' &$% 7O$A*99' b<F9 &$% \'8#*EL9.'/76.'L8*-'$' 6N% &$' D$.8%-'$'69.77 .'& &$' /$#BF98$' '.5$%*7EF$' M)7.'/70$%6<F%$': R-9/$'&$ @Y2($%'5-&$99$ #.%&$' *' Y$.87EF9<'& $'8#*EL$98 .'& 7*'& *5 O%<L8*7EF$' *'7<8AC ó^T[kZ‘TT[xk M^D21kJ kM^D23k 6N% p<&%<8*7EF$ T%$''$9$5$'8$J YjD@Yk+P‘k 6N% p<&%<8*7EF$.'& F$e</-'<9$ T%$''$9$5$'8$.'& U^DT[x-&$% Z^VZ^ Y\@Y 6N% p<&%<8*7EF$ T%$''$9$5$'8$: W5 *'8$ %'<8*-'<9$' T$%$*EF 7*'& #$*8$%$ @Y2($%'5-&$99$ 0$%6N/K<%:

Y*$ @Y2($%'5-&$99$ #$%&$' $*/$'78B'&*/ 6N% T$%$EF.'/$' &$7 ($%'0$%F<98$'7 $*'/$7$8A8: RN% V8)%6<99K$%$EF.'/$' #$%&$' 7*$ F$.8$ K$0-%A./8 *' (-OO9.'/ 5*8 8F$%5-F_&%<.9*7EF$' V_78$5E-&$7 #*$ ^GcM\G A.% T$%$EF.'/ &$7 /$7<58$' ^'9</$'0$%F<98$'7 $*'/$7$8A8:

4.3.3 Validierung

Y*$ I<9*&*$%.'/ &$% @Y2($%'5-&$99$ $%6-9/8$ &.%EF D<EF%$EF.'/ 0-' 78<8*-'B%$' T$8%*$K75$77.'/$' 0-' ($%'A.78B'&$' *' P$<L8-%<'9</$' #*$ A: T: L%*8*7EF$% T-%L-'A$'8%<8*-'$'J L%*8*7EF$% V8$.$%78<K78$99.'/$' .'& /$5$77$'$% M$*78.'/72 0$%8$*9.'/$': V8<8*-'B%$ T$8%*$K7A.78B'&$ #.%&$' <.EF *5 P<F5$' 0-' *'8$%'<8*-'<9$' T$'EF5<%L7 K$%EF'8: RN% V8)%6<99K$&*'/.'/$'J &*$*' P$<L8-%<'9</$' '*EF8 .'8$%7.EF8 #$%&$' L)''$'J #.%&$' *5 P<F5$' &$% [\ZYkD\^2^L8*0*8B8$' A. ($%'8%<'7*'8$' 5$F%$%$ T$'EF5<%LO%-K9$5$ &$6*'*$%8 A: T: kRWD21kJ kRWD23kJ kRP^k:

Y<K$* #.%&$' V8)%6B99$.'8$%7.EF8 #*$ &$% 7EF'$99$ V8$.$%78<K<.7#.%6J &$% <97 ^.79$/.'/778)%6<99 A. .'8$%7.EF$' *78J .'& &<7 R$F96<F%$' 0-' V8$.$%78<K/%.OO$': W'7K$7-'&$%$ 5*8 /$L-OO$98$' Z-&$7 #.%&$ &$% R%*7EF&<5O69$*8.'/7K%.EF *5 YbP kWI^21kJ kWI^23kJ kWI^2@k .'& &$% G.%K*'$'7EF'$997EF9.77*' $*'$5 VbP kWI^2IkJ kWI^2=k .'8$%7.EF8: Y*$ $%A*$98$' \%/$K'*77$.'& &$% I$%/9$*EF 0-' 0$%7EF*$&$'$' *'8$%'<8*-'<9 0$%6N/K<%$' U%-/%<557_78$5$' 7*'& *' [\ZYkD\^2T$%*EF8$' .'& *' a$*82 7EF%*68K$*8%B/$' &-L.5$'8*$%8J #-K$* 6N% &*$ VbP2G%<'7*$'8$ <.EF $*' I$%/9$*EF 5*8]$77&<8$' 0-' &$% P$<L8-%<'9</$ 5)/9*EF #<%: a.7<55$'6<77$'& $%/*K8 7*EF<.7 &$' K*7F$%*/$' I$%/9$*EF$'J &<77 &*$ @Y2($%'K$%$EF'.'/$' <.EF *' /$L-OO$98$' U%-/%<557_78$5$' 5*8 /.8$% +$'<.*/L$*8 &.%EF/$6NF%8 #$%&$' L)''$':

4.3.4 Weiterentwicklung

Y*$ #7'89*EF$']-&$99<''<F5$' *' &$' F$.8$ 0$%6N/K<%$' @Y2($%'5-&$99$' 6N% Mb P2($%'K$%$EF'.'/$' 7*'& &*$ ^''<F5$ &$% Y*66.7*-'7'BF$%.'/ 6N% F-5-/$'*7*$%8$ T%$''$9$5$'8$.'& &*$ T$7EF%B'L.'/ <.6 A#$* \'$%/*$/%.OO$': T$*&$ ^''<F5$' 7*'& I-%<.77$8A.'/ 6N% &*$ \'8#*EL9.'/ &$% $66*A*$'8$' M)7.'/70$%6<F%$' *' &$' '-&<9$' I$%6<F%$'J 7*$ K$7EF%B'L$' <K$% /9$*EFA$*8*/ &*$ $%%$*EFK<%$ +$'<.*/L$*8 6N% &*$ T$78*55.'/ &$% 9-L<9$' M$*78.'/ $*'A$9'$% T%$''78BK$: ^.7 &$% GF$-%*$ &$7 D$.8%-'$'8%<'7O-%87 .'& <.EF <.7 &$% \%6<F%.'/ 0-' G$786B99$' $%/*K8 7*EFJ &<77 &*$ Y*66.7*-'7'BF$%.'/ 6N% V*8.<8*-'$' 5*8 78<%L .'8$%7EF*$&9*EF$' D$.8%-'$'7O$L8%$'J <97-A: T:*' &$% D<EFK<%7EF<68 0-' '%<'2 .'&][x2T%$''$9$5$'8$' -&$% 0-' 6%*7EF$' .'& F-EF <K/$K%<''8$' T%$''$9$5$'8$'J *' R%</$ A. 78$99$' *78: Y<7 /*98 K'7- 6N% T%$''$9$5$'8$ *' 78<%L$' D$.8%-'$'69.77/%<&*$'8$' #*$ A: T: *' &$% DBF$ 0-' V8$.$%78BK$' -&$%<5 ($%'%<'&:

Y*$ b$*8$%$'8#*EL9.'/ &$% @Y2($%'K$%$EF'.'/$' A*$98 &<%<.6 <KJ &*$ +$'<.*/L$*8 &$% T$%$EF'.'/$' A. $%F)F$': Y<A. #$%&$' 0$%7EF*$&$'$ ^'7B8A$ 0$%6-9/8: Y*$ \'8#*EL9.'/ 0-' /$'<.$%$' T$%$EF'.'/70$%6<F%$' #*%& &.%EF &*$ F$.8$ &$.89*EF $%F)F8$ M$*78.'/ &$% PEF'8$EF'*L .'8$%78N8A8: Y$% &*%$L8$ ^'7<8A *78 &*$ M)7.'/ &$% &$8$%5*'*78*7EF$' D$.8%-'$'8%<'7O-%8/9$*EF.'/$' '<EF &$5 V_D2I$%6<F%$' 5*8 F)F$%$% \'$%/*$/%.OO$'A<F9J &$% A#$*8$ ^'7<8A *78 &*$ \'8#*EL9.'/0-' DBF$%.'/70$%6<F%$' 6N% &*$ G%<'7O-%8/9$*EF.'/J &*$ A. I$%K$77$%.'/$' /$/$'NK$% &$% Y*66.7*-'7'BF%.'/ 6NF%$':

a.5 &*%$L8$' ^'7<8A\7 #.%&$' ''8$%7.EF.'/$' A.5 U-8$'A*<9 &$% &$8$%5*''78*7EF$' D$.8%-'$'8%<'7O-%85$8F-&$' &.%EF T$%$EF'.'/$' 5*8 &$' V_D2Z-&$7 Y[PGkG[PG 0-'[PDM.'&<.EF 5*8 Gb[Y^DGkGcP\\Y^DG 0-' M^DM &.%EF/$6NF%8:\7 #.%&$' 5$F%$%$ L%*8*7EF$ \eO$%*5$'8$ #*$ (PWGa .'& I\D'V 7-#*$ &$% *'8$%'<8*-'<9$ T$'EF5<%L Z=+nkU^D 21kJ kV\'k K$%$EF'$8: Y*$7$ ^'-%&'.'/$' K$78F' <.7 '%<'2 .'&]$x2T%$''78BK$' *' &$% +%),$ 0-' 3e3 K*7 @e@ ^'-%&'.'/$' 5*8 .5/$K$'&$' P<'&A-'$': RN% <99$ ^'-%&'.'/$' #.%&$ 'K' &$5].98*O9*L<8*-'76<L8-% <.EF &*$ K%$''78<K#$*7$ M$*78.'/ -&$% VO<98%<8$ K$%$EF'$8: W5 I$%/9$*EF A. &$' eO%*5$'8$99$' \%/$K'*77$' L-''8$ $*'$ /.8$ HK$%$*'78*55.'/ $%A*$88 #$%&$': W5]*88$9 9*$/8 &*$ ^K#$*EF.'/ *' &$% 9-L<9$' VO<98%<8$ *''$%F<9K 0-' 3v*' $*'A$9'$' P<'&78BK$' A$*/8$' 7*EF $8#<7 /%),$%$ ^K#$*EF.'/$' K*7 $8#< =v W' &$' T$%$EF'.'/$' #.%&$ $*'$ \'$%/*$/%.OO$'A<F9 0-' mK *7 1> 0$%#$'&$8J K$* $*'$% /$%*'/$%$' +%.OO$'A<F9 '$F5$' &*$ ^K#$*EF.'/$' &$.80*EF A.: U<%<99$9 &<A. #.%&$' &*$ ^'-%&'.'/$' 5*8 &$5]-'8$ Z<%9- Z-&$]ZDU K$%EF'8: Y<K$* K$78B8*/8$ 7*EFJ &<77 &*$ 78<8*-'B%$' U%-K9$5$ /%.'&7B8A0*EF 0-']-'8$ Z<%9-]$8F-&$' 5*8 U.'L8&<8$' .'& $V_D2]$8F-&$' 5*8 +%.OO$'&<8$' *' /9$*EF$% +$'<.*/L$*8 K$%EF'8 #$%&$' L)''$':

a.5 ^'7<8A 5*8 DBF$%.'/75$8F-&$'C *'$ (9<77$ 0-' DBF$%.'/75$8F-&$' A.% M)7.'/ &$% @Y G%<'7O-%8/9$*EF.'/ 78$99$' &*$ VU$_D2]$8F-&$' S7*5O9*6*$& U$_D2]$8F-&$'X &<%:]<' $%FB98 &*$ +9$*EF.'/$' &$% VU$_D2]$8F-&$'J *'&$5 &*$ +9$*EF.'/$' &$% L9<77*7EF$' U$_D2]$8F-&$J &*$ *' $*'&*5$'7*-'<9$% K'$% +$-5$8%*$ $*'$% \'8#*EL9.'/ &$% b*'L$9<KFB'/*/L$*8 &$% D$.8%-'$'78%-5&*EF8$.'& &$% b*'L$9<KFB'/*/L$*8 &$% V8%$..'/ '<EF M$/$'&%$7EF$' U-9_'-5$' $'87O%*EF8J *' $*'6<EF$% b$*7$ <.6 &%$*&*5$'7*-'<9$ +$-5$8%*$ NK$%8%</$' #$%&$': +$/$'NK$% &$% Y*66.7*-'7/9$*EF.'/J &*$ &$% U12DBF$%.'/ Bp*0<9$'8 *78J 78$998 &*$ VU @2]$8F-&$ $*'$ F)F$%$ DBF$%.'/ &$% G%<'7O-%8/9$*EF.'/ &<%: Y*$]$8F-&$ #*%& *' @2&*5$'7*-'<9$' U%-/%<55$' A.% T$%$EF'.'/ &$% D$.8%-'$'69.770$%8$*9.'/ *' D-&$7 &$% +%),$ 0-' ^K7EF'*88$' &$% T%$''$9$5$'8$ -&$% &$% T%$''78<KA$99$' <'/$#$'&$8: V_78$5$ 5*8][x2T%$''78-66 L)''$' 5*8 &*7']$8F-&$' K$* I$%#$'&.'/ $*'$% /%),$%$' ^'A<F9 0-' \'$%/*$/%.OO$' Sn2d \'$%/*$/%.OO$'X /$/$'NK$% &$' F$%L)55*EF$' I$%6<F%$' 5*8 $*'$% K77%$' +$'<.*/L$*8 K$%EF'8 #$%&$': Y*$]$8F-&$' K$6*'&$' 7*EF '-EF *' \'8#*EL9.'/: \%/$K'*77$ 6N% &<7 [\ZY 9@@m2Z=][xT$'EF5<%L U%-K9$5 $%/<K$' $*'$' +$'<.*/L$*87/$#*''*5 P]V b$%8 6N% &*$ T%$''$9$5$'82M$*78.'/$' 0-' 1:m v &$% 32+%.OO$' '-&<9$' Y*66.7*-'75$8F-&$ <.6 >:@ vK$* O*'#$*7$% VU @2P$EF'.'/ 5*8 n\'$%/*$/%.OO$' kZc^ k: \%78$ \%/$K'*77$ 6N% &<7 3Y I\D'V23][x2T$'EF5<%L A$*/$'J &<77 &*$ ^K#$*EF.'/$' &$% K%$''78<K#$*7$' M$*78.'/7&*EF8$J &*$ K$*

^'#$'&.'/ &$% /$#)F'9*EF$' Y*66.7*-'75$8F-&$' dv /$/$'NK$% G%<'7O-%8 2 %$EF'.'/$' K$8%</$'J 5*8 ^'#$'&.'/ &$% VU@2]$8F-&$ <.6 3:= v%$&.A*$%8 #$%&$' L)''$' kc^ck: V8<8*-'B%$ +<'AL$%'%$EF'.'/$' 5*8 &$%]$8F-&$ K$')8*/$' <.6 /$/$'#B%8*/$' *'2U%-A$77-%%EF'%' ZU'2a$*8$' *' &$% +%),$'-%&'.'/ 0-' V8.'&$': V*$ 7*'& &<5*8 $*'$ +%),$'-%&'.'/ 7EF'$99$% <97 &*$ VD2]$8F-&$':

''8$% T$%NEL7*EF8*/.'/ &$% \'8#*EL9.'/ &$% PEF'8$EF'*L L<'' $*'/$7EFB8A8 #$%&$'J &<77 5*8 &$% VU@2]$8F-&$ 78<8*-'B%$.'& A$*8<KFB'/*/$ U%-K9$5$ 5*8 0$%'N'68*/$% PEF'A$*8 .'& 5*8 0$%K77%8$% +$'<.*/L$*8 /$9)78 #$%&$' L)''$':

4.3.5 Zusammenfassung zum Forschungsbereich „3D-Kernberechnung“

Y*$ &$%A$*8*/$' O%<L8*7EF$' ^'6-%&$%.'/$' 6N% @Y2($%'K$%$EF'.'/$' L)''$' 5*8 &$' '-&<9$' I$%6<F%$' -&$% &$' +%-K/*88$%0$%6<F%$' $%6N998 #$%&$': +%$'A$' $%/$K$' 7*EF &.%EF &*$ T$78*55./ 9-L<9$% M$*78.'/7#$%8$ 6N% &$' $*'A$9'$' F-EF K$9<78$8$' T%$''78<KJ &*$ /%-,$ 7*EF$%F$*878$EF'*7EF$ T$&$.8.'/ F<K$' .'& &*$ 6N% &*$ 5<e*5<9 A.9B77*/$ M$*78.'/ K$/%$'A$'& 7$*' L)''$': W'8$%'<8*-'<9 /$F8 &*$ b$*8$%$'8#*EL9.'/ A.%M)7.'/ &$% D$.8%-'$'8%<'7O-%8/9$*EF.'/$': ^.7 T$'EF5<%LO%-K9$5$' 9*$/$' /.8$ \%6<F%.'/$' 6N% &$' *'7<8A &$% &$8$%5*'*78*7EF$' VD2]$8F-&$' 0-%: Y< 6N% &*7 M)7.'/$' &*$ PEF'A$*8$' 7$F% F-EF 7$*' L)''$'J 7*'& <98$%'<8*0$ M)7.'/$' <.6 *F% U-8$'A*<9 A. NK$%O%N6$':

4.4 Störfallanalysen mit gekoppelten Rechenprogrammen

W5(<O*8$9 A. &$' @Y2($%'K$%$EF'.'/$' #.%&$ K$%$*87 &<%<.6 F*'/$#*$7$'J &<77 6N% %$<9*78*7EF$ V8)%6<99K$%$EF'.'/$' &$7 P$<L8-%<'9</$'0$%F<98$'7 /$L-OO$98$ PEF'O%-/%<55$ $*'/$7$8A8 #$%&$'J <97- &*$ @Y2($%'K$%$EF'.'/ *' &*%$L8$% (-OO9.'/ 5*8 8F$%5-F_&%<.9*7EF$' V_78$5E-&$7 #*$ ^GcM\G &.%EF/$6NF%8 #*%&: Y*$7$ \'8#*EL9.'/ *78 *'8$%'<8*-'<9 A. K$-K<EF8$'J 7-&<77 F$.8$ h$&$% 0$%6N/K<%$ V_78$5E-&$ /$L-OO$98$ @Y2($%'5-&$99$ A.% I$%6N/.'/ F<8: Y$% V_78$5E-&$ ^GcM\G #.%&$ 5*8 0$%7EF*$&$'$' @Y2($%'5-&$99$' /$L-OO$98J #*$ A: T: 5*8 ó^T[k Z'TT[x YjD@Y SY$.87EF9<'&XJ TWUPi SP.779<'&X .'& (W([@Y S''/<%'X: Y$% *'7<8AK$%$*EF &*$7$% /$L-OO98' Z-&$7 7*'& G%<'7*$'8$' 5*8 78<%L$% (-OO9.'/ A#*7EF$' R9.*&&_'<5*L *5 (NF9L%$*79<.6 .'& D$.8%-'$'&_'<5*L *5 P$<L8-%L$%'J <97- A: T: Y$K-%*$%.'/7$%$*/''*77$ -&$% &$% R%*7EF&<5O69$*8.'/7K%.EF*5 YbPJ ^GbV2RB99$.'& &*$ '.L9$<%28F$%5-F_&%<.9*7EF$ V8<K*9*8B8 *5 VbP: Y$% #$7$'89*EF$ I-%8$*9 &*$7$%

PEF’5$8F-&*L *78 &*$ I$%5$*&.’/ &$% VEF’*8878$99$’O%-K9$5<8*L A#*7EF$’ ($%’K$%$EF’.’/ .’& ^’9</$’K$%$EF’.’/J &*$ 8$*9#$*7$ A. L-’7$%0<8*0$’ ^’’<F5$’ 6N% &*$ T$%$EF’.’/$’ 6NF%8$: Y*$ &*%$L8 /$L-OO98 T$%$EF’.’/ L<’’ .’8$% %$<9*78*7EF$’ P<’&K$&*’/.’/$’ &$% (-OO9.’/ A#*7EF$’ ($%’ .’& (NF9L%$*79<.6 &.%EF/$6NF%8 #$%&$’:

W’ &$’ &.%EF/$6NF%8$’ I<9*&*$%.’/7%$EF’.’/$’ *5 P<F5$’ &$% *’8$%’<8*-’<9$’ [\ZYkD\^ T$’EF5<%L<L8*0*8B8$’ L-’’8$’ 7$F% /.8$ \%/$K’*77$ $%A*$98 #$%&$’: b$*8$%$ T$%$EF’.’/$’ #.%&$’ *5 P<F5$’ 0-’ \‘2U%-h$L8$’ #*$ VPP1kd=k]WG21kJ kcs] k -&$% I^MZ[kbW\kJ k]WG23kJ kI^DkJ kM^D2@k &.%EF/$6NF%8J #-K$* <.EF *5 I$%/9$*EF A.]$77.’/$’ 0-’ ^’9</$’8%<’7*$’8$’ /.8$ HK$%$*’78*55.’/ $%A*$98 #$%&$’ L-’’8$:

^.7 &$’ K*7F$%*/$’ T$%$EF’.’/$’ $%/$K$’ 7*EF 6-9/$’&$ ^’6-%&$%.’/ 6N% &*$ b$*8$%$’8#*EL9.’/C \7 7*’& I$%K77%.’/$’ *’ &$% T%$’’78<K5-&$99*$%.’/ $%6-%&$%9*EFJ .5 &*$ PNEL#*%L.’/$’ 0-’ &$’ T%$’’78-668$5O$%<8.%B’&$%.’/$’ /$’<.$% A. $%6<77$’J .’& $7 *78 $*’$ 0$%K$77$%8$]-&$99*$%.’/ 0-’ I$%5*7EF.’/70-%/B’/$’ *5 P$<L8-%&%.ELK$FB98$% $%6-%&$%9*EFJ .5 &*$ %B.59*EF$ I$%8$*9.’/ 0-’ (NF9 5*88$92 8$5O$%<8.%$’ -&$% &$% T-%L-’A$’8%<8*-’ /$’<.$% A. K$78*55$’: \%6-%&$%9*EF *78 F*$% &*$ (-OO9.’/ 5*8 $*’$5 ZRY2]-&.9 #*$ A:T: &$5 5$F%&*5$’7*-’<9$’ R9.*&5-&$99 RM‘T[x<97@Y 2]-&.9*’ ^GcM\G:

4.5 Monte Carlo und deterministische Transportmodelle

Y*$ V8<’&<%&2PEF’5$8F-&$’ A.% T$%$EF’.’/ 78<8*-’B%$% L%*8*7EF$% ^’-%&’.’/$’ 7*’& &*$]-’8$ Z<%9-]$8F-&$ #*$]ZDU 5*8 U.’L8&<8$’ -&$% (\D[5*8 +%.OO$’&<8$’ 7-#*$ &8%5*’*78*7EF$ G%<’7O-%85$8F-&$’ #*$ 7*$ *’ &$’ $V_D2Z-&$7 Y[PGkG[PG -&$% Gb[Y^DGkGcP\\Y^DG /$’.8A8 #$%&$’: Y*$]-’8$ Z<%9-]$8F-&$ 5*8 U.’L8&<8$’ #*$ *’]ZDU L<’’ <97 P6%$’A5$8F-&$ 6N% &*$ T$%$EF’.’/ L%*8*7EF$% ^’-%&’.’/$’ <’/7F$’ #$%&$’: *’$ *’7EF%B’L.’/ $%/*K8 7*EF /%.’&7B8A9*EF ’.% &.%EF &*$ $%6-%&$%9*EF$ PEF’A$*8 .’& &*$ +%),$ &$% ^’-%&’.’/: ^.7 &$% \%6<F%.’/ 0-’ T$%$EF’.’/$’ 6N% 7$F% /%-,$ ^’-%&’.’/$’ #*$ A:T: $*’$ /<’A$ @Y ($%’<’-%&’.’/ $%/*K8 7*EFJ &<77 &<K$* (-’0$%/$’AO%-K9$5$ 6N% &*$ D$.8%-’$’0$%8$*9.’/ <.68%8’ L)’’$’:

Y*$ &8%5*’*78*7EF$’ D$.8%-’$’8%<’7O-%85-&$99$ ’<EF &$% $V_D2]$8F-&$ 9)7$’ &*$ +%.’&/9$*EF.’/$’ 5*8 F-F$% +$’<.*/L$*8J #$’’ &*$)%89*EF$ Y*7L%$8*7*$%.’/ .’& &*$

b*'L$9<.69)7.'/ $'87O%$EF$'& 6$*' /$#BF98 #$%&$': Y*$ \%6<F%.'/$' <.7 &$% T$%$EF'.'/ 0-' L%*8*7EF$' ^'-%&'.'/$' #.%&$'*5 (<O*8$9 A.% b$*8$%$'8#*EL9.'/ &$% @Y2($%'K$%$EF'.'/$' K$7EF%*$K$': RN% T$%$EF'.'/$' $*'$7 R-%7EF.'/7%$<L8-%7 #.%&$ $*'$ A$*8<KFB'/*/$J 0-992*5O9*A*8$ I$%7*-' 0-' Y[PG $%78$998 .'& $%6-9/%$*EF 6N% &*$ T$%$EF'.'/ 0-' 7EF'99' P$<L8*O*8B8778)%6B99$' $*'/$7$8A8 kU^D23kJ kU^D2@k: Y*$ HK$%8%</.'/ <.6 @Y2+$-5$8%*$*' G[PG #.%&$*' $*'$% G780%7*-' 6$%8*/ /$78$998:

Y$% I-%8$*9 &$%]-'8$ Z<%9- I$%6<F%$' 9*$/8 *' &$% R9$e*K*9*8B8 &$% T$7EF%$*K.'/ L-5O9e% +$-5$8%*$' .'& &$%])/9*EFL$*8 U.'L8&<8$' A. 0$%#$'&$': Y*$ #$*8$%$ \%F)F.'/ &$% P$EF$'9$*78.'/ $%#$*8$%8 &$' *'7<8AK$%$*EF &*7% PEF'5$8F-&$: RN%]$F%/%.OO$'&<8$'2T$%$EF'.'/$' 7*'& &*$ b*EF8.'/77O$L8%$' $*'$ #*EF8*/$ *'69.77/%),$: Y$% I-%8$*9 &$% &8%5*'*78*7EF$' I$%6<F%$' *78J &<77 *F%$ M)7.'/$' '*EF8 5*8 78<8*78*7EF$' V8%$..'/$' K$F<68$8 7*'&: ^.7 &*$7$5 +%.'& 7*'& 6N% A$*8<KFB'/*/$ T$%$EF'.'/$' &*$ &8%5*'*78*7EF$' I$%6<F%$' A. K$0-%A./$':

4.6 Berechnungen der Neutronenfluenz

RN% &$' T$8%*$K 0-' ($%'%$<L8-%$' 5N77$' R9.$'A2T$%$EF'.'/75$8F-&$' A.% I$%6N/.'/ 78$F$'J &*$ &$5 *'8$%'<8*-'<9$' \'8#*EL9.'/778<'& $'87O%$EF$': Y*$7$ T$%$EF'.'/$' 7-99$' 5)/9*EF78 /$'<. &*$ R9.$'A$' &$% D$.8%-'$'2 .'& +<55<78%<F9.'/76$9&$% 9*$6$%'J &*$ 7*EF *5 P$<L8-%L$%' .'& *' &$' '<EF <.,$' 6-9/$'&$' V8%.L8.%$' $*'7EF9*$,9*EF Y%.ELK$FB98$% .'& /$/$K$'$'6<997 &<%NK$% F*'<.7 NK$% $*'$' 0-%/$/$K$'$' T$8%*$K7A_L9.7 <'7<55$9': V*$ K*9&$' *F%$%7$*87 &*$ +%.'&9</$ 6N% &*$ T$%$EF'.'/$' 0-' <LL.5.9*$%8$']<8$%*<97EFB&*/.'/$' .'& ^L8*O*$%.'/$' &$% T<.8$*9$: Y<5*8 7*'& R9.$'AK$%$EF'.'/75$8F-&$' $*' '-8#$'&*/$% T$78<'&8$*9 &$% P$<L8-%K$%$EF'.'/75$8F-&$' 7-#-F9*5 c*'K9*EL <.6 $*'$' 7*EF$%$' T$8%*$K <97 <.EF*5 c*'K9*EL <.6 &$' PNELK<. 0-' ($%'%$<L8-%$':

R9.$'AK$%$EF'.'/$' 6N% T$%$*EF$ <.,$%F<9K &$7 P$<L8-%L$%'7 #$%&$' <97 78<8*-'B%$ G%<'7O-%8O%-K9$5$ 5*8 $*'$% /$/$K$'$'J 66L8*O$' I$%8$*9.'/ &$% VO<98%$<L8*-'$' *5 P$<L8-%L$%' &.%EF/$6NF%8: Y*$ VO<98p$99O$%8$*9.'/ 5.77 <.7 T$8%*$K7&<8$' .'& <.7 \%/$K'*77$' 0-' P$<L8-%L$%'K$%$EF'.'/$' <.6K$%$*8$8 #$%&$': \7 K78F8 &*$ G$'&$'AJ &*$ o$99O$%8$*9.'/ 7- &$8<*99*$%8 #*$ 5)/9*EF A. K$7EF%$*K$'J A: T: &*$ [%87<KFB'/*/L$*8 K%$''78<K#$*7$ 5*8 $*'$% <.7%$*EF$'&$' W'8$%O<998$*9.'/ NK$% &*$ c)F$: V-9EF$ R9.$'AK$%$EF'.'/$' #$%&$' F$.8$ <.77EF9*$,9*EF 5*8 c*96$ 0-' G%<'7O-%8E-&$7 '<EF &$% V_D2 .'& '<EF &$%]-'8$2Z<%9-2]$8F-&$ <.7/$6NF%8: T$* &$'

&8%5*'*78*7EF$' V_D2P$EF'.'/$' #$%&$' &*$ 5<L%-7L-O*7EF$' b*%L.'/7p$%7EF'*88$ *' &$% \'$%/*$/%.OO$''BF$%.'/ 0$%#$'&$8: [68 #*%& &<A. &*$ 6N% MbP 7O$A*$99 $'8#*EL$98$ +%.OO$'&<8$'K*K9*-8F$L T'+M\2dim&*$ 6N% &*$ 8_O*7EF 0-%F<'&$'$' D.L9*&$ o$ %7EF'*8870$%9B.6$ 5*8 In\'$%/*$/%.OO$' 6N% D$.8%-'$' .'& 3> +%.OO$' 6N% +<5 5<7 K$7EF%$*K8: Y$% 5$8F-&*7EF K77%$ b$/ *78J &*$7$ +%.OO$'&<8$' A.0-% 6N% &$' K$8%<EF8$8$' P$<L8-% <&Bp<8 <.7 &$' 5*L%-7L-O*7EF$' o$%7EF'*88$'J &*$ *' &$' $0<9.*$%8$' ($%'&<8$'K*K9*-8F$L$' #*$ A: T: \DYRkT .'& f\R 6N% $*'A$9'$ W7-8-O$ /$/$K$' 7*'&J A. K$%EF'':]-'8$2Z<%9-2Z-&$7 L)''$' O%*'A*O*$99 K'6<997 &$%<%8*/$ +%.OO$'&<8$'7B8A$ <K$% <.EF $'$%/*$O.'L8#$*7$ <K/$7O$*EF$%8$ o$%7EF'*887 2 0$%9B.6$ 0$%#$'&$'J -F'$ &<77 &*$ PEF'A$*8 $%F$K9*EF <'#BEF78: Y<%NK$% F*'<.7 L)''$' 7*$ &*$ &%$*&*5$'7*-'<9$' /$-5$8%*7EF$' V8%.L8.%$' &$%]<8$%*<9*$' 7$F% &$8<*99*$%8 K$%NEL7*EF8*/$' -F'$ #7'89*EF$ DBF$%.'/$' A. 5<EF$': V_D2U%-/%<5 5$ F<K$' &*$7$' V8<'& '-EF '*EF8 $%%$*EF8: Y*$ F$.8*/$ U%<e*7 K$* &$% ^'#$'&.'/ &*$7$%]$8F-&$ 7*'& $*'2 .'& A#$*&*5$'7*-'<9$ P$EF'.'/$' *' 0$%8*L<9$% P*EF8.'/ KA#: *' F-%*A-'8<9$' \K$'$'J &*$ A. &%$*&*5$'7*-'<9$' I$%8$*9.'/$' 7_'8F$8*7*$%8 #$%&$': W' &$' 9$8A8$' f<F%$' #.%&$' 0-' 0$%7EF*$&$'$' R-%7EF.'/7$*'%*EF8.'/$' A.'$F5$'& <.EF &%$*&*5$'7*-'<9$ V·2P$EF'.'/$' 5*8 U%-/%<5 5$' #*$ G[PG .'& U\DGP^D <.7/$6NF%8: *'$ I$%*6*L<8*-' 0-' @Y2R9.$'AK$%$EF'.'/$' 5*8 G[PG #.%&$ *5 P<F5$' &$7 I\D'V2@ T$'EF5<%L7 &.%EF/$6NF%8Q $*'$ HK$%7*EF8 NK$% &*$ ^L8*0*8B8$' A. &*$7$5 T$'EF5<%L /*K8k[\Zk:

T*7F$% #.%&$' R9.$'AK$%$EF'.'/$' F<.O87BEF9*EF '<EF &$%]-'8$2Z<%9-2]$8F-&$ 5*8 c*96$ &$% Z-&$7]ZDU .'& GP^][<.7/$6NF%8: GP^][*78 $*'$ */$'$'8#*EL9.'/J &*$ <.6 ^.6/<K$'78$99.'/$' &$% P$<L8-%&-7*5$8%*$ 7O$A*<9*7*$%8 *78: W5 '8$%7EF*$& A.5]ZDU2Z-&$J &$% $'$%/*$O.'L8#$*7$ <K/$7O$*EF$%8$ b*%L.'/7p$%7EF'*88$ 0$%#$'&$8 .'& &<5*8 &*$ +%.OO$''BF$%.'/ 0$%5$*&$8J K$'.8A8 GP^][66L8*0$ +%.OO$'p$%7EF'*88$: Y<5*8 '*5 58 &*$7$% Z-&$ $*'$ V8$99.'/ A#*7EF$' &$' V D2Z-&$7 .'&]ZDU $*' .'& *78 &<&.%EF <.EF 6N% 5$8F-&*7EF$ ''8$%7.EF.'/$' 7$F% 'N8A9*EF: Y*$ 5*8 GP^][K$7EF%$*KK<%$' +$-5$8%*$' $%9<.K$' $*'$ <.7%$*EF$'& /$'<.$ D<EFK*9&.'/0-']<8$%*<978%.L8.%$'J &*$ 8_O*7EF 6N% &*$ P$<L8-%8$EF'*L 7*'&: \7L)''$' 7-#-F9 V8<'&<%&7B8A$ 0-' 66L8*0$' +%.OO$'&<8$'J #*$ A: T: T'+M\2dim-&$% $*/$'$ Y<8$'7B8A$J &*$ <.7 0$%7EF*$&$'$' ($%'&<8$'K*K9*-8FL' 5*8 c*96$ &$% *'8$%'<8*-'<9 0$%K%$*8$8$' Z-&$7 Df[j .'& GP^DVx /$/K'$'6<997 6N% $*'$ 6$*'$%$ \'$%/*$/%.OO$'8$*9.'/ $%78$998 #.%&$'J 0$%#$'&$8 #$%&$': +$/$'#B%8*/ #*%& &*$ V*5.9<8*-' &$7 D$.8%-'$'k+<5 5<8%<'7O-%87 0-' GP^][<'F<'& 0-' $*/$'7 &<6N% &.%EF/$6NF%8$' \eO$%*5$'8$' 0$%*6*A*$%8 .'& &$7 #$*8$%$' &*$ ^'#$'&.'/ 6N% R9.$'AK$%$EF'.'/$' *' &$' Y%.ELK$FB98$%' &$% %.77*7EF$' b b\P2P$<L8-%$' K*7 *'

&$' c)F$'K$%$*EF &$% ^.69</$78.8A$' 0<9*&*$%8: W5 a.7<55$'F<'/ 5*8 &$% PYT2 V*EF$%F$*8 K$* U%$77.%*A$& GF$%5<9 VF-EL SUGVX2V8)%6B99$' *78 &*$7$ U%-K9$578$99.'/ <.EF 6N% &$.87EF$ P$<L8-%<'9</$' 0-' T$&$.8.'/:

+%-,$7 ('-#2F-# K$78$F8 A.%]-'8$2Z<%9-2]$8F-&$.'& A.% +$'$%*$%.'/ 66L8*0$% +%.OO$'&<8$' 6N% %$<L8-%&-7*5$8%*7EF$ R9.$'AK$%$EF'.'/$': Y*$7 7-998$ 7-#-F9 &.%EF T$<%K$*8.'/ <'#$'&.'/7-%*$'8*$%8$% U%-h$L8$ <97 <.EF &.%EF 5$8F-&*7EF$ \'8#*EL9.'/$' 5*8 GP^][6N% &*$ a.L.'68 /$7*EF$%8 #$%&$': ^97 'BEF78$ 5$8F-&*7EF$ \'8#*EL9.'/ #*%& 0-%/$7EF9</$'J $*'$ *' &*$ G%<'7O-%87*5.9<8*-' *'8$/%*$%8$ T$%$EF'.'/ 0-' ''7*EF$%F$*8$' .'& V$'7*8*0*8B8$' 0-' R9.$'A*'8$/%<9$' <97 P$7O-'7$' *' T$A./<.6 ''/$'<.*/L$*8$' &$% b*%L.'/7p$%7EF'*88$ A. $%<%K$*8$'J A. *5O9$5$'8*$%$' .'& A. 8$78$': W5 ''8$%7EF*$& A. &$% *']ZDU <'/$K-8$'$' G$EF'*L &$% V$'7*8*0*8B87K$%$EF'.'/ 7-99 F*$% $*'$ #$*8$%$ V8.6$ *' &$' ''8$%7.EF.'/$' $*'/$6NF%8 #$%&$'J *' &$% '.' <.EF &<7 V_78$5 *' 7$*'$% +$-5$8%*$.'& &$' b*%L.'/7p$%7EF'*88$' <97 78-EF<78*7EF K$8%<EF8$8 #*%&: V*$ F<8 &$' O%*'A*O*$99$' I-%8$*9J L$*'$ I-%<.77$8A.'/$' NK$% &*$ ^%8 &$% ^KFB'/*/L$*8 &$% P$7O-'7$ 0-' &$' U<%<5$8$%' A. 5<EF$' #$'' 5<' 0-' K$%EF'8$' V$'7*8*0*8B8$' <.6 &*$ ''7*EF$%F$*8 &$% ^.7#*%L.'/$' 7EF9*$,$' #*99: V-998$ 7*EF &*7% b$/ <97 \%6-9/ 0$%7O%EF'& F$%<.778$99$'J 7- L)''8$ &*7]$8F-&$ <.EF *']-'8$2Z<%9-2T$%$EF'.'/$' 0-' P$<L8-%L$%'$' <'/$#<'&8 #$%&$':

Y$%A$*8 #$%&$' 6N% &*$ D$.8%-'$'69.$'AK$%$EF'.'/J &*$ K$0-%A./8 *' @Y2+$-5$8%*$ &.%EF/$6NF%8 #*%&J]-'8$2Z<%9-2.'& &8%5*'*78*7EF$ $V_D2]$8F-&$' $*'/$7$8A8:

4.7 Zusammenfassung zum Forschungsbereich „Störfallanalysen mit gekoppelten Rechenprogrammen“

^97 ^.7/<'/7O.'L8 6N% T%$''$9$5$'82 .'& ($%'K$%$EF'.'/$' 78F' F$.8$ '.L9$<%$ Y<8$'K*K9*-8F$L$' *' R-%5 0-' U.'L8&<8$' -&$%]$F%$'$%/*$/%.OO$'&<8$' A.% I$%6N/.'/: Y*$ *'8$%'<8*-'<9$' ^L8*O*8B8$' A.% T$%$*878$99.'/ 0-' T<7*7&<8$'2 K*K9*-8F$L$' #$%&$' 6-%8/$6NF%8J #-K$**5]*88$9O.'L8 &*$ I$%K$77$%.'/ &$% Y<8$'K<7*7 6N% ^L8*'*&$' *'7K$7-'&$%$ <.EF *5 T$%$*EF F)F$%$% \'$%/*$' 78$F8 .'& &*$ o<'8*6*A*$%.'/ &$% Y<8$'.'7*EF$%F$*8J .5 7*$ *' V$'7*8*0*8B87<'<9_7$' &$% '.L9$<%$' Y<8$' <.7A.#$%8$': Y*7 *'8$%'<8*-'<9$' \'8#*EL9.'/$' 7*'& A. 0$%6-9/$': b$/$' &$%$' /%.'&7B8A9*EF$% T$&$.8.'/ 7-998$ <.EF 0-' &$.87EF$% V$*8$ *'69.77 <.6 &*$ I$%K$77$%.'/ &$% T<7*7&<8$' /$'-55$' #$%&$':

Y*$ P$<L8*0*8B872 .'& W'0$'8<%K$%$EF'.'/$' 7*'& 6N% ^L8*'*&$' A. 0$%K$77$%' .'& *'7K$7-'&$%$ 6N% F)F$%$ ^KK%B'&$ &.%EF &$' I$%/9$*EF 5*8 eO%*5$'8$99$' Y<8$' A. 0<9*&*$%$': Y*$ T$%$*878$99.'/ .'& o<9*6*A*$%.'/ $*'$7 0-' &$' L-55$%A*99' Z-&$7 .'<KFB'/*/$' U%-/%<557_78$57 #*$ (\D[P\VG*78 $%6-%&$%9*EF:

RN% @Y2($%'K$%$EF'.'/$' *78 $*'$ #$*8$%$ I$%K$77$%.'/ &$% K%$''78<K#$*7$' M$*78.'/7K$%$EF'.'/ '.% &.%EF &$' HK$%/<'/ 0-' &$% Y*66.7*-'7'BF$%.'/ <.6 &*$ /$'<.$%$ D$.8%-'$'8%<'7O-%8/9$*EF.'/ .'& &$' HK$%/<'/ A. 5$F% \'$%/*$/%.OO$' $%%$*EFK<%: W' *'8$%'<8*-'<9$' T$'EF5<%L<L8*0*8B8$' #*%& &$%A$*8 &<7 U-8$'A*<9 0-' &*%$L8$' M)7.'/70$%6<F%$' $%O%-K8: *'/$7$8A8 #$%&$']-'8$ Z<%9- I$%6<F%$' .'& &8%5*'*78*7EF$ M)7.'/70$%6<F%$' <.6 T<7*7 &$% $V_{D}2$]$8F-&$ -&$% <.EF &$% ZF<%<L8$%*78*L$'5$8F-&$: a.% \'8#*EL9.'/ &*7% &*%$L8$' M)7.'/70$%6<F%$' 6N% @Y2($%'K$%$EF'.'/$' 7*'& '-EF .56<'/%$*EF$ ^%K$*8$' $%6-%&$%9*EF: Y$% ^.6#<'& L<''h$&-EF A. $*'$% '$.$' +$'$%<8*-' 0-' PEF'O%-/%<55$' 6N% ($%'K$%$EF'.'/$' 6NF%$'J*' &$'$' 0-5 ^'7<8A F$% &*$ M$*78.'/ 6N% h$&$' $*'A$9'$' T%$''78<K K$%$EF'$8 #*%&: ^98$%'<8*0$' 0-' DBF$%.'/79)7.'/$' #*$ A: T: <.6 T<7*7 &$% $VU_{D}2$]$8F-&$ F<K$' &$' $%L$''K<%$' I-%8$*9 &$% /$%*'/$%$' PEF'A$*8J &*$ $%%$*EFK<%$ +$'<.*/L$*8 7-998$ h$&-EF <'F<'& 0-' T$'EF5<%LO%-K9$5$' <.6/A*/8 #$%&$':

W5 a.7<55$'F<'/ 5*8 &$' 0$%K$77$%8$' ($%'K$%$EF'.'/$' *78 <.6 &$' #$7$'89*EF$' T$*8%</ &$% '.L9$<%$' Y<8$'0$%7-%/.'/ F*'A.#$*7$': *'$ $%F)F8$ +$'<.*/L$*8 $%6-%&$%8 $*'$ L-'7*78$'8$ T$%$*878$99.'/ &$% '.L9$<%$' Y<8$' 6N% &*$ M)7.'/ &$% G%<'7O-%8/9$*EF.'/: Y*$ \%6<77.'/ &$% ^KFB'/*/L$*8 0-' <99$' a.78<'&7B'&$%.'/$' 0-' (NF95*88$9 .'& T%$''78-66 $%6-%&$%8 69$e*K9$.'& <'#$'&$%6%$.'&9*EF$ U%-/%<557_78$5$J #$9EF$ &*$ ^%K$*87K*K9*-8F$L$' 6N% &*$ ($%'K$%$EF'.'/ <.7/$F$'& 0-']<78$%K*K9*-8FL' $%78$99$':

RN% V8)%6<99<'<9_7$' &$7 /$7<58$' P$<L8-%<'9</$'0$%F<98$'7 #.%&$' &*$ /$L-OO$98$' P$EF$'O%-/%<55$ $%78$998J *' &$'$' 8F$%5-F_&%<.9*7EF$ V_78$5E-&$7 &*%$L8 5*8 @Y2($%'5-&99' /$L-OO$98 7*'&: RN% #*EF8*/$ 7*EF$%F$*878$EF'*7EF$ T$#$%8.'/$' #*$ &*$ Y$K-%*$%.'/7$%$*/'*77$ *' YbP .'& &$' R%*7EF&<5O69$*8.'/7K%.EF <97 ^.79$/.'/72 78)%6<99 *78 $*'$ 0$%K$77$%8$]-&$99*$%.'/ &$% I$%5*7EF.'/70-%/B'/$ &$% (NF95*88$978%)5.'/ *5 P$<L8-%&%.ELK$FB98$% &.%EF ZRY2]-&$99$ $%6-%&$%9*EFJ .5 &*$ ($%'$*'8%*887K$&*'/.'/$' <.7%$*EF$'& /$'<. A. K$78*55$': Y*$])/9*EFL$*8$' &$% %$<9*78*7EF$' V8)%6<99K$%$EF'.'/J &*$ *' &$' /$L-OO98' PEF'O%-/%<55$' /$/K' 7*'&J L)''$' '.% '<EF $*'$% &$%<%8*/$']-&99%#$*8$%.'/ 0-99 /$'.8A8 #$%&$':

‘ 5 &$’ *’7<8A &$% %$<L8-%OF_7*L<9*7EF$’ T$%$EF’.’/70$%6<F%$’ 6N% &*$ 7*EF$%F$*878$EF’*7EF$’ ^’#$’&.’/$’ <.7%$*EF$’ <KA.7*EF$%’J 7*’& &*$ F$.8$ 0$%6N/K<%$’ .’& &*$ #$*8$%$’8#*EL$98$’ I$%6<F%$’ &.%EF I$%/9$*EF 5*8]$77&<8$’ 0-’ \eO$%*5$’8$’ -&$% &*%$L8 0-’ &$% P$<L8-%<’9</$ .56<’/%$*EF A. 0<9*&*$%$’: D.% &.%EF &*$ HK$%O%N6.’/ &$% T$%$EF’.’/70$%6<F%$’ <’F<’& eO%*5$’8$99$% \%/$K’*77$ L)’’$’ &*$ +$’<.*/L$*8 .’& &*$ a.0$%9B77*/L$*8 &$% \%/$K’*77$ 6N% ^’#$’2 &.’/7O%-K9$5$ K$78*5 58 #$%&$’:

4.8 Literatur zum Forschungsbereich „Reaktorphysik“

kT\P21k b:T$%’’<8 $8 <9:C ^OO9*E<8*-’ -6 D.E9$<% Y<8< M*K%<%*$7 T<7$& -’ f\R23:3J \DYRkT2IW<’& f\DYM2@:3 8- MbP Z%*8*E<9*8_ <’& T.%’.O U%-K9$57:W’8: Z-’6: -’ D.E9$<% Y<8< 6-% VE*$’E$ <’& G$EF’-9-/_J G%*$78 1ddn

kT\P23k b:T$%’’<8J Y:M.8AJ f:($*’$%8J]:]<88$7J y%78$99.’/ .’& I<9*&*$%.’/0-’ b*%L.’/7p$%7EF’*887K*K9*-8F$L$’*5 VZ^M\ 2R-%5<8<.6 &$% T<7*7 &$% $0<9.*$%8$’ Y<8$*$’ f\R23.’& \DYRkT2IW6N% (%*8*L<9*8B872 .’& P$<L8-%<.72 9$/.’/7K$%$EF’.’/$’ 7-#*$ V8)%6<99<’<9_7$’yW(\ m21id S1ddlX

kT\P2@k b:T$%’’<8J V:M<’/$’K.EFJ]:]<88$7J b:a#$%5<’’C I<9*&<8*-’ -6 D.E9$<% Y<8< M*K%<%*$7 6-% P$<E8-% V<6$8_<’& Y$7*/’ Z<9E.9<8*-’7: U%-E: W’8: Z-’6: -’ D.E9$<% Y<8< 6-% VE*$’E$ <’& G$EF’-9-/_DY3>>1J G7.L.K<J f<O<’J I-9:1WVVD >>332@1@1O: i i l S3>>1X

kTcYk T:M: T%-<&F$<&J T:G: P$<%&$’J Z:]:c-OO$%J f:f: b</7EF<9J <’& Z:I:U<%L7J ;V$’7*8*0*8_2<’& .’E$%8<*’8_2K<7$& E%*8*E<9*8_7<6$8_0<9*&<8*-’ 8$EF’*p$7qD.E9:VE*:\’/: 1lmj@l>2@m8B>>lX

kTDYk I:D:]<’-LF*’ $8: ^9:C TP[DY23:3 P.77*<’ \0<9.<8$& D$.8%-’ P$<E8*-’ Y<8< M*K%<%_W^\^2DYV dlX>: P$0: i S1ddlX

kTP[21k Z:c:]:T%-$&$%7J ;\’8#*EL9.’/7<%K$*8$’ 6N% &*$ ’$.8%-’$’OF_7*L<9*7EF$ ^.79$/.’/0-’ R-%87EF%*889*EF$’ Y%.EL#<77$%%$<L8-%$’ SRY bPX 5*8 L-5O<L8$’ Y%$*$EL7/*88$%’ *’ F$e</-’<9$’ T%$’’$9$5$’8$’;J (R(=>8 S1dd3X

kTP[23k Z:c:]:T%-$&$%7J P:Y</<’J I:V<’EF$AJ ^:G%<09$$0J ;(^UP[V2\C]-&.9<% U%-/%<5 V_78$5 6-% D.E9$<% P$<E8-% ^’<9_7*7J V8<8.7<’& P$7.987 -6 V$9$E8$& ^OO9*E<8*-’7qf<F%$78</.’/ ($’8$EF’*L YN77$9&-%6 S3>>lX

kTP [2@k R:T: T%-#'J $8 <9:J }] ZDU I$%7*-' =} G%<'7: ^5: D.E9: V-E:J i n3@
M^2 ‘ P2>32@d@= SD-0$5K$% 3>>3XQ M: V: b <8$%7J $&:C }] ZDUx‘ 7$%y
]<'.<9J I$%7*-' 3:@:>J}M^ 2 ‘ P2>323mn^O%*9 3>>3X

kTP [2Ik Z:c:]:T%-$&$%7J I:V<'EF$AJ \:V8$*'J ^:G%<09$$0J ! I<9*&<8*-' -6 Z-.O9$&
D$.8%-' UF_7*E7 <'& GF$%5<9 c_&%<.9*E7 ^'<9_7*7 6-% cUM b P;J WZ^UU}@J
Z-%&-K< S3>>@X

kZc^k ZF<'/2c- M$$J G: f: Y-#'<%J ;^OO9*E<8*-' -6 < G#-2M$0$9 ^EE9%<8*-'
]$8F-& 8- 8F$ U*'2K_2U*'] .98*/%-.O VU@ ^OO%-e*5<8*-' qG%<'7: ^5:
D.E9: V-E:J i=J 3I@ S3>>1X

kZWDk Z-5O.8$% W'&$e -6 D$.8%-' Y<8< SZWDY^X Y<8<K<7$ I$%7*-' -6 3>>I2>@2>i

kZDYk Z\DYM23C GF$ ZF*'7 D.E9$<% Y<8< Z$'8$%C f\DYM23J GF$ ZF*'7
\0<9.<8$& D.E9$<% Y<8< M*K%<%_ 6-% D$.8%-' P$<E8*-' Y<8<: P$O: W^\^2
DYV2dnP$0: @ S1ddXn VF$' o /K*<-J bU\Z V+ 31]$$8*'/J G7.L.K<J
[E8-K$% 1>J 3>>1

kY^+k P: Y</<'J Z:c:]:T%-$&$%7J Y: V8%.#$J ;V-.%E$ G%*O \66$E87 -' G%<'7*$'8
^YV T$F<O*-.%q^ZZ^UU}@ V<' Y*$/- S3>>@X

kY^Dk PVWZ Z-5O.8$% Z-&$ Z-99$E8*-'J Y^DGV j V @:>J ['$2J G#-J <'& GF%$$2
Y*5$'7*-'<9J].98*/%-.OJ Y*7E%8 [%&*'<8$7 G%<'7O-%8 V_78$5J E-'8%*K.8$&
K_M-7 ^9<5-7 D<8*-'<9 M<K-%<8-%_J M-7 ^9<5-7J D$#]$e*E- S1dd=XQ
P:\:^9E-.66$J P:V: T<L$%J R: b: T%*'L9$_J Y:P:]<%%J P:Y: [Y$99J
b:R: b<98$%7J Y^DGV j VC ^ Y*66.77*-' ^EE9%<8$& D$.8%<9 U<%8*E9$
G%<'7O-%8 Z-&$ V_78$5;J M^213ddn 2] S1dd=X

k\DYk \DYR21>3 Y<8< R-%5<87 <'& U%-E$&.%$7 6-% 8F$ \0<9.<8*-' D.E9$<% Y<8<
R*9$ \DYR2dm Z%-77 V$E8*-' \0<9.<8*-' b-%L*'/ +%-.OJ ^O%*9 3>>1J
TDM2DZV2IIdI=2>1k>I2P\I

kR^Pk P:\:]<ER<%9<'$ Y:b:].*%C GF$ Df[j D.E9$<% Y<8< U%-E$77*'/
V_78$5J I$%7*-' d1J M^213mh> 2] S[E8-K$% 1ddIXQ P:\:]<ER<%9<'$C D$#
GF$%5<9 D$.8%-' VE<88$%*'/ R*9$7 6-% \DYRkT2IWJ P9<7$ 3: M^213@d 2] V
S\DYR @=Xm]<%EF 1ddIX: U%7'8 0$ %7*-'C Df[j dd:d>

kRWD21k c:R*''$5<''J ^:+<9<8*J D\^ZPU @2Y M b P Z-%$ G%<'7*$'8 T$'EF5<%LJ
R*'<9 VO$E*6*E<8*-'7J D\^ZPU2M2@@= SP$01XJ [E8-K$% 1dd1 Sf<'.<%_ 1dd3X

kRWD23k c:R*''$5<''J c:T<.$%J ^:+<9<8*J P:]<%8*''$99*J P$7.987 -6 M b P Z-%$ G%<'7*$'8 T$'EF5<%L7J D\^kDVZkY[ZSd@X3=J [E8-K$% 1dd@

kRWVk ':R*7EF$%J c:b: b*$7$J!([PW+\D?*'' U%-/%<5 5 A.% T$78*5 5 .'/ &$7 '.L9$<%$'W'0$'8<%7 0-' P$<L8-%K%$''78-66$'*5 T%$''78-66L%$*79<.6;J (R(@>1l S1di@X

kR[P21k P:^:R-%%$78J f: (-O$EL_<'& f2Z c V.K9$8J!GF$\.%-O$<' ^E8*0<8*-' R*9$C \^R23>>@E%-77 7$E8*-' M*K%<%_: '(\^R.7 l imSY$E: 3>>3X

kR[P23k R-%%$78 T: T%-#'J $8<9:J}] ZDU I$%7*-'=J}G%<'7: ^5:D.E9: V-E:J in3@ SD-0$5K$% 3>>3X: SM^2'P2>32@d@=XQ M: V: b<8$%7J $&:C}] ZDUx'7$%y]<'.<9J I$%7*-' 3:@:>J}M^ 2'P2>323mn^O%*9 3>>3X

kRP^k P:R%<*L*'J U b P T$'EF5<%L -' ''E-'8%-99$& P-&7 b*8F&%<#<9<8 a$%-U-#$%J R*'<9 P$O-%8J D\^kDVZkY[ZSdK3>J V$O8$5K$% 1ddn

k+]^k T:+5<9J \:R:]-7$%J b:a#$%5<''J V:M<'/$'K.EFJ b: b$K$%J b:T$%''<8J]:]<88$7C Z-5O<%*7-' -6 Z%*8*E<9*8_ T$'EF5<%L Z<9E.9<8*-'7 .7*'/ \DYRkT2 I W<'& f\R23 T<7$& D$.8%-' Z%-77 V$E8*-' M*K%<%*$7: W'8: Z-'6 -' D.E9$<% Z%*8*E<9*8_ V<6$8_J ^9K.p$%p$J D$#]$e*E-J ' V^J V$O8: 1n231J 1dd=

k+P'k ':+%.'&5<''J ':P-F&$J V:]*88</J Y j D@Y ? GF%$$2Y*5$'7*-'<9 Z-%$]-&$9 6-% V8$<&_2V8<8$ <'& G%<'7*$'8 ^'<9_7*7 -6 GF$%5<9 P$<E8-%7J U%-E: [6W'8: G-O:]8/:-' ^&0<'E$7*' P$<E8-% UF_7*E7 <'&]<8F$5<8*E7 <'& Z-5O.8<8*-'*'8-8F$ D$e8]*99$''*.5 SUF_7-%3>>>XJ U*887K.%/FJ 'V^J]<_ n211J3>>>

kc^ck Y:]:c<F'J (:D:W0<'-0J U: P<0$88-J]:P*78</'-J;\66*E*$'8 c_K%*& D\]kT\] G%<'7*$'8]$8F-&qU%-E: UF_7-%3>>l 2GF$ UF_7*E7 -6 R.$9 Z_E9$7 <'& ^&0<'E$& D.E9$<% V_78$57J ZF*E</-J ^O%*9 3=23d S3>>lX

kcs]k ^:cB5B9B*'$' $8:<9:J I<9*&<8*-' -6 Z-.O9$& D$.8%-' (*'$8*EkGF$%5<92 c_&%<.9*E Z-&$7J U<%8 3C ^'<9_7*7 -6 < I I \P2 I I > 8%<'7*$'8 SM-0**7<21XJ ^''<97 -6 D.E9$<% \'$%/_ 3dJ3==23dn S3>>3X

kc\Vk ':c77J V:M<'/$'K.EFJ b:a#$%5<''J D.E9$<% Z-&$7 <'& Y<8< M*K%<%*$7 6-% P$<E8*0*8_ <'& D.E9*&$ W'0$'8-%_ Z<9E.9<8*-'7: \'P[V^R\ 3>>@J U<%*7J 3=:23mD-0: 3>>@

kc [Mk Y: R: c -99$'K<EFJ D:] : U$8%*$J M:R: M<'&$%7C (\D [2 l WC ^ /$'$%<9 p<&%<8*E 0$%7*-' -6 (\D [O%-/%<5 : [PDM D ' P \ +kZVY23kPjml -9: 3kV$E8: 1jhV$O8 1ddd

kW l ^21k (:W0<'-0 $8:<9:J U b P] <*' V8$<5 M*'$ T%$<L S] VMTX T$'EF5<%LJ I -9:WC R*'<9 VO$E*6*E<8*-'7J D \ ^kDVZkY [ZSddXiJ ^O%*9 1ddd

kW l ^23k (:W0<'-0 $8: <9:J U b P] <*' V8$<5 M*'$ T%$<L S] VMTX T$'EF5<%LJ I -9 WW ? W l J P$7.987 -6 UF<7$ W 8- UF<7$ WWWJ D \ ^kDVZkY [ZS3>>>X31J Y [ZS3>>3X13J Y [ZS3>>@X31

kW l ^2@k (:W0<'-0J D:G-&-%-0<J \:V<%8-%*J ' 7*' / 8F$ [\ ZYkDPZ U b P] VMT T$'EF5<%L 8- V8.&_ Z.%%$'8 D.5$%*E<9 <'& Z-5O.8<8*-'<9 W77.$7 -6 Z-.O9$& Z<9E.9<8*-'7J D.E9:G$EF'-9-/_J1 l 3J3Jd=S3>>@X

kW l ^2 l k (:W0<'-0 $8:<9:J T b P G.%K*'$ G%*O SGGX T$'EF5<%LJ I -9: WC R*'<9 VO$E*6*E<8*-'7J D \ ^kDVZkY [ZS3>>1X1J f.'$ 3>>1

kW l ^2=k (:W0<'-0J ^: [97-'J \:V<%8-%*J [\ ZYkDPZ T b P G.%K*'$ G%*O G%<'7*$'8 T$'EF5<%L <7 < T<7*7 6-% Z-5O%F'7*0$ o<9*6*E<8*-' <'& V8.&_*'/ T$78 2 \78*5<8$ Z-.O9$& Z-&$7J D.E9:VE*: \ ' /:J1 l iJD-3J1d=23>jh[E8 3>>l

kf \ R21k GF$ f \ R23:3 D.E9$<% Y<8< M*K%<%_J f \ R2P$O-%8 1jh^O%*9 3>>>

kf \ R23k GF$ f \ R23 8F$%5<9 '$.8%-' 7E<88$%*'/ 9<# &<8< 9*K%<%_J K_ f: ($*'$%8 <'&] :] <88$7J 1d i l : = '$.8%-' 5-&$%<8-% 5<8$%*<97: V.5 5<%_ &-E.5$'8<8*-'C W^ \ ^2DYV2131 P$0: 1J V$O8: 1ddl

kf \ Dk (: VF*K<8<J G: (<#<'-J G: D<L</<#<J [: W#<5-8-J f: (<8<L.%<J G: R.L<F-%*J V: ZF*K<J ^: c<7$/<#<J G:] .%<8<J c:] <87.'-K.J G: [F7<#<J j : D<L<h*5<J G: j -7F*&<J ^: a.L$%<'J] : (<#<*J] : T<K<J] : W7F*L<#<J G: ^7<5*J G: b<8<'<K$J j : b<8<'<K$J] : W/<7F*%<J D: j<5<5.%-J c: (*8<A<#<J D: j<5<'- <'& c: G<L<'-C}f<O<'7 \0<9.<8$& D.E9$<% Y<8< M*K%<%_ I $%7*-' @ P$0*7*-'2@C f \ DYM2@:@J}f: D.E9: VE*: G$EF'-9: @dJ 113= S3>>3X

k(W \ k \ : (*$6F<K$%J !GF$ (R(WDP2V$8 -6 /%-.O Z-'78<'87Q D.E9$<% Y<8< T<7*7 <'& 6*%78 P$7.987 8- 8F$ P$E<9E.9<8*-' -6 R<78 a$%- U-#$% P$<E8-%7;J (R(1=6i S1d8X

k([Zk M: (-EFJ V: VEF--6J !GF$ W7-8-O$ Z-%%$9<8*-' \eO$%*5$'8 WZ \ ;J \ V^PY^3ki1J \ ' P mhDJ (6(@@@n51di1X

k([Y21k W:(-&$9*J U%-/%$77 -' Z-5O.8<8*-'<9 G--97 6-% @Y V$'7*8*0*8_ <'&
''E$%8<*'8_ ^'<9_7*7J U%-E: [\ZY2D\^ V$5*'<% -' @Y Y$8$%5*'*78*E
P<&*<8*-'J G%<'7O-%8 Z-5O.8$% U%-/%<57 R$<8.%$7J ^OO9*E<8*-'7 <'&
U$%7O$E8*0$7J U<%*7J 32@ Y$E: 1ddm

k([Y23k W:(-&$9*J V'VY@YC ['$2J G#-2 <'& GF%$$2Y*5$'7*-'<9 Z%-77 V$E8*-'
V$'7*8*0*8_ <'& ''E$%8<*'8_ Z-&$: [\ZYk D\^2YTJ D\^ O<EL</$

kM^D21k V:M<'/$'K.EFJ b:]<.%$%J b:b$%'$%J Z-<%7$]$7F R9.e2\eO<'7*-'
]$8F-& 6-% 8F$ ^'<9_7*7 -6 VO<E$ G*5$ \66$E87 *' M<%/$ M b P Z-%$7J
D.E9:VE*:\'/: @nJl@n 2l=n31dKn

kM^D23k V:M<'/$'K.EFJ b:]<.%$%J b:b$%'$%J c*/F2[%&$% VEF$5$7 6-% D$.8%-'
(*'$8*E7 Z<9E.9<8*-' K<7$& -' < M-E<9 U-9_'-5*<9 ^OO%-e*5<8*-'J
D.E9:VE*:\'/:mJ=>i 2=1n31dKn

kM^D2@k V: M<'/$'K.EF $8 <9:J Z-5O%$F$'7*0$ ''E$%8<*'8_ <'& V$'7*8*0*8_ ^'<9_7*7
6-% Z-.O9$& Z-&$ Z<9E.9<8*-' -6 I I\P U9<'8 G%<'7*$'87J D.E9: \'/: <'&
Y$7*/'J I-9 3@=k32lJ =312=l>JS3>>=X

k]^Vk b:]<7EF$LJ ^: P*'$*7L*J G: V.A.L*J x 2D: ZF$'J]/:]-%*J V: b<'/ SRa(XJ
j: G-K*8<J V<: (-'&-J c: j<5<'- <'& V: R.h*8< SfDZXJ G: Z<&*-. SZ\^2
Z<&<%<EF$XJ U: Z-78$ SZ\^2+%$'-K9$XJ GF$ VW]]\P2WWW <'& VW]]\P2WI
Z-&$ R<5*9_C 32Y <'& @2Y]$EF<'*78*E V*5.9<8*-' G--97 6-% P$<E8-%
G%<'7*$'87 <'& ^EE*&$'87J G$EF'*E<9]$$8*'/ -' U%-/%$77 *' Y$0$9-O5$'8
<'& '7$ -6 Z-.O9$& Z-&$7 6-% ^EE*&$'8 ^'<9_7*7J I*$''<J ^.78%*<J
D-0$5K$% 3m23iJ S3>>@X

k]WVk]*7.J $8: <9:C GF$ Z-5O%F'7*0$]$8F-&-9-/_ 6-% ZF<99$'/*'/ T b P R.$9
^77$5K9_ <'& Z-%$ Y$7*/' '7$& <8 RP^]^G[ ]\ ^DUJ Uc j V[P 3>>3J
V$-.9J (-%$<J [E8-K$% n21>J 3>>3

k]WG21k V:]*88</ $8:<9:J I<9*&<8*-' -6 Z-.O9$& D$.8%-'kGF$%5<92c_&%<.9*E Z-&$7J
U<%8 1C ^'<9_7*7 -6 < I I\P21>>> G%<'7*$'8 ST<9<L-0-2lXJ ^''<97 -6 D.E9$<%
\'$%/_ 3iJi=n2d@JS3>>1X

k]WG23k V:]*88</ $8 <9:J D$.8%-'2(*'$8*E Z-&$ I<9*&<8*-' </<*'78]$<7.%$5$'87 *'
8F$]-7E-# I21>>> a$%-2U-#$% R<E*9*8_J D.E9: \'/: <'& Y$7*/'J
I-9 3@=k32lJli=2=>JS3>>=X

kD\^23k GF$ W'8$%'<8*-'<9 Z%*8*E<9*8_ V<6$8_ T$'EF5<%L \0<9.<8*-' U%-h$E8
SWZVT\UXJ D\^kDVZkY[ZSd=X>@J 3>>l \&*8*-'

kD [Pk Z: D-%&K-%/J] : V<90<8-%$7J !V8<8.7 -6 8F$ f \R \0<9.<8$& Y<8< M*K%<%_y
U%-E: W'8: Z-'6: -' D.E9$<% Y<8< 6-% VE*$'E$ <'& G$EF'-9-/_J +<89*'K.%/
1ddlJ O:m>: f \RR 2@:> V8<%8$% R*9$ Sf \RkY [Z 1dddX

k [T \k U: [K$%9$J \%78$99.'/ $*'$% m +%.OO$'L-'78<'8$' T*K9*-8F$L 5*8 \'$%/*$'
K*7 1=>] $I 6N% (^UP [VJ Y*O9-5<%K$*8 ''*0$%7*8B8 (<%97%.F$J
[L8-K$% 3>>l

k [\Zk U%$&*E8*-' -6 D$.8%-' \5K%*889$5$'8*' 8F$ P$<E8-% U%$77.%$ I$77$9C
I \D'V21 <'& I \D'V2@ T$'EF5<%L7J [\ZYkD\^kDVZ U.K9*E<8*-'J 3>>>

kU^Dk P: T)$%J P: T)F5J c: R*''$5<''J P:] N99$%J GF$ E-.O9$& '$.8%-'*E7 <'&
8F$%5<9 F_&%<.9*E7 E-&$ 7_78$5 U^DT [x6-% U b P 7<6$8_ <'<9_7*7J
($%'8$EF'*L =jhld 2=l S1dd3X

kU^'21k ^:U<.8AJ V:M<'/$'K.EFJ ^:V$.K$%8J b:a#$%5<''J P$7.987 -' 8F$
[\ZYkD\^ Z=+n2] [xT$'EF5<%L -K8<*'$& #*8F 8F$ Y*7E%8 [%&*'<8$7
Z-&$ Y [PGJ U%-/%$77*' D.E9$<% \'$%/_J I-9:l=JD-32lJ1=@21mJS3>>lX

kU^'23k ^:U<.8AJ ^: T*%LF-6$%J Y [PG2GYC ^ G%<'7*$'8 D$.8%-' G%<'7O-%8 Z-&$ #*8F
R.99_ W5O9*E*8 G*5$ W'8$/%<8*-'J D.E9: VE*: \'/:J 1l=J3dd2@1dJS3>>@X

kU^'2@k ^: U<.8AJ ^: T*%LF-6$%J Z-.O9*'/ -6 G*5$2YO'&$'8 D$.8%-' G%<'7O-%8
GF$-%_ #*8F 8F$ GF$%5<9 c_&%<.9*E7 Z-&$ ^GcM\G <'& ^OO9*E<8*-' 8- 8F$
P7<%EF P$<E8-% RP] 2WWJ D.E9: VE*: \'/:J1l=J@3>2@l1JS3>>@X

kP^Tk Z: P<K*8*J ^: P*'$*7L*J \e8$'7*-' -6 (WD@YJ < (*'$8*E7 Z<O<K*9*8_ -6
I^PW^DGJ 6-%] -&$9*'/ R<78 G%<'7*$'87*' ^EE9%<8-% Y%*0$' V_78$57J
Ucj V [P 3>>l 2 GF$ UF_7*E7 -6 R.$9 Z_E9$7 <'& ^&0<'E$& D.E9$<%
V_78$57C +9-K<9 Y$0$9-O5$'87J ZF*E</-J W99*'-*7J 'V^J ^O%*9 3=23dJ S3>>lX

kP\^k T:G: P$<%&$'J ;U$%8.%K<8*-' 8F$-%_ $*/$'0<9.$ 7$'7*8*0*8_ <'<9_7*7 #*8F
] -'8$ Z<%9- 8$EF'*p$7jqD.E9: VE*: \'/: 1lmJ @m 2@i3 S3>>lX

kPc [k b:^C PF-<&$7J P:M: ZF*9&7C GF$ G [PG GF%$$2&*5$'7*-'<9 Y*7E%$8$
[%&*'<8$7 D$.8%-'kUF-8-' G%<'7O-%8 Z-&$: S [PDM28mmX:
D.E9: VE*: \'/: 1>nS1dd1X

kV\'k ^:V$.K$%8J b:a#$%5<''J V:M<'/$'K.EFJ V-9.8*-' -6 8F$ Z=+n@ 2Y
\e8$'7*-' T$'EF5<%L K_ 8F$ V_D Z-&$ G [PGJ GF$ UF_7*E7 -6 R.$9 Z_E9$7
<'& ^&0<'E$& D.E9$<% V_78$57 SUF_7-%3>>lXJ ZF*E</-JW99:J
^O%*9 3=23dJS3>>lX

kVG\k \: V8$*'J \: b*$/'$%J Z: T%-$&$%7J!(.%AK$7EF%$*K.'/ &$7 (^UP[V2
]-&.97 T‘PD‘UA.%'.5$%*7EF$'M)7.'/ &$% ^KK%<'&/9$*EF.'/$';J
W'8$%'$% (^UP[V D-8*A d S1di3X: ['2 9*'$ 0$%6N/K<%*' (^UP[V

kVG‘k V8.&70*LC Z^V][2IJ^R.$9^77$5K9_T.%'.O U%-/%<5J‘7$%7]<'.<9J
VVU2>1kI>> P$0@Jf.9_ 3>>@

kI^Dk G:I<'88-9< $8<9:JI<9*&<8*-' -6 Z-.O9$& Z-&$7 .7*'/ II\P U9<'8
]$<7.%$5$'87J D.E9: \'/:<'& Y$7*/'JI-9 3@=k32IJ=>n2=1dJ S3>>=X

kb\Wk R:U:b$*, $8<9:JI<9*&<8*-' -6 Z-.O9$& D$.8%-'*E7 k GF$%5<92c_&%<.9*E7
Z-&$7 6-% II\P P$<E8-%7 SI^MZ[XJ RWV^23>>@J U%-E: -6 \‘ P7<%EF*'
P$<E8-%V<6$8_J M.e$5K-.%/J D-0$5K$% 1>21@J3>>@J \‘P31>3m
WVTD d32idI2m>@ 2d

kbW\k c:b: b*7JV8<8.7.'& b$*8$%$'8#*EL9.'/ &$7W'0$'8<%E-&$7 ([PW+\DJ
&$%VA$'<%*-E-&$7 ([PP\Z.'&V[M\o7-#*$ &$7 D<EF#B% 5$E-&$7
Z^M[PJ Ra(^ m1 S3>>3X

kb[Mk Y:b-99J!+P‘Z^MJ$*'U%-/%<5 57_78$5 A.% T$%$EF'./ 5<L%-7L-O*7EF$%
+%.OO$'L-'78<'8$';J (R(31>i S1dmX.'& ['2 9*'$ Y-L.5$'8<8*-'
(^UP[V

kbU\k U:[K9-A*'7L_J!GF$ V8<8.7-6 8F$ \DYR U%-h$E8;J bU\Z]$$8*'/J ^*e $'
U%-0$'E$J R%<'E$J]<_ 3m23iJ 3>>l

kab\k b:a#$%5<''JV:M<'/$'K.EFC (%*8*L<9*8B87K$%$EF'.'/$' 6N% 7EF#$%$
V8)%6B99$ 5*8 ($%'A$%78)%.'/ .'&o<9*6*L<8*-' &$% P$EF$'5$8F-&*L:
+PV2^23id1

5 Brennstabverhalten

Y$% U%-A$77 &$% '.L9$<%$' \'$%/*$$%A$./.'/J &*$ ($%'7O<98.'/J /$7EF*$F8 *5 ($%'K%$''78-66J &$% *5 P$<L8-%L$%' *' E<: I>:>>> 9<'/$'J &N''$' cN99%-F%$'J E<: = 5 9<'/$' A_9*'&%*7EF$'J <' &$' \'&$' <K/$&*EF8$8$' P)F%$' 0-' E<:1E5 Y.%EF5$77$% .'&'.% E<: >Jn5 5 b<'&78B%L$.'8$%/$K%<EF8*78: Y$% ($%'K%$''78-66 S‘ [3 -&$%] [k *78*' 8<K9$88$'6)%5*/$' +$K*9&$'J&$' U$99$87J*5 cN99%-F%*''$%$' /$78<O$98 .'& 6N998 &$' W''$'%<.5 &$7 cN99%-F%$7 6<78 0-9978B'&*/ <.7: cN99%-F% .'& ($%'K%$''78-66 K*9&$' A.7<5 5$' &$' T%$''78<K:

+<'A *5 +$/$'7<8A A. 7$*'$5 7EF$*'K<% $*'6<EF$' ^.6K<. *78 &<7 +$7EF$F$' *5 T%$''78<K 0-' <.,$%-%&$'89*EF$% (-5O9$e*8B8: Y*$7 9*$/8 A.5 $*'$' &<%<'J &<77 7$F% 0*$9 0$%7EF*$&$'$ '.L9$<%$J 5$EF<'*7EF$J EF$5*7EF$ 7*EF #BF%$'& &$7 T$8%*$K$7 B'&$%'&$ U%-A77 <.6 &$' T%$''78<K $*'#*%L$'J A.5 <'&$%$' &<%<'J &<77 &*$ cN99$ /9$*EFA$*8*/ 7$F% /$/$'7B8A9*EF$ ^'6-%&$%.'/$' $%6N99$' 5.77: V*$ 5.77 5)/9*EF78 &N'' 7$*'J .5 &$' ^K69.77 &$% &.%EF ($%'7O<98.'/ *5 W''$%$' $'878<'&$'$' bB%5$ '<EF <.,$' A.5 (NF9#<77$% '*EF8 A. K$F*'&$%'J 7*$ 5.77 78<K*9 /$'./ 7$*'J .5 &*$ %<&*-<L8*0$' V8-66$ &*EF8 0$%7EF9-77$' *5 W''$%$' A. F<98$' .'& 7*$ 5.77 $*'#*%L$'&$' (%B68$' &.%EF I$%6-%5.'/$' '<EF/K'J-F'$A.%$*,$':

a.% T$&$.8.'/ &$7 T%$''78<K2I$%F<98$'7*5 (-'8$e8 &$% P$<L8-%7*EF$%F$*876-%7EF.'/ #.%&$ 6$78/$78$998 kM^V >1k! " bBF%$'& &$% T$78%<F9.'/ 0-' T%$''78BK$' *5 P$<L8-% 0$%.%7<EF8 &$% VO<98.'/7O%-A$77 $%F$K9*EF$ a$%%N88.'/$' &$% OF_7*L<9*7EF$' .'& 8F$%5-&_'<5*7EF$']<8$%*<9$*/$'7EF<68$' 0-' T%$''78-66 .'& cN99$: Y<%NK$% F*'<.7 $'878$F8 $*' L-5O9$e$7 8F$%5-25$EF<'*7EF$7 V_78$5J &<77 /$O%B/8 *78 0-' 7$F% 78$*9$' %<&*<9$' G$5O$%<8.%2+%<&*$'8$' *5 T%$''78-66J &$% cN99$.'& <.EF *5 (NF95*88$9: W' &$% +$7<587EF<. *78 &<F$% $*' T%$''78<K <99$7 <'&$%$ <97 $*' $*'6<EF$7 V_78$5C

1: Y$% T%$''78<K *78 $*'$7 &$% L-5O9$e78' K$L<''8$' 8$EF'-9-/*7EF$' V8%.L8.%$':

3: \% *78 0-' F-F$% 7*EF$%F$*878$EF'*7EF$% T$&$.8.'/J &< $% &*$ $%78$ T<%%*$%$ A.% I$%F*'&$%.'/ 0-' VO<98O%-&.L82R%$*7$8A.'/$' &<%78$998:

@: Y$% T%$''78<K 5.77 .'8$%7EF*$&9*EF78$' T$&*'/.'/$' 78<'&F<98$'J &*$ NK$% K$8%*$K9*EF$ T$&*'/.'/$' F*'<.7 &.%EF <'-5<9$' T$8%*$K -&$% F_O-8F$8*7EF$ V8)%6B99$ <97 <.EF 7EF9*$,9*EF &.%EF $*'$M<'/A$*89</$%.'/ $'878$F$' L)''$' " :;:

5.1 Fragestellung im Forschungsbereich „Brennstabverhalten“

Y*$ T$5NF.'/$' &$% c$%78$99$% .5 [O8*5*$%.'/ &$7 T%$''78<K2]<8$%*<97 .'& .5 b$*8$%$'8#*EL9.'/ &$% T%$''$9$5$'8$ F<K$' &<A. /$6NF%8J &<77 &$% K$8%*$K9*EF$ *'7<8A &$% T%$''78BK$ F$.8$ '*EF8 5$F% &.%EF (-%%-7*-' K$/%$'A8 #*%&: D$.$ cN99%-F%2b$%L78-66$ 7*'& F-EF L-%%-7*-'76$78: VEFB&$' #*$ I$%K*$/.'/$' &$7 T%$''$9$5$'82VL$9$887J VEF<88$'2(-%%-7*-'J U$99$82Z9<&&*'/2W'8$%<E8*-'2 SUZW%2VEFB2 &$' F<K$' '*EF8 5$F% &$' V8$99$'#$%8 #*$ '-EF 0-% f<F%$': ^.79$/.'/7/%$'A$'J #*$ A: T: &*$ R-%&$%.'/J &<77 &$% T%$''78<K*''$'&%.EL &$' ^.77$'&%.EL &$7 (NF95*88$97 0-' 1mK<% '*EF8 NK$%78$*/$' &<%6J L-''8$' A: T: 5*8 c*96$ 0-' '$.$%$' T%$''78<K2 ‘'8$%7.EF.'/$' &.%EF &<7 M*682[662(%*8$%*.5 -&$% &<7 P[U\ SP-& [0$% U%$77.%$ \eO$%*5$'8X2 (%*8$%*.5 0$%9</$%8 #$%&$': Y*$7$7 0$%9<'/8 '.% '-EFJ &<77 7*EF *5 K$8%*$K9*EF$' *'7<8A &$% bB%5NK%/<'/ 0-5 U$99$8 NK$% &$' VO<98 A.% cN99$ '*EF8 0$%7EF9$EF8$%8J .'& 9B778 &<5*8 *5O9*A*8 $*'$' #7'89*EF F)F$%$' W''$'&%.EL <97 &<7 K*7F$%*/$ ^.79$/.'/7L%*8$%*.5 6N% &$' W''$'&%.EL A.:

Y<5*8 8%8' &*$ ^.79$/.'/7L%*8$%*$' A.% +$#BF%9$*78.'/ &$% T%$''78<K*'8$/%*8B8 6N% 7$*'$ MK'7&<.$% .'8$% <99$' K$8%*$K9*EF$' *'7<8AK$&*''/.'/$' *' &$' c*'8$%/%.'&Q <.EF &$% T%$''78<K2W''$'&%.EL K*9&$8 7-5*8 L$*'$ ^.7'<F5$ 5$F%:]*8 &$% %$9<8*0$' ^K'<F5$ &$% T$&$.8.'/ &$% ^.79$/.'/7L%*8$%*$' %NEL$' /9$*EFA$*8*/ &*$ D-8LNF9L%*8$%*$' 6N% T%$''78BK$.'& &*$ &<A. $%6-%&$%9*EF$' D<EF#$*7$J #*$ 7*$*'' &$' M$*89*''$' &$% P$<L8-%7*EF$%F$*87L-55*77*-' SPV(X A.% ^.79$/.'/ &$% D-8LNF92 V_78$5$ 6$78/$9$/8 7*'&J *' &$']*88$9O.'L8: Y<7 /$'$F5*/.'/78$EF'*7EF &-5*2 '*$%$'&$ (%*8$%*.5 *78 &*$ R-%&$%.'/J &<77 '*EF8 5$F% <97 1> v&$% T%$''78BK$.'8$% &$' T$&*''/.'/$' $*'$7 (NF95*88$90$%9.782V8)%6<997 SM-77 -6 Z--9<'8 ^EE*&$'8 u M[Z^X K$%78$' &N%6$': ^.79$/.'/7L%*8$%*$' #*%L$' F$.8$ K$AN/9*EF $*'$% T%$''78<K2 *'7<8AO9<'.'/ #$'*/$% K$/%$'A$'& <97 &*$7$7 (%*8$%*.5 A.5 VEF<&$'7.56<'/: Y*$ VEF<&$'7.56<'/2^'<9_7$ A.5 M[Z^J &*$ F$.8$ 0-' #7'89*EF F)F$%$' T%$''78<K2 W''$'&%NEL$' <.7/$F$' 5.77J 5.77 9$8A89*EF A$*/$' L)''$'J &<77 &$% VEF<&$'7.56<'/ 6N% &$' +$7<58L$%' *55$% '-EF *' &$' 0-%/$/$K$'$' +%$'A$' 0-' 1> v9*$/8: Y*$7$ \'8#*E L9.'/ 0$%9$*F8 &$%]-&$99*$%.'/ A.5 T%$''78<K2I$%F<98$' .'8$% M[Z^?T$&*''/.'/$' &*$ F$%<.7%</$'&$ T$&$.8.'/:

RN% 8F$%5-F_&%<.9*7EF$ ^'<9_7$' *5 a.7<55$'F<'/ 5*8 +$'$F5*/.'/ .'& ^.67*EF8 #$%&$' F$.8$!T$782\78*5<8$;2PEF'O%-/%<55$ $*'/$7$8A8: (-'7$%0<8*0*8B8$' #$%&$' *' &*$7$' ^'<9_7$' '.% &.%EF $'87O%$EF$'& L-'7$%0<8*0 /$#BF98$ P<'&K$&*''/.'/$' <.6%$EF8$%F<98$': Y*$ 8F$%5-F_&%<.9*7EF$]-&$99*$%.'/ *78

#$*8/$F$'& %$<9*8B87'<F .'& &.%EF .56<'/%$*EF$ eO%*5$'8$99$ \%L$''8'*77$ /$7*EF$%8: ^97 T$*7O*$9 7*'& F*$% &*$ \%L$''8'*77$ <.7 &$% &$.87EF$' W'8$/%<9<'9</$!'OO$% U9$'.5 G$78 R<E*9*8_; A.% GF$%5-F_&%<.9*L &$7 (NF95*88$9O$%9.782V8)%6<997 A. '$''$': Y< *' &$' F$.8*/$' 8F$%5-F_&%<.9*7EF$' ^'<9_7$' &*$ $'87O%$EF$'&$' P<'&K$&*'/.'/$' 5*8 A.'$F5$'& /$%*'/$%$% (-'7$%O<8*O*8B8 <'/$7$8A8 #$%&$'J L)''$'J #*$ '$.$78$ ''7*EF$%F$*87<'<9_7$' *' &*$7$5 a.7<55$'F<'/ A$*/$'J ''7*EF$%F$*8$' .'& I$%$*'6<EF.'/$' *' &$%]-&$99*$%.'/ A.5 T%$''78<K2I$%F<98$' '*EF8 5$F% &<7 D<EF#$*7A*$9 $%%$*EF$': T$*7O*$97#$*7$ A$*/8 &*$ ^.7#$%8.'/ &$% T%$''78<K2]-&$992 ''7*EF$%F$*8$' *5 P<F5$' $*'$% /$'$%*7EF$' ''7*EF$%F$*87<'<9_7$ A.5 D<EF#$*7 $*'$7 VEF<&$'7.56<'/7 0-' L9$*'$% /9$*EF 1>v &<77 &*$ /$'$F5*/.'/78$EF'*7EF 0-%/$7F'$' L-'7$%O<8*O$' P<'&K$&*'/.'/$' <99$*' L<.5 '-EF <.7%$*EF$'J &*$ *'F<98.'/ &$7 1>v 2*/$' VEF<&$'7.56<'/7 5*8 $*'$5 d=v 2*/$' I$%8%<.$'7'*O$<. K$78B8*/$' A. L)''$' S&<7 d=v 2*/$ D*O$<. *78 Bp*O<9$'8 A.5 3s2b$%8 &$% D-%5<9O$%8$*9.'/X: Y*$7 K$9$/8J #*$ 7$F% &*$ T%$''78<K2]-&$99*$%.'/ 6N% M[Z^2T$&*'/.'/$' *' &$' T%$''O.'L8 /$%NEL8 *78: Y*$ /$'<.$%$]-&$99*$%.'/ %$9$0<'8$% T%$''78<K2UFB'-5$'$*78*'7-6$%' .'0$%A*EF8K<% /$#-%&$':

W5 D<EF6-9/$'&$' #$%&$' &*$ \66$L8$.'& UFB'-5$'$ *5 T%$''78-66 .'& cN99%-F% A.7<55$'/$78$998J &*$ 6N% &<7 T%$''78<K0$%F<98$' K$* V8)%6<99K$&*'/.'/$' .'& F*$% 7O$A*$99 K$* F-F$5 ^KK%<'& 5<,/$K$'& 7*'&: ''8$% V8)%6<99K$&*'/.'/$' #*$ &$5 (NF95*88$9O$%9.7878)%6<99 SM[Z^X .'& &$5 P$<L8*O*8B8778)%6<99 SP$<E8*O*8_ W'8*<8$& ^EE*&$'8 uPW^X X F<K$' &*7 c-EF<KK%<'&66L8$.'& 2OFB'-5$'$ $*'$' *'69.77 <.6 5)/9*EF$ T%$''78<K7EFB&$' .'&*'7K$7-'&$%$ <.6 &<7 T$%78$' 0-' cN99%-F%$':

Brennstoff

Y*$ a.'<F5$ &$7 ^KK%<'&7 6NF%8 A.% I$%%*'/$%.'/ &$% bB%5$9$*86BF*/L$*8 *5 '[32 U$99$8: Y*$7 $%/*K8 7*EF <.7 ś&$%.'/$' *' &$% V8%.L8.% &$% T%$''78-66 2]<8%*e .'& &.%EF P*77K*9&.'/: f$ '<EF ^KK%<'& .'& T%$''78-662G$5O$%<8.% L<'' &*$7 $*'$ P$&.L8*-' &$% bB%5$9$*86BF*/L$*8 .5 K*7 A. => vK$&$.8$': Y*$ P$&.L8*-' &$% bB%5$9$*86BF*/L$*8 5*8 A.'$F5$'&$5 ^KK%<'& #*%L8 $*'$% ^K7$'L.'/ &$% a$'8%<98$5O$%<8.% <97 R-9/$ &$7 M$*78.'/7%NEL/<'/7 $'8/$/$'J 7-&<77 9$8A89*EF &*$ /$7O$*EF$%8$ \'$%/*$ *5 T%$''78<K K$* F)F$%$' ^KK%B'&$' #$'*/$% 78<%L <97 &*$ M$*78.'/ <K7*'L8: Y*$ /$7O$*EF$%8$ \'$%/*$ *78 6N% &*$ T$78*55.'/ &$7 VEF<&$'7.56<'/7 $*' K$&$.8$'&$% U<%<5$8$%J &<7*EF &<%<.7 &*$ bB%5K9<78.'/ 6N% &<7 cN99%-F% .'8$% (]IV2T$&*'/.'/$' $%/*K8:

] [x2T%$''78-66 .'8$%7EF$*&$8 7*EF 0-5 ' [32T%$''78-66 &.%EF $*'$ /$%*'/6N/*/ 0$%5*'&$%8$ bB%5$9$*86BF*/L$*8J *5 HK%*/$' 7*'& &*$ ^KFB'/*/L$*8$' F*'7*EF89*EF ^KK%<'& .'& T%$''78-662G$5O$%<8.% BF'9*EF A. &$'$' &$7 ' [32T%$''78-667: Y*$ I$%5*'&$%.'/ &$% bB%5$9$*86BF*/L$*8 9*$/8 K$* E<: = vO%- 1> vU. 2^'8$*9: W' $*'A$9'$' W'O*9$2G$787 #*%& 0-' c<9&$' $*'$O<.7EF<9$]*'&$%.'/ 0-' i v/$6.'&$':

Y<7 %<&*<9$ M$*78.'/7O%-6*9 *5 U$99$8 $%6BF%8 5*8 A.'$F5$'&$' ^KK%<'& $*'$ HK$%F)F.'/ A.5 U$99$82P<'&J 7-&<77 K$*7O*$97#$*7$ <5 U$99$82P<'& *5 7-/: PW]2 T$%$*EF &*$ A#$*6<EF$ M$*78.'/7&*EF8$ *5 I$%/9$*EF A.5]*88$9#$%8 &$7 U$99$87 K$* F-F$' ^KK%B'&$' $%%$*EF8 #*%&: *'$ M$*78.'/7NK$%F)F.'/ A.5 P<'& F*' K$/N'78*/8 &*$ bB%5$<K6.F% A.% cN99$J <'&$%$%7$*87 K$&$.8$8 &*7 HK$%F)F.'/ A./9$*EF $*'$ HK$%F)F.'/ &$7 ^KK%<'&7 <5 U$99$82P<'& 5*8 $'87O%$EF$'&$' ^.7#*%L.'/$' <.6 bB%5$9$*8.'/J T%$''78-665<8%*e2V8%.L8.% .'& K$8%*$K9*EF$ VO<98/<76%$*7$8A.'/: Y< 7*EF &*7% \66$L8 5*8 &$5 ^KK%<'& 6-%89<.6$'& 0$%78B%L8J *78 $*'$ T$%NEL7*EF8*/.'/ *' &$']-&$99<'7B8A$' 6N% bB%5$9$*8.'/ .'& VO<98/<76%$*7$8A.'/ $%6-%&$%9*EF:

Y$% VO<98#B%5$NK$%/<'/ A#*7EF$' U$99$8 .'& cN99%-F%2W''$'7$*8$ #*%& K$$*'69.778 0-' &$% VO<98#$*8$J &$% +<72a.7<55$'7$8A.'/ *5 VO<98J &$5 VO<98/<7&%.EL .'& &$' [K$%69BEF$'$*/$'7EF<68$' 0-' T%$''78-66 .'& cN99%-F%: Y*$ VO<98#$*8$ #*%& U$99$827$*8*/ K$78*55 8 &.%EF D<EF0$%&*EF8.'/J VEF#$99$'J 8F$%5*7EF$ Y$F'.'/ .'& P$9-E<8*-' *'6-9/$ 0-' VO<''.'/7%*77$' *5 U$99$8: \7 A$*/8 7*EFJ &<77 &<7 a.7<55$'#*%L$' &$% /$'<''8$' \66$L8$ A.7<55$' 5*8 &$5 D*$&$%L%*EF' &$7 cN99%-F%7 K$* $*'$5 ^KK%<'& 0-' <K $8#< 3=] b&kL/ $*'$' &*%$L8$' (-'8<L8 0-' T%$''78-66 .'& cN99%-F% 0$%.%7<EF8: Y$% VO<98#B%5$NK$%/<'/ F<8 5*8 T9*EL <.6 &*$ T$78*55.'/ &$% /$7O$*EF$%8$' \'$%/*$ K$* F-F$' ^KK%B'&$' $*'$ /%-,$ T$&$.8.'/: T$* /$7EF9-77$'$5 VO<98 F<8 &*$ +<7A.7<55$'7$8A.'/ *5 T%$''78<K '.% '-EF $*'$' /$%*'/$' *'69.77 <.6 &*$ bB%5NK%8%</.'/J &*$ bB%5$ #*%& 6<78 <.77EF9*$,9*EF &.%EF (-'8<L8 NK$%8%</$':

Y*$ K$8%*$K9*EF$ VO<98/<76%$*7$8A.'/ <97 R-9/$ &$% Y*66.7*-' &$% VO<98/<7$ (% .'& x$ FB'/8 .:<: 0-' &$% (-%'/%),$ &$7 U$99$87 <K: f$ /%),$% &$% 5*889$%$ Y.%EF5$77$% &$7 (-%'7 SA:T: 1> 45X *78J &$78- /$%*'/$%$ R%$*7$8A.'/$' #$%&$' K$-K<EF8$8J 0-%<.7/$7$8A8 &*$ T%$''78-668$5O$%<8.% NK$%7EF%$*8$8 '*EF8 $%F$K9*EF &*$ NK9*EF$' T$8%*$K7#$%8$: Y*$]-&99 A.% T$78*55.'/ &$% VO<98/<76%$*7$8A.'/ '$F5$' &<F$% T$A./ <.6 &*$ <L8.99 (-%'/%),$:]*8 A.'$F5$'&$5 ^KK%<'& 0$%%*'/$%8 7*EF &$% (-%'2Y.%EF5$77$% <5 T%$''78-66<.,$'%<'&: W'7K$7-'&$%$ *' &$% c-EF<KK%<'&2 78%.L8.% &$7 U$99$87 #$%&$' ()%'$% *' $*'$% +%),$'-%&'.'/ 0-' 1 2 3 4 5 6$78/$78$998:

^.7 &*7' ()%'$%' #*%& 8%-8A &$% '*$&%*/$' T%$''78-668$5O$%<8.% VO<98/<7 6%$*/$7$8A8: *' +%-,8$*9 &$7 +<7$7 9</$%8 7*EF *' &$% U-%-7*8B8 &$% c-EF<KK%<'&78%.L8.% $*'J .'& $*' L9$*'$%$% G$*9 #*%& *' &<7 6%$*$ V8<K0-9.5$' <K/$/K': a.7B8A9*EF *78 A. NK$%9$/$'J -K .'8$% G%<'7*$'8$'2T$&*'/.'/$' <.7 &$5 U$99$82P₩] T$*8%B/$ A.% VO<98/<76%$*7$8A./ L-55$':

Hüllrohr

₩5 I$%9<.6 &$% *'7<8AA$*8 #*%& 0-5 cN99%-F% V<.$%78-66 <.6/$'-55$': Y$% V<.$%78-66 9*$/8 -K$%69BEF$''<F *' /$K.'&$'$% R-%5 <97 a*%L-'2[e*& 0-%: M$/*$%.'/7K$78<'&8$*9$.'& <.EF &$% +$6N/$A.78<'& 7*'& 'K' &$' K$8%*$K9*EF$' *'7<8AK$&*'/.'/$' #*$ G$5O$%<8.% .'& b<77$%EF$5*$ K$78*55$'& 6N% &<7 (-%%-7*-'70$%F<98$': Y<%NK$% F*'<.7 5*'&$%8 &*$ [e*&7EF*EF8 &*$ bB%5$9$*8.'/ *5 cN99%-F% .'& 8%B/8 7-5*8 A. $*'$% \%F)F.'/ &$% /$7O$*EF$%8$' \'$%/*$ K$*:

U<%<99$9 A.% K$8%*$K9*EF$' V<.$%78-662^.6'<F5$ 6*'&$8 $*'$ b<77$%78-662^.6'<F5$ 78<88: Y$% b<77$%78-66 0$%8$*98 7*EF &.%EF Y*66.7*-' *5 cN99%-F%J #-K$* <.6 +%.'& &$7 G$5O$%<8.%/%<&*$'8$' 7*EF &$% b<77$%78-66 K$0-%A./8 <' &$% cN99%-F%<.,$'7$*8$ <'9</$%8: HK$%7EF%$*8$8 &$% b<77$%78-66 &*$ 8$5O$%<8.%<KFB'/*/$ M)79*EFL$*87/%$'A$J 7-L-558 $7 A.% 9-L<9$' ^.77EF$*&.'/ 0-' c_&%*&$' *5 cN99%-F%: c*'7*EF89*EF &$7 VEF<&$'7.56<'/7 K$* (]IV *78 &$% b<77$%78-662+$F<98 *5 cN99%-F% $*' U<%<5$8$%J &$% &<7 G$5O$%<8.%2D*0$<. &$7 UF<7$'NK$%/<'/7 0-' &$% 2 A.% 2UF<7$ K$78*558: T$*7O*$97#$*7$ L)''$' =>> 005 b<77$%78-66 *5 cN99%-F% &*7' UF<7$'NK$%/<'/ <.6 $*'$ K*7 A. 1>> ('*$&%*/$%$ cN99%-F%2G$5O$%<8.% 0$%9</$%': *' 0$%78B%L8$7 cN99%-F%2 (%*EF' 6*'&$8 7-5*8 K$%$*87 K$* '*$&%*/$%$' cN99%-F%2G$5O$%<8.%$' 78<88:

(-%%-7*-'76$78*/L$*8 #*%& &.%EF 6-%89<.6$'&$ [O8*5*$%.'/ .'& ś&$%.'/ &$% M$/*$%.'/7A.7<55$'7$8A./ &$% cN99%-F%2]<8$%*<9*$' <'/$78%$K8: cN99%-F%$ 5*8 &$5 M$/*$%.'/7K$78<'&8$*9 D*-K A$*/$' F*$% $*'$ &$.89*EF$ I$%K$77$%./ &$% (-%%-7*-'76$78*/L$*8J 7-#*$ $*'$ 0$%%*'/$%8$ b<77$%78-66<.6'<F5$ /$/$'NK$% &$5 V8<'&<%&2cN99%-F%2]<8$%*<9: a.% T$78*55./ &$7 VEF<&$'.56<'/7 K$* (]IV *78 6N% D*-K2F<98*/$ M$/*$%./$' &*$ ś&$%./ &$% UF<7$'.5#<'&9./78$5O$%<8.% A. K$<EF8$': Y*$7$ UF<7$'.5#<'&9./ FB'/8 '*EF8 '.% 0-' &$% c)F$ &$% G$5O$%<8.% 7$9K78 7-'&$%' <.EF 0-' &$%$' ś&$%./7/$7EF#*'&*/L$*8 .'& 7-5*8 0-' &$% a$*8 A.% *'#*%L./ <.6 &<7 +$6N/$ <K: Y*$ D*-K2$/*$%8$' cN99%-F%$ A$*/$' /$/$'NK$% &$'

V8<'&<%&2cN99%-F%$' $*'$ $%F$K9*EF$ P$&.A*$%.'/ *' &$% +$6N/$2s'&$%.'/72 /$7EF#*'&*/L$*8:

Y<7 c-EF8$5O$%<8.%2cN99%-F%2(%*EF' K'7- #*$ &*$ T$%787O<''.'/ 7*'& 5*8 &$5 UF<7$'A.78<'& &$7 +$6N/$7 /$L-OO$98J &<%NK$% F*'<.7 FB'/$' &*7 */$'7EF<68$' 0-' &$' M$/*$%.'/7K$78<'&8$*9$' &$7 cN99%-F%#$%L78-66$7 <K: D*-K29$/*$%8$ cN99%-F%$ #$*7$' .'8$% 7-'78 /9$*EF$' T$&*'/.'/$' '*$&%*/$%$ T$%787O<''.'/$' <97 V8<'&<%&2 cN99%-F%$ <.6:

Y$% c-EF<KK%<'& K$#*%L8 $*'$ Y$F'.'/ &$7 U$99$87 &.%EF VEF#99' .'& P$9-E<8*-'J 7-&<77 <.6 &<7 cN99%-F% 'K' &$5 W''$'&%.EL <.EF $*' R$78L)%O$%&%.EL #*%L8: Y*$7$ U$99$82*'#*%L.'/ K$&$.8$8 6N% &<7 cN99%-F% $*'$ I-%7O<''.'/J &*$ $*'$ (%*$EF2 0$%6-%5.'/ &$7 cN99%-F%$7 F$%0-%%.68: \'87O%$EF$'& &$% (%*$EF0$%6-%5.'/ 5*'&$%8 7*EF &*$ b<'&78B%L$ &$7 cN99%-F%7 S+%),$'-%&'.'/ 1v K$* $*'$5 ^KK%<'& 0-' =>]b&kL/X: Y<%NK$% F*'<.7 L<'' &.%EF &*$ cN99%-F%2Y$F'.'/ $*'$ ^KO9<8A.'/ 0-' [e*&7EF*EF8$' <' &$% cN99%-F%2^.,$'7$*8$ $%6-9/$'J &< &*7 [e*&7EF*EF8 '*EF8 *' &$% M</$*78J &$% I$%6-%5.'/ A.6-9/$': b$*8$%F*' *78 &*$ ^.77EF$*&.'/ 0-' c_&%*&$' .'8$% $*'$% 7-9EF$' VO<''.'/ F% %<&*<9 <97 *' '56<'/7%*EF8.'/ -%*$'8*$%8J #<7 K'6<997 $*'$ P$&.L8*-' &$% R$78*/L$*8 &$7 cN99%-F%7 K$&$.8$8:

Y*$ c-EF8$5O$%<8.%2[e*&<8*-'7L*'$8*L .'& &*$ &<5*8 *' a.7<55$'F<'/ 78$F$'&$ I$%7O%)&.'/ 7*'& /$'$%$99 <KFB'/*/ 0-' &$% cN99%-F%2M$/*$%.'/: Y*$7 L<'' <'F<'& &$% +$/$'NK$%78$99.'/ 0-' $'87O%$EF$'&$' VEF9*66K*9&$%' -e*&*$%8$% cN99%-F%2b$%L78-66$ <K/$9$7$' #$%&$': D$.$%$ P*'/&%.EL8$787 5*8 -e*&*$%8$' cN99%-F%$' A$*/$' h$&-EFJ &<77 .'<KFB'/*/ 0-5 cN99%-F%2]<8$%*<9 K$* <'7-'78$' /9$*EF$% c-EF8$5O$%<8.%2 T$9<78.'/ #BF%$'& &$% [e*&<8*-'7OF<7$ $*'$ I$%7O%)&.'/ -K$%F<9K 0-' 1:1>>fZ 0-%9*$/8J &*$ *' A.%NEL9*$/$'&$' ''8$%7.EF.'/$' 7- '*EF8 K$-K<EF8$8 #.%&$: b$9EF$ \66$L8$ &*$7$7 UFB'-5$' F$%0-%%.6$'J *78 A.5 /$/$'#B%8*/$' V8<'& &$% ''8$%7.EF.'/$' '-EF .'L9<%:

5.2 Heutiger Entwicklungsstand

Y*$ D<EF#$*76NF%.'/ A.5 VEF<&$'7.56<'/ &$% T%$''78BK$ .56<778 &*$]-&$92 9*$%.'/7K$%$*EF$C

- K$8%*$K9*EF$7 T%$''78<K2I$%F<98$' S^.79$/.'/XJ
- GF$%5-F_&%<.9*L ScGZ2b$%8 Sc$<8 G%<'76$% Z-$66*E*$'8XJ (NF95*88$9&%.ELJ

- (NF95*88$98$5O$%<8.%X .'&
- T%$''78<K2I$%F<98$' K$* M[Z^:

Y< &*$ K$8%*$K9*EF$ VO<98/<76%$*7$8A.'/ <.7 &$5 U$99$8 .'& &<5*8 &$% T%$''78<K W''$'&%.EL 5<,/$K9*EF 0-5 ^KK%<'& .'& 0-' &$% M$*78.'/7/$7EF*EF8$ <KFB'/8J #*%& 0-' &$' T%$''$$5$'8F$%78$99$%' &$% ^.6#<'& .'& &*$ Y$8<*99*$%.'/ *' &$% D<EF#$*76NF%.'/ A.% K$8%*$K9*EF$' VO<98/<72R%$*7$8A.'/ 78B'&*/ $%F)F8 #$%&$': \7 #*%& <97 .'A.%$*EF$'& <'/$7F'J &<K$* <K&$EL$'&$ M$*78.'/7/$7EF*EF8$' *' &$% D<EF#$*76NF%.'/ A. 0$%#$'&$'J &< &<&.%EF '.8AK<%$ P7%0$' 0$%/K' #$%&$': Y<%NK$% F*'<.7 #$%&$' &*$ c$%78$99$% '$.<%8*/$ T%$''78-66$ A.5 *'7<8A K%*'/$'J &*$ *'7K$7-'&$%$ F*'7*EF89*EF &$% VO<98/<76%$*7$8A.'/ -O8*5*$%8 7$*' #$%&$':

^.6 c$%78$99$%7$*8$ #*%& &<7 U%-/%<55 Z^P[2\ $'8#*EL$98 .'& 0$%#$'&$8J &<7 *' $*'$5 L-55$'&$' \'8#*EL9.'/77EF%*88 *' &<7 T%$''78<K2U%-/%<55 Z[U\PDWZ NK$%/$F$' #*%&: b$*8$%F*' #$%&$' *' &*$7$% D<EF#$*7L88 &<7 GF$%5-F_&%<.9*L U%-/%<55 V2P\M^U .'& T\Gcj2^x6N% &$' T%$''78<K .'8$% M[Z^ 2T$&*'/.'/$' $*'/$7$8A8: Y$5/$/$'NK$% 78$F$' F$.8$ <.6 +.8<EF8$%7$*8$ &*$ U%-/%<55$ GP^DV‘P^D‘V 6N% &<7 K$8%*$K9*EF$ T%$''78<K2I$%F<98$'J ^GcM\G A.% Y<%78$99.'/ &$% GF$%5-F_&%<.9*L .'& G\VU^2P[Y 6N% &<7 T%$''78<K2I$%F<98$' .'8$% M[Z^2 T$&*'/.'/$' A.% I$%6N/.'/:

Y*$ PEF'O%-/%<55$ &$7 c$%78$99$%7 SZ^P[J V2P\M^UJ T\Gcj2^¥ .'8$%9*$/$' $*'$% O$%5<'$'8$' b$*8$%$'8#*EL9.'/:

b$'' <.6 V$*8$' &$7 ^'8%</78$99$%7 &*$]$8F-&$' <.6#B'&*/$% .'& &$8<*99*$%8$% #$%&$'J &<'' *78 <.EF &$% +.8<EF8$% /$A#.'/$'J 7$*'$]$8F-&$' .'& PEF'O%-/%<55$ <.6 &$' /9$*EF$' V8<'& '<EFA.%N78$': ^'&$%'6<997 #*%& &$% ^'8%</78$99$% PEF'$%/$K'*77$ 0-%9$/$'J &*$ 0-' +.8<EF8$% K$78$'6<997 <.6 U9<.7*K*9*8B8 /$O%N68 #$%&$' L)''$': Y<F$% 7*'& b$*8$%$'8#*EL9.'/$' '-8#$'&*/:

Y$% T%$''78<K2Z-&$ GP^DV‘P^D‘V #*%& &$%A$*8 <.6/$%N78$8J .5 NK$% &*$ K$8%*$K9*EF$ T%$''78<K2W''$'&%.EL2T$%$EF'./ F*'<.7 <.EF &<7 T%$''78<K2I$%F<98$' .'8$% M[Z^ K$%$EF'$' A. L)''$':

Y$% GF$%5-F_&%<.9*L2Z-&$ ^GcM\G #.%&$ 5*8]-&99' A.% T%$''78<K2]-&$9*$%.'/ $%#$*8$%8J &*$ h$8A8 ^KK%<'&2\66$L8$ &$7 U$99$87 .'& &$7 VO<987 K$%NEL7*EF8*/$' L)''$':

b$*8$%F*' #.%&$ G\VU^2P [Y <.7/F'& 0-5 I-%9B.6$%2Z-&$ G\VU^ A.5 U%-/%<55 G\VU^2P [Y $%#$*8$%8J &<7 #$7$'89*EF$ ^KK%<'&2\66$L8$ K$%NEL7*EF8*/8:

5.3 Weiterentwicklung von Brennstab-Programmen

' VEF#$%O.'L8 &$% b$*8$%$'8#*EL9.'/ *5 T$%$*EF &$% T%$''78<K2]-&$99*$%.'/ #%& #$*8$%F*' &*$]-&$99*$%.'/ &$% cN99%-F%A.78B'&$ 6N% &<7 T%$''78<K2U%-/%<55 G\VU^2 P[Y 7$*': c*$% A$*/$' &*$ '$.$78$' ''8$%7.EF.'/7$%/$K'*77$J &<77 &*$ *5 V8)%6<99 K8*9*/8$' Y*66.7*-'70-%/B'/$ &$% b<77$%78-662 .'& V<.$%78-662Y*66.7*-' '-EF .'A.%$*EF$'& 0-' &$' T%$''78<K2U%-/%<55$' $%6<778 #$%&$': Y*$7$ Y*66.7*-'72 0-%/B'/$ '$F5$' <.6 &<7 (%*$EF2 .'& T$%782I$%F<98$' 7-#*$ <.6 &$' I$%7O%)&.'/7A.78<'& &$7 cN99%-F%7 $%F$K9*EF$' *'69.77: c*'A. L-558J &<77 &*7 Y*66.7*-'70-%/B'/$ &.%EF &$' VO<''.'/7A.78<'& &$7 cN99%-F%7 NK$%9</$%8 #$%&$' .'& &<F$% 6N% $*'$ $*'6<EF$ Y*66.7*-'75-&$99*$%.'/ ''EF8 A./B'/9*EF 7*'&: T$7-'&$%7 ^%/-''$ D<8*-'<9 M<K-%<8-%*$7 S^DMXJ S'V^X F<8 7*EF 5*8 .56<'/%$*EF$' ''8$%2 7.EF.'/$' A. &$' <L8.$99 $*'/$7$8A8$' cN99%-F%#$%L78-66$' #*$]=-&$% a*%9- .5 5$778$EF'*7EF$ ^.6L9B%.'/ &*$7$7 T%$''78<K2I$%F<98$'7 K$5NF8 .'& &<5*8 &$' b$/ 6N% $*'$ 5-&998EF'*7EF$ b$*8$%$'8#*EL9.'/ K$%$*8$8:

]-&$99*$%.'/7K$%$*EF$J &*$ &<%NK$% F*'<.7 b$*8$%$'8#*EL9.'/$' $%6-%&$%'J K$8%$66$' &*$ T%$''78<K2UFB'-5$'$ <e*<9$ T%$''78-662I$%9</$%.'/ K$* (]I2K$&*'/8$% cN99%-F%2 Y$6-%5<8*-'J T%$''78-66kcN99$2T-'&*'/ SI$%7EF#$*,.'/X K$* ^.7K*9&.'/ &$% c-EF2 <KK%<'&2V8%.L8.%J 7-#*$ &*$ c_&%*&2^.77EF$*&.'/ <' P*777O*8A$' .'8$% *'#*%L.'/ 0-' 9-L<9$' cN99%-F%2VO<''.'/$': Y*$7$' T%$''78<K2UFB'-5$'$' *78 /5*'7<5J &<77 7*$ G$*9$ $*'$7 L-5O9e' VEF<&$'75$EF<'*75.7 7*'&: W'7-6$%' *78 $*'$ b$*8$%$'8#*EL9.'/ *5 T$%$*EF &$% T%$''78<K2]-&$99*$%.'/ <.EF $*'$ b$*8$%2 $'8#*EL9.'/ *' &$% W&$'8*6*L<8*-' 0-' VEF<&$'75$EF<'*75$': T$%782Y$F.'/$' &$7 cN99%-F%7 K$*5 (]I-&$% \'8F<9O*$2*'8%B/$ *'7 U$99$8 K$* P$<L8*0*8B8778)%6B99$' SPW^X 7*'& F$.8$ 0$%#$'&8 $5O*%*7EF$ U<%<5$8$%J &*$ $%7<8A#$*7$ /$'.8A8 #$%&$'J &< $'87O%$EF$'&$ 5$EF<'*78*7EF$ VEF<&$'75-&$99$ 6$F9$': a*$9 $*'$% b$*8$%$'8#*EL9.'/ *5 T%$''78<K2T$%$*EF *78 &<F$% <.EF &*$ W&$'8*6*L<8*-' .'& ^'<9_7$ 0-' VEF<&$'75$EF<'*75$' K$* M[Z^ .'& PW^:

W'8$%'<8*-'<9$ I$%7.EF7O%-/%<55$ 7*'&<.6/9/8 #-%&$'J .5 VEF<&$'75$EF<'*75$' *5 a.7<55$'F<'/ 5*8 (]I .'& PW^ A. *&$'8*6*A*$%$': Y*$ #7'89*EF78$' *'%*EF8.'/$'J &*$ 7*EF 5*8 &$% ''8$%7.EF.'/ &$7 T%$''78<K2I$%F<98$'7 K$* (]I

K$6<77$'J 7*'& &<7 ^DM S‘V^XJ &$% c<9&$'2P$<L8-% .'& &*$ V8.&70*L2 I$%7.EF7$*'%*EF8.'/: Y<%NK$% F*'<.7 6*'&$8 *5 P<F5$' &$7 [\ZY2 R-%7EF.'/7O%-h$L87 Z^TP‵ &*$ eO%*5$'8$99$ ‘'8$%7.EF.'/ &$% P‵^2 VEF<&$'75$EF<'*75$' 78<88: ‵'7-6$%' *78 5*8 &*7' I$%7.EF7$*'%*EF8.'/$' &*$ I-%<.77$8A.'/ /$7EF<66$'J &<77 6N% $*'$ b$*8$%$'8#*EL9.'/ &$% T%$''78<K2U%-/%<55$ <.EF &*$ $%6-%&$%9*EF$ Y<8$'K<7*7A.%]-&$992I<9*&*$%.'/ K$%$*878$F8:

5.4 Zusammenfassung zum Forschungsbereich „Brennstabverhalten“

Y*$ +$#*EF8$ *' &$% b$*8$%$'8#*EL9.'/ 0-' T%$''78<K2Z-&$7 F<K$' 7*EF 0$%9</$%8:]-&$99K*9&.'/$' A.% Y<%78$99.'/ &$7 K$8%*$K9*EF$' T%$''78<K2I$%F<98$'7 #$%&$' #$*8$%F*' $%6-%&$%9*EF 7$*'Jh$&-EF *' *F%$% T$&$.8.'/ /$/$'NK$% &$']-&$99K*9&.'/$' A.5 T%$''78<K2I$%F<98$' .'8$% V8)%6<992T$&*'/.'/$' A.%NEL8%$8$': \'8#*EL2 9.'/77EF#$%O.'L8$ *5 T$%$*EF T%$''78<K2I$%F<98$' K$* V8)%6B99$' *78 T%$''78<K2 UFB'-5$'$' A.A.-%&'$'J &*$ K*7F$% '-EF 5*8 /%-,$' ‘'7*EF$%F$*8$' K$F<68$8 7*'&: T$*7O*$97#$*7$ &$% VO<98#B%5$NK$%/<'/ .'8$% &$' T$&*'/.'/$'J &<77 $*' !T-'&*'/; A#*7EF$' T%$''78-66 .'& cN99$ 0-%9*$/8J *78 $*' 7-9EF$% \'8#*EL9.'/77EF#$%O.'L8: ^.EF #$%&$' &*$ #$*8$% -O8*5*$%8$' cN99%-F%2M$/*$%.'/$' ^'9<77 7$*'J $'87O%$EF$'&$]-&$99K*9&.'/$' &<%<.6F*' <.7A.%*EF8$': Y.%EF &*$ T8*9*/.'/ Y$.87EF9<'&7 <' &$' *'8$%'<8*-'<9$' I$%7.EF70-%F<K$' A. M[Z^ .'& P‵^ *78 &<K$* 7*EF$%/$78$998J &<77 $*'$ I<9*&*$%.'/ &$% #$*8$%$'8#*EL$98$']-&$99<'7B8A$ 8%-8A &$7 7-'78 *5 T$%$*EF &$% T%$''78<K2R-%7EF.'/0-%F$%%7EF$'&$' I$%8%<.$'77EF.8A$7 5)/9*EF *78:

5.5 Literatur zum Forschungsbereich „Brennstabverhalten“

kM^V >1k (:M<775<''J!GF$ GP^DV‘P^D‘V Z-&$?U<78JU%$7$'8<'& R.8.%$J
P$0*$# ^%8*E9$dq3>>1JO: 1m233J‵G‘ ^E8*0*8_ P$0-%8 3>>1?\‘P 3>3=3J
‵VTD d32idI2@@d 2=

6 Stör/Unfallanalyse Kühlkreislauf

Y*$ ($''8'*7 &$7 P$<L8-%L$%'2 .'& (NF9L%$*79<.60$%F<98$'7 #BF%$'& &$7 ^K9<.67 0-' V8)%2 .'& ''6B99$' *78 6N% &*$ 6.'&*$%8$J 7*EF$%F$*878$EF'*7EF$ T$#$%8.'/ &$% ($%'L%<68#$%L$ 7-#*$ &*$ #$*8$%$ [O8*5*$%.'/ .'& I$%K77%.'/ &$% VEF<&$'72 0-%7-%/$ 0-' 77'8*99% T$&$.8.'/: b$98#$*8 #$%&$' &$7F<9K P$EF$'2 O%-/%<5 57_78$5$ A.% V*5.9<8*-' &$7 ^K9<.67 0-' G%<'7*$'8$'J V8)%6B99$' .'& ''6B99$' *' #<77$%/$LNF98$' ($%'L%<68#$%L$' $'8#*EL$98 S A: T: ^GcM\Gk^GcM\G2ZYJ Z^Gc^P\kWZ^P\J P\M^UkVZY^UJ GP^ZXJ .5 &$' 7*EF$%$' T$8%*$KJ G%<'7*$'8$'J V8)%6B99$.'& ''6B99$ 7-#*$ 7EF<&$'7K$/%$'A$'&$ -&$% 7EF<&$'75*'&$%'&$ D-86<995<,'<F5$' K$#$%8$' .'& .5 0-%F<'&$'$ V*EF$%F$*87%7%0$' p<'8*6*A*$%$' A.L)''$':

^.6 $*'$5 b-%L7F-0 &$7 ZVDW &$% [\ZY2D\^ *5 ^O%*9 3>>> #.%&$ A.5 V8<'& &$% \'8#*EL9.'/ *'8$%'<8*-'<9$% V_78$52Z-&$7 6$78/$78$998J &<77 &*$]-&99J '.5$%*7EF$']$8F-&$' .'& &*$ O%-/%<5 58$EF'*7EF$ P$<9*7*$%.'/ ''-EF '*EF8 &$5 A: a: 0$%6N/K<%$' ($''8'*778<'& $'87O%$EF$' .'& &<77 I$%K77%.'/$' .:<: '-8#$'&*/ 7*'&J .5 %$<9*78*7EF$ ^'<9_7$' A.% T$.%8$*9.'/ &$% V*EF$%F$*8 K78F$'&$% ($%'L%<68#$%L$ 6N% $*' $%#$*8$%8$7 V8)%6<9970$L8%.5 5*8 &$% $%6-%&$%9*EF$' +$'<.*/L$*8 .'& 5*8 0$%8%$8K<%$5 ^.6#<'& &.%EF6NF%$' A. L)''$': Y*$ 5*88$96%*78*/$ b$*8$%$'8#*EL9.'/ 0-%F<'&$'$% P$EF$'O%-/%<5 5$ #*%& <.EF *5 P<F5$' &$% U9<'./ &$7 \'2U%-h$L8$7 D'P\V] SD'E9$<% P\<E8-% V].9<8*-'X &*7L.8*$%8J &<7 *' &$% R-9/$ &$7 <K/$7EF9-77$'$' \'2U%-h$L8$7 \'P[R^VGD\G .'& &$% &<%*' /$#-''$'$' \%L$''8'*77$ *'*8**$%8 #.%&$: \7 #.%&$.:<: 6$78/$78$998J &<77 7-#-F9 &*$]-&$99*$%.'/ OF_7*L<9*7EF$% UFB'-5$'$ <97 <.EF &*$ '.5$%*7EF$' M)7.'/70$%6<F%$' '-EF $%F$K9*EF$ Y$6*A*8$ <.6#$*7$': V*$ 7*'& K$/%N'&$8 &.%EF 0$%$*'6<EF8$]-&$99*$%.'/ &$% L-5O9e' a#$*OF<7$'O%-A77.'& &*$ *5 ^99/5*'$' *' V_78$52Z-&$7 0$%#$'&$8$' M)7.'/70$%6<F%$' $%78$% [%&'./ .'& Y*7L%$8*7*$%.'/ 5*8 0$%7$8A8$' +*88$%':

W5 R-9/$'&$' #$%&$' 6N% &*$ A.% V*5.9<8*-' &$7 ^K9<.67 0-' G%<'7*$'8$'J V8)%6B99$' .'& ''6B99$' *' #<77$%/$LNF98$' ($%'%$<L8-%$' $*'/$7$8A8$' PEF'O%-/%<5 52 7_78$5$J &$% \'8#*EL9.'/778<'& .'& '-8#$'&*/$ b$*8$%$'8#*EL9.'/$' K$7EF%*$K$' .'&&*7L.8*$%8:

6.1 Simulation von Transienten, Leckagen und Störfallabläufen ohne Kernschäden

T$* &$% ^'<9_7$ 0-' V8)%6B99$' -&$% ''6B99$' -F'$ /%),$%$ ($%'7EFB&$' 78$F8 &*$ V*5.9<8*-' &$% GF$%5-F_&%<.9*L *5 '.L9$<%$' Y<5O6$%A$./.'/77_78$5 *5 I-%&$%/%.'&: Y*$ #*EF8*/78$' K$* &$% V*5.9<8*-' A. K$%NEL7*EF8*/$'&$' UFB'-5$'$.'& U%-A77 7*'&

- \'$%/*$6%$*7$8A.'/ .'& bB%5$9$*8.'/*' &$' T%$''78BK$'J
- bB%5NK%8%</.'/ A#*7EF$' V8%.L8.%$' ST%$''78BK$J P-F%9$*8.'/$'X .'& R9.*&J
- V8%)5.'/7&%.EL0$%9.78$.'& K$7EF9$.'*/8$ V8%)5.'/ &.%EF Y%.EL<K6<99J
- I$%&<5O6.'/ .'& (-'&$'7<8*-'J
- UF<7$'7$O<%<8*-' .'&]*7EF.'/70-%/B'/$J
- (-5O-'$'8$'0$%F<98$' SU.5O$'J I$'8*9$J G.%K*'$'XJ
- M$*82 .'& P$/$97_78$5$J
- D$.8%-'$'L*'$8*L:

a.% V*5.9<8*-' &*7% I-%/B'/$ #$%&$' 7$*8 5$F%$%$' Y$L<&$' PEF'O%-/%<55$ $'8#*EL$98J &*$ *' &$% M</$ 7*'&J &<7 /<'A$ '.L9$<%$ Y<5O6$%A$./.'/77_78$5 <KA.K*9&$': Y*7 PEF'O%-/%<55$ SV_78$52Z-&$7X F<K$' *'A#*7EF$' $*'$ F-F$ V*5.9<8*-'7p<9*8B8 $%%$*EF8 .'& &*$ b$*8$%$'8#*EL9.'/ L-'A$'8%*$%8 7*EF <.6 &*$ I$%K$77$%.'/ &$%]-&$99*$%.'/ &$% a#$*OF<7$'78%)5.'/ .'& 5$F%&*5$'7*-'<9$% V8%)5.'/$'J &$% \%F)F.'/ &$% T$'.8A$%6%$.'&9*EFL$*8J &: F: F-F$ P-K.78F$*8 .'& P$EF$'/$7EF#*'&*/L$*8 7-#*$ &*$ \%78$99.'/ 0-' b$%LA$./$' A.% ''8$%78N8A.'/ &$% ^'#$'&$% K$* &$% Y<8$'7<8A$%78$99.'/J W'8$%O%$8<8*-' .'& ^.7#$%8.'/ &$% P$EF$'$%/$K'*77$ S^GM^V kT\P>3kJ VD^U kf[D>@kX: ^.6 &*$ \'8#*EL9.'/ 0-' T$'.8A$%-K$%69BEF$' #*%& *' (<O*8$9 !W'8$%<L8*0$ ^'9</$'7*5.9<8*-' .'& ^'<9_7$#$%LA$./$; 'BF$% $*'/$/<'/$':

Y$%A$*8 #$%&$' 6N% V8)%6<99<'<9_7$' 0-% ^99$5 &*$ PEF'O%-/%<55$ P\M^U= kP\M ddkJ GP^Z2UkT kVZc d3kJ kGP^ d3kJ Z^Gc^P\ kY[P>Ik .'& ^GcM\G kGP^>Ik 0$%#$'&$8: W' $*'$5 V8<8$2-628F$2^%8 P$O-%8 kT\V>3k #.%&$' &*7 0*$% P$EF$'O%-/%<55$ K$7EF%*$K$' .'& &$%$' T$/%$'A.'/$' <.6/A*/8: Y*$]-&99 &*7% PEF'O%-/%<55$ K$%.F$' <.6 &$' /9$*EF$']-&$99<''<F5$' 6N%

a#$*OF<7$'78%)5.'/$' 5*8 0-9.5$'/$5*88$98$' +%),$' .'& }5<L%-7L-O*7EF$ '}
7$O<%*$%8$' T*9<'A/9$*EF.'/$' 6N%]<77$J W5O.97 .'& \'$%/*$ &$% A#$* UF<7$'J $*'$5
7- /$'<''8$' a#$*2R9.*&]-&$99 Sb<77$% .'& Y<5O6XJ K$* &$5 &$% ^.78<.7EF NK$% &*$
a#*7EF$'OF<7$'69BEF$ <97 o998%5 *' &$' \%F<98.'/7/9$*EF.'/$' K$%NEL7*EF8*/8 #*%&:
Y.%EF &$']*88$9.'/7O%-A$77 L)''$' R$*'78%.L8.%$' &$% V8%)5.'/76-%5J &$%
a#*7EF$'OF<7$'69BEF$.'& &$% +%$'A7EF*EF8 '*EF8 5-&$99*$%8 #$%&$': Y*$]-&99 .'&
\%F<98.'/7/9$*EF.'/$' .'8$%7EF$*&$' 7*EF &<&.%EF #$7$'89*EF 0-' &$'$' &$% ZRY2
Z-&$7:W' &$5 a#$*2R9.*&]-&$99 #$%&$' <.EF #$*8$%$ (-5O-'$'8$' K*9<'A*$%8CW' &$%
b<77$%OF<7$ /$9)78$ V8-66$ -&$% +<7$ ST-% -&$% V8*EL78-66X .'& *' &$% Y<5O6OF<7$
'*EF8L-'&$'7*$%$'&$ +<7$ #*$ b<77$%78-66J V8*EL78-66J V<.$%78-66 -&$% \&$9/<7:

Y*$ PEF'O%-/%<55$ F<K$' $*'$ /5*'7<5$ T<7*7 K$AN/9*EF &$% OF_7*L<9*7EF$'
]-&99: V*$ F<K$' h$&-EF .'8$%7EF*$&9*EF$ '.5$%*7EF$ M)7.'/70$%6<F%$'J <.6 &*$ F*$%
'*EF8 'BF$% $*'/$/<'/$' #$%&$' L<'' SkT\V d3kX: Y*$ I$%6<F%$' K$%.F$' <.6
*5O9*A*8$' -&$% 8$*9*5O9*A*8$' M)7.'/7<'7B8A$'J &<5*8 &*$ ^'<9_7$' 5*8 %$9<8*0 /%-,$'
a$*87EF%*88$' .'& F-F$% '.5$%*7EF$% V8<K*9*8B8 &.%EF/$6NF%8 #$%&$' L)''$': Y<5*8
$%%$*EF$' &*$7$ Z-&$7 F-F$ PEF'/$7EF#*'&*/L$*8$'J 7-&<77 &*$ ^'<9_7$' *''$%F<9K
$*'*/$% V8.'&$' SA.5 G$*9 *' \EF8A$*8X -&$% A.5*'&$78 *''$%F<9K #$'*/$% G</$
&.%EF/$6NF%8 #$%&$' L)''$':

Y*$ PEF'O%-/%<55$ 0$%6N/$' <.,$%&$5 NK$%]-&$99$ A.% P$<L8-%%$/$9.'/ .'&
^'9</$'78$.$%.'/ .'& A.% 0$%$*'6<EF8$' V*5.9<8*-' 0-' DK'2 -&$% c*%77_78$5$':
Y< ^'<9_7$' 5*8 ZRY2Z-&$7 #7'89*EF 5$F% P$EF$'A$*8*' ^'7O%.EF '$F5$' .'&*5
^99/5*'$' '.% <.6 &*$ V*5.9<8*-' 0-' G$*97_78$5$' K$7EF%B'L8 7*'&J #$%&$' &*7
&*$ PEF'O%-/%<55$*' <K7$FK<%$% a$*8 '*EF8 $%7$8A$' L)''$':

Y*$ \'8#*EL9.'/ &$% P$EF$'O%-/%<55$ #*%& 0-' $*'$% *'8$'7*0$' U%-/%<552
0<9*&*$%.'/ <'F<'& 6%NF$%$% I$%7.EF$J &*$ NK$% *'8$%'<8*-'<9 <K/$78*558$
I<9*&*$%.'/75<8%*A$' <.7/$#BF98 #.%&$' .'& <L8.99% eO%*5$'8$99$% U%-/%<55$J
&*$*' *'8$%'<8*-'<9$ (--O$%<8*-'$' .'& U%-h$L8$ $*'/$K.'&$' 7*'&J K$/9$*8$8:

[K#-F9 &*$ b$*8$%$'8#*EL9.'/ &$% F*$% K$7EF%*K'$' P$EF$'O%-/%<55$ *5
b7'89*EF$' <K/$7EF9-77$' *78J #$%&$' &*$ U%-/%<55$ #$*8$%F*' 7_78$5<8*7EF
0$%K$77$%8 .'& '$.$' ^'6-%&$%.'/$'J &*$ 7*EF <.7 &$% K%$*8$' ^'#$'&.'/ &$%
PEF'O%-/%<55$ $%/$K$'J $'87O%$EF$'& <.7/$K<.8: Y<K$* 78$F8 $*'$ %$<9*78*7EF$%$
T$7EF%$*K.'/ K$78*558$% V8)%<997p'A$'J &*$ $*'$ $%F)F8$ ^.77</$7*EF$%F$*8J $*'$

F)F$%$ %B.59*EF$ ^.69)7./ -&$% $*'$ $'/$%$ PNELL-OO9./ 5*8 &$% D$.8%-'$'L*'$8*L $%6-%&$%'J*5 I-%&$%/%.'&:

W' &$' 'V^ #*%& &$% Z-&$ GP^Z\ k[Y^>@k #$*8$% $'8#*EL$98: \% K<.8 <.6 &$' &%$* U%-/%<55$' P\M^U= k^'] >3kJ GP^Z2U .'& GP^Z2T <.6 .'& #*%& &.%EF &*$ I$%K$77$%./ &$7 T%$''78<K5-&$997 .'& &$7 @Y2R9.*&&_'<5*L5-&$997J &*$ (-OO9./ 5*8 &$5 D$.8%-'$'L*'$8*L5-&$99 P^][D^ kP^] ilk -&$% U^PZV k]W ddk .'& &$5 Z-'8<*'5$'8O%-/%<55 Z[DG^WD k]'P >@k 7-#*$ &*$ *'K*'&.'/ 0-' ZRY2]-&.9$' #$7$'89*EF $%#$*8$%8:

Y*$ /9$*EF$ G$'&$'A *78 *' R%<'L%$*EF A. K$-K<EF8$'J #- Z^Gc^P\ <97 P$EF$'O%-/%<55 5*'&$78$'7 6N% &*$ 'BEF78$' a$F' f<F%$ <97 .'0$%A*EF8K<% /*98J -K#-F9 &*$ '$.$ \'8#*EL9.'/7O9<886-%5 D\UG'D kT\V>lk $*'/$%*EF8$8 #.%&$J <.6 &$% &*$ 'BEF78$ +$'$%<8*-' $*'$7 PEF'O%-/%<557 5*8 0$%K$77$%8$% 5$F%&*5$'7*-'<9$%]-&$99*$%./ .'& $*'$% VEF'*8878$99$ A.5 @2Y2D$.8%-'$'L*'$8*L2Z-&$ Y\VZ^PG\V $'8#*EL$98 #*%&:

^.EF *' Y$.87EF9<'& #.%&$' (-OO9.'/$' 0-' ^GcM\G 5*8 &$5 @Y2R9.*&&_'<5*L2 5-&.9 RM'T[xk+P^ >1kJ 5*8 D$.8%-'$'L*'$8*LO%-/%<55$' #*$ ó^T[kóTT[x kM^D ddk -&$% YjD@Yk+P' d=k7-#*$ 5*8 &$5 Z-'8<*'5$'8 Z-&$ V_78$5 Z[Z[VjV k(M\ >3k $'8#*EL$98J &*$ $7 #$*8$% <.7A.K<.$' /*98:

DK' &*7' O%-/%<558$EF'*7EF$' \%#$*8$%./$' *78 A.% \%F)F./ &$% ^.77</$7*EF$%F$*8 $*'$ #7'89*EF$]-&990%K77%./ 6N% L-5O9e A#$*OF<7*/$ V8%)5./76-%5$' '-8#$'&*/ kT\V>3k: Y$7F<9K #$%&$' <.EF 6N% P$EF$'O%-/%<55$ ^'7B8A$ $'8#*EL$98J .5 5*88$97 $*'$% \%F<98./7/9$*EF.'/ 6N% &*$ a#*7EF$'2 OF<7$'69BEF$ $*'$ &_'<5*7EF$ \'8#*EL9./ &$% V8%)5./76-%5$' A. $%5)/9*EF$' .'& &<5*8 &*$ T$7EF%$*K./ &$7]<77$'2J W5O.972 .'& \'$%/*$<.78<.7EF7 A#*7EF$' &$' UF<7$' A. 0$%K77%':

W' ($%'L%<68#$%L$' L-55$' A.'$F5$'& T%$''$9$5$'8$ A.5 *'7<8AJ &*$ 7*EF &.%EF 9B'/$%$ V8<'&A$*8$' *5 ($%'J &.%EF F)F$%$ ^KK%B'&$J &.%EF /$B'&$%8$ T%$''78-66A.7<55$'7$8A./ S][XJ &.%EF /$B'&$%8$ cN99%-F%9$/*$%./$' S]=J a*%9-X .'& <.EF &.%EF F)F$%$ V8<K9B'/$'9$*78./$' <.7A$*EF'$': W5 (<O*8$9 !T%$''78<K0$%F<98$'; #*%& &<7 T%$''78<K0$%F<98$' <.76NF%9*EF &*7L.8*$%8: '5 &*$ PNEL#*%L./$' A#*7EF$' T%$''78<K0$%F<98$' .'& GF$%5-F_&%<.9*L 5-&$99*$%$' A.

L)''$'J 5N77$' <.EF &*$]-&99 &$% PEF'O%-/%<55$ $'87O%$EF$'& $%#$*8$%8 #$%&$':

6.1.1 Entwicklungsbedarf aus Programmvalidierung und -anwendung

'56<'/%$*EF$ PEF'O%-/%<55$ 6N% &$' *'7<8A*' &$% P$<L8-%7*EF$%F$*876-%7EF.'/ S#: A: T: ^GcM\G -&$% Z^Gc^P\XJ 5N77$' 78$8*/ #$*8$% $'8#*EL$98 #$%&$'J .5 &$5 V8<'& 0-' b*77$'7EF<68 .'& G$EF'*L A. /$'N/$' .'& .5 &$' 7*EF B'&$%'&$' ^'6-%&$%.'/$'*' &$% V*EF$%F$*87K$#$%8.'/0-' ($%'%$<L8-%$' SA: T: Y$K-%*$%.'/-&$% Z9-//*'/X /$%$EF8 A. #$%&$': '5 Y$6*A*8$.'& T$/%$'A.'/$'*' &$']-&99' .'&*' &$% ^'#$'&K<%L$*8 &$% U%-/%<55$ <.6A.A$*/$'J *78 'K' &$% U%-/%<550<9*&*$%.'/ $*'$ #$*8 /$6BEF$%8$ U%-/%<55<'#$'&.'/ F*96%$*EF: W5 R-9/$'&$' #*%& &$% '5/<'/ 5*8 &$% ^'#$'&$%$%6<F%.'/ K$*7O*$9F<68 6N% &*$ ^GcM\G2\'8#*EL9.'/ <.6/A*/8 kGP^>Ik:

I-% &$% R%$*/<K$ '$.$% I$%7*-'$' #*%& &<7 U%-/%<55 &.%EF &<7 PEF'' .'8$%7EF*$&9*EF$% G$786B99$ /%N'&9*EF NK$%O%N68: U<%<99$9 A.% U%-/%<55$'8#*EL9.'/ #$%&$' *'7K$7-'&$%$ &*$ '$.$' U%-/%<558$*9$ F*'7*EF89*EF &$%]-&$99*$%.'/ &$% OF_7*L<9*7EF$' U%-A$77$J &$% ^K9<.66BF*/L$*8 .'& &$% c<'&F<K.'/<'F<'&7O$A*6*7EF$% T$*7O*$9$ /$8$78$8: Y*$ <'7EF9*$,$'&$ I<9*&*$%.'/ #*%& 0-' ^'#$'&$%' &.%EF/$6NF%8J &*$ '*EF8 <' &$% \'8#*EL9.'/ K$8$*9*/8 7*'&: c*$% #$%&$' 0-% <99$5 W'8$/%<9O$%7.EF$ 7*5.9*$%8J .5 &<7 a.7<55$'7O*$9 0$%7EF*$&$'$%]-&$99$ *5 V_78$5E-&$ A. NK$%O%N6$': Y*$ I<9*&*$%.'/ $%6-9/8*' $'/$% a.7<55$'<%K$*8 5*8 &$' \'8#*EL9$%':

Y< ^GcM\G 6N% $*' 7$F% K%$*8$7 VO$L8%.5 0-' G%<'7*$'8$' .'& V8)%6B99$' *' 0$%7EF*$&$'$' P$<L8-%8_O$' SY bPJ VbPJ bb\PJ PT](J R-%7EF.'/7%$<L8-%$'J '$.$ T<.9*'*$'X $*'/$7$8A8 #*%&J L<'' 8%-8A &$% <.6#B'&*/$' .'& 5*8 /%-,$% V-%/6<98 &.%EF/$6NF%8$' o<9*8B877*EF$%.'/ &<7 G$78K$&$EL.'/75<, '*$ 0-9978B'&*/ 7$*': bBF%$'& &$% ^'#$'&.'/ $%/$K$' 7*EF *55$% #*$&$% '$.$]-&$992 .'& I$%6<F%$'7L-'78$99<8*-'$'J <.6 &*$ $*'$ 6%$*/$/K'$ ^GcM\G2I$%7*-' '*EF8 -&$% '.% .'A.%$*EF$'&0-%K$%$*8$8*78:

c*'A. L-558J &<77 &$% $%6-9/%$*EF$ *'7<8A 0-' V_78$5O%-/%<55$' F-F$ ^'6-%&$%.'/$' <' &$' U%-/%<55<'#$'&$% 78$998: \% 5.77 '*EF8 '.% &*$ ^'9</$'/$-5$8%*$.'& &*$ ^'6<'/72 .'& P<'&K$&*'/.'/$' L-%%$L8 0-%/$K$'J 7-'&$%' &*$ A<F9%$*EF$']-&$99-O8*-'$' 7*''/$5B, .'& #*&$%7O%.EF76%$* $*'7$8A$': W'7K$7-'&$%$ *78 $*'$ &$5 7*5.9*$%8$' U%-A$77 <&Bp<8$ D-&<9*7*$%.'/ A. #BF9$'J

#<7 $%6<F%.'/7/$5B, 0-% <99$5 &<'' U%-K9$5$ K$%$*8$8J #$'' 5$F%&*5$'7*-'<9$ V8%)5.'/$' &.%EF &*$ <' 7*EF $*'&*5$'7*-'<9$' V*5.9<8*-'75-&$99$ F*'%$*EF$'& /$'<. &<%/$78$998 #$%&$' 7-99$': T$* &$% ^KK*9&.'/ &$% M$*82 .'& P$/$98$EF'*L #*%& &$% ^'#$'&$% A.5 !]-&99'8#*EL9$%;J &$% /%-,$' *'69.77 '*EF8 '.% <.6 &<7 R.'L8*-'*$%$' &$% P$/$9.'/ F<8J 7-'&$%' <.EF <.6 &*$ '.5$%*7EF$ V8<K*9*8B8 .'& &*$ ^K9<.66BF*/L$*8 &$% P$EF'.'/:

T$78<'&8$*9 &$% ^GcM\G2\'8#*EL9.'/ #<% &$7F<9K *55$% <.EFJ &.%EF 0$%K$77$%8$ U%-/%<55$*'/<K$8$EF'*L$'J $%#$*8$%8$' (-'8%-99$' &$% *'/<K$&<8$' .'& &$7 U%-/%<55<K9<.67 7-#*$ '$.$]$8F-&$' &$% \%/$K'*7&<%78$99.'/ .'& 2<.7#$%8.'/ &$' ^'#$'&$%*' &$% U%-/%<55F<'&F<K.'/ A. .'8$%78N8A$': G%-8A&$5 F<8 &*$7$% '<EF #*$ 0-% $*'$' &-5*'*$%$'&$' *'69.77 <.6 &*$ o<9*8B8 .'& a.0$%%B77*/L$*8 &$% V*5.9<8*-'7$%/$K'*77$: I-' &$% P$<9*8B8 <K#$*EF$'&$ V*5.9<8*-'7$%/$K'*77$ 7*'& *' 0*$%$' RB99$' <.6 R$F9$%*' &$% U%-/%<55<'#$'&.'/ A.%NELA.6NF%$':

^.7 &*7% V*8.<8*-' F$%<.7 $%/*K8 7*EF 6N% &*$ ^GcM\G2\'8#*EL9$% A#*'/$'& &*$ D-8#$'&*/L$*8J 7*EF 5*8 &$' \%6<F%.'/$' .'& U%-K9$55$' &$% T$'.8A$% <L8*0 <.7$*'<'&$%A.7$8A$': Y*$ \%6<F%.'/ F<8 /A*/8J &<77 '*EF8 '.% I<9*&*$%.'/72 7-'&$%' <.EF ^'#$'&.'/7%$EF'.'/$' 0$%#$%8K<%$ c*'#$*7$ <.6]-&$992 -&$% c<'&F<K.'/72 7EF#BEF$' 9*$6$%' L)''$': R<997 $%6-%&$%9*EFJ #$%&$' O$% \2]<*9 -&$% 68O2V$%O$% &*$ Y<8$'7B8A$ &$' \'8#*EL9$%' K$%$*8/$78$998J &<5*8 &*7 &*$ U%-K9$55$ *5 Y$8<*9 <'<9_7*$%$' .'& U%-/%<550$%K77%.'/$' 0-%'$F5$' L)''$'J &*$ &<'' //6: <& F-E <97 *'A$9O$%K77%.'/ SU<8EFXJ*' h$&$5 R<99 <K$% 5*8 &$% 'BEF78$' U%-/%<556%$*/<K$ &$' ^'#$'&$%' A.% I$%6N/.'/ /$78$998 #$%&$': RN% $*'$ A$*8/$5B,$ (-55.'*L<8*-' A#*7EF$' \'8#*EL9$%' .'& ^'#$'&$%' 7-998$ $*'$W'8$%'$8O9<886-%5 $*'/$%*EF8$8 #$%&$':

V-9<'/$ ^GcM\G *5 *'7<8A *78J 5.77 $*'$ b$*8$%$'8#*EL9.'/ &$7 U%-/%<557 /$#BF%9$*78$8 .'& $*' $%6<F%$'$7 G$<5 A.% T$%<8.'/ &$% ^'#$'&$% 0$%6N/K<% 7$*': *'$ <L8*0$ ^.7$*'<'&$%7$8A.'/ 5*8 &$% T$'.8A$%$%6<F%.'/ L<'' F*$%K$* <.EF <97 $*')L-'-5*7EF$% T$*8%</ A.% U%-/%<55$'8#*EL9.'/ K$8%<EF8$8 #$%&$'J &< I<9*&*$%.'/7<%K$*8 0-5 ^'#$'&$% /9*78$8 #*%&: ^.EF &*$ \'8#*EL9$% <'&$%$% V_78$50%-/%<55$ 7*'& &$% /9$*EF$' ^.66<77.'/: V- #.%&$ <.6 &$5 &*$7hBF%*/$' Z^Gc^P\2b-%L7F-O /$B.,$%8J &<77 &*$ Z^Gc^P\2\'8#*EL9.'/ A#<% #$*8/$F$'& <K/$7EF9-77$' *78 .'& &*$ A.LN'68*/$ \'8#*EL9.'/ <.6 &$% D\UG‘D\2U9<886-%5 kT\V>Ik 78<886*'&$' #*%&: \7 #*%& <K$% $%#<%8$8J &<77 Z^Gc^P\ 6N% 5*'&78'7 A$F' #$*8$%$ f<F%$ &$% GF$%5-F_&%<.9*LE-&$ 6N% V*EF$%F$*87<'<9_7$' 0-' ($'L%<68#$%L$'

K9$*K$' #*%&: W' &*7% a$*8 #$%&$' &*$ 6N% <L8.99 ^'#$'&.'/$' '-8#$'&*/$' \'8#*EL9.'/7<%K$*8$' A./$7*EF$%8:

6.1.2 Dynamische Entwicklung von Strömungsbildern

'$ K$7-'&$%$ c$%<.76-%&$%.'/ 6N% &$ V_78$52Z-&$7 7*'& &*$ V*5.9<8*-' &$% 8%<'7*$'8$' a#$*OF<7$'78%)5.'/ .'& &*$ L-'7*78$'8$]-&$99*$%.'/ 0-' bB%5NK%8%</.'/J I$%&<5O6.'/J (-'&$'7<8*-' .'& V8%)5.'/7&%.EL0$%9.78$': W' '<F$A. <99$' Z-&$7 K<7*$%$' &*$]-&99 <.6 I-9.5$' /$5*88$98$' +%),$' .'& !5<L%-7L-O*7EF$'; 7$O<%*$%8$' \%F<98.'/7/9$*EF.'/$' &$% A#$* R9.*&$ b<77$% .'& +<72Y<5O6/$5*7EF kT\V>3k: Y<K$* 7O*$98 &*$ UF<7$'/%$'A69BEF$ A#*7EF$' &$' K$*&$' R9.*&$' $*'$ 5<,/K'&$ P-99$ A.% T$78*55.'/ &$% ^.78<.7EF8$%5$ *' &$' 7$O<%*$%8$']<77$'2JW5O.972 .'& \'$%/*$K*9<'A$': Y*$ ^.78<.7EF8$%5$ #$%&$' *' &$' F$.8*/$' V_78$52Z-&$7 5*88$97 $5O*%*7EF$% (-%%$9<8*-'$' *' ^KFB'/*/L$*8 0-5 V8%)5.'/7A.78<'& K$%$EF'$8: Y*$7$ (-%%$9<8*-'$' 7*'& K$78*55 8$' V8%)5.'/7K*9&$%' A./$-%&'$8 .'& F<K$' $*'$' K$/%$'A8$' +N98*/L$*87K$%$*EF K$AN/9*EF +$-5$8%*$.'& 8F$%5-F_&%<.9*7EF$% T$&*'/.'/$': Y*$ HK$%/<'/7L%*8$%*$' A#*7EF$' 0$%7EF*$&$'$' V8%)5.'/7K*9&$%' 7*'& K'6<997 $5O*%*7EF .'& '.% /N98*/ 6N% 78<8*-'B%$J0-99 $'8#*EL$98$ V8%)5.'/$': c*78-%*7EF K$&*'/8 #$%&$' *: ^99/: 6N% &*$ T$%$EF'./ 0-' bB%5$2 NK$%8%</.'/J I$%&<5O6.'/J (-'&$'7<8*-'J V8%)5.'/7&%.EL0$%9.78 .'& a#*7EF$'2 OF<7$'%$*K.'/ .'8$%7EF*$&9*EF$ V8%)5.'/7K*9&$% .'& HK$%/<'/7L%*8$%*$' 0$%#$'&$8:

W5 P<F5$' &$% \'8#*EL9.'/ 0-' Z-&$7 A.% 5$F%&*5$'7*-'<9$' V*5.9<8*-' 8%<'7*$'8$% A#$*OF<7*/$% V8%)5.'/$' #$%&$' 2 #*$ #$*8$% .'8$' <.7/$6NF%8 2 I$%7.EF$ A.% eO%*5$'8$99$' T$78*55.'/ &$% a#*7EF$'OF<7$'69BEF$ &.%EF/$6NF%8 .'& <.7/$#$%8$8: Y*$ \%/$K'*77$ &*7% ^%K$*8$' L)''$' <.EF $*'$' #7'89*EF$' T$*8%</A.% I$%K$77$%.'/ &$% V*5.9<8*-' &$% a#$*OF<7$'78%)5.'/ *' V_78$52Z-&$7 9$*78$'J #$'' &.%EF $*'$ OFB'-5$'-9-/*7EF K<7*$%8$ T$78*55.'/ &$% UF<7$'/%$'A69BEF$' $*'$ L-'7*78$'8$ T$%$EF'./ &$% ^.78<.7EF8$%5$ $%%$*EF8 #*%&: \'87O%EF'&$ ^%K$*8$' #.%&$' K$* &$% ^GcM\G2\'8#*EL9.'/ &.%EF/$6NF%8 .'& 7*'& 6N% &*$ b$*8$%$'8#*EL9.'/ 0-%/$7F':

^GcM\G $'8FB98 $*'$' ^'7<8A A.%]-&$99*$%.'/ &$% &_'<5*7EF$' \'8#*EL9.'/ 0-' V8%)5.'/7K*9&$%'J &$% <.6 $*'$% G%<'7O-%8/9$*EF.'/ 6N% &*$ UF<7$'/%$'A69BEF$ K<7*$%8 .'& 6N% &*7O$%/*$%8$J 7$'L%$EF8$ a#$*OF<7$'78%)5.'/ ST9<7$'2 KA#: G%-O6$'78%)5.'/X <'#$'&K<% *78: \7 #*%& &<K$* <'/$'-55$'J &<77 &*$ G%<'7O-%8/$7EF#*'&*/L$*8 &$%

UF<7$'/%$'A69BEF$ 5*8 &$% 0-' ^GcM\G K$%EF'8$' 5*889$%$' +$7EF#*'&*/L$*8 &$% &*7O$%/*$%8$' UF<7$ /9$*EF /$7$8A8 #$%&$' L<'':

W5 T$%$*EF T9<7$'2 .'& VEF*%5K9<7$'78%)5.'/ #$%&$' A.% T$78*55.'/ &$% o998 %5$ *' &$% G%<'7O-%8/9$*EF.'/ 6-9/$'&$]$EF<'*75$' K$%NEL7*EF8*/8C T9<7$'L-<9$7A$'A &.%EF A.6B99*/$ (-99*7*-'$' .'& &.%EF V-/5*8%*77J R%</5$'8*$%.'/ &.%EF 8.%K.9$'8$' ^.6O%<99 7-#*$ I-9.5$'B'&$%.'/ &.%EF UF<7$'#$EF7$9: Y*$ $'87O%$EF$'&$']-&99 #.%&$' <'F<'& 0-' 5$F% <97 3>>]$77&<8$' 6N% 7$'L%$EF8$ M.682b<77$%2V8%)5.'/ K$* 0$%7EF*$&$'$' P-F%&.%EF5$77$%' SA#*7EF$' 1J@ .'& 1=E5X .'& +<70-9.5$'<'8$*9$' K*7 @>v NK$%O%N68: Y$% I$%/9$*EF A#*7EF$' /$55$77$'$' .'& K$%$EF'8' b$%8$' A$*/8J &<77 &$%]-&$99<'7<8A &*$ UF<7$'/%$'A69BEF$'*' &*$7$5 T$%$*EF A.6%*$&$' 78$99$'& '<EFK*9&$' L<'':

W5 T$%$*EF P*'/2 .'& G%-O6$'78%)5.'/ 5*8 $*'$5 +<70-9.5$'<'8$*9 0-' 5$F% <97 ɲ v#$%&$' <97 o$998$%5$ *' &$% G%<'7O-%8/9$*EF.'/ 6-9/$'&$]$EF<'*75$' K$%NEL7*EF8*/8C G%-O6$'L-<9$7A$'AJ R%</5$'8*$%.'/J G%-O6$'5*8%*77 <.7 &$5 b<77$%6*95 .'& G%-O6$'<K9</$%.'/: Y<K$* #*%& <'/$'-55$'J &<77 &$% T$*8%</ &$7 b<77$%6*957 A.5 G%<'7O-%8 &$% UF<7$'/%$'A69BEF$' /$%*'/ *78 .'& 0$%'<EF9B77*/8 #$%&$' L<'':]$77&<8$' A. UF<7$'/%$'A69BEF$' *' &*$7$5 T$%$*EF 7*'& '*EF8 0$%6N/K<%: Y*$]-&$99NK$%O%N6.'/ #*%& A.%A$*8 <'F<'& 0-' eO%*5$'8$99 $%5*88$98$' b$%8$' 6N% &$' 5*889$%$' Y.%EF5$77$% &$% b<77$%8%-O6$' .'& &*$ Y*EL$ &$7 b<77$%6*957 *' <.6#B%87 /$%*EF8$8$' M.682b<77$%2V8%)5.'/$' &.%EF/$6NF%8: Y*$ \%/$K'*77$ &$% $%78$' I<9*&*$%.'/7%$EF.'/$' 7*'& '-EF '*EF8 A.6%*$&$' 78$99$'&: *' #$7$'89*EF$% +%.'& &<6N% *78 &*$.'/$'<.$ T$78*55.'/ &$% R*95/$7EF#*'&*/L$*8 <97 R.'L8*-' &$% K$%EF'8$' UF<7$'/$7EF#*'&*/L$*8$': Y*$7 &$.8$8 &<%<.6 F*'J &<77 A.7B8A9*EF$ R$9&/9$*EF.'/$' 6N% &$' b<77$%6*95 '-8#$'&*/ 7*'&J .5 P*'/78%)5.'/$' %$<9*8B87'<F 7*5.9*$%$' A. L)''$':

Y*$ UF<7$'/%$'A69BEF$' 6N% (-9K$'K9<7$'2 .'& VEF<.578%)5.'/ 5*8 +<70-9.5$'2 <'8$*9$' 0-' @> K*7 ɲ v#$%&$' A.%A$*8 5*8 c*96$ $*'$% HK$%/<'/76.'L8*-' A#*7EF$' T9<7$'2 .'& G%-O6$'78%)5.'/ $%5*88$98: b$*8$%$ \'8#*EL9.'/7<%K$*8$' 7*'& *' &*$7$5 T$%$*EF 0-%/7F$':

\'8#*EL9.'/7K$&<%6 K$78$F8 <.EF K$* &$% T$78*55.'/ &$% UF<7$'/%$'A69BEF$' *' F-%*A-'8<9$' V8%)5.'/$'J*'7K$7-'&$%$ K$* 8%<'7*$'8$' V8%<8*6*A*$%.'/70-%/B'/$': ^.6 +%.'& &$7 K$/%$'A8$' ^'#$'&.'/7K$%$*EF$7 &$% h$8A*/$' R-%5.9*$%.'/ &$% &_'<5*7EF$' \'8#*EL9.'/ &$% V8%)5.'/7K*9&$% /*K8 $7 A.%A$*8 '-EF L$*'$ PNEL#*%L.'/

&$% K$%EF'8$' UF<7$'/%$'A69BEF$' <.6 <'&$%$ G$*95-&$99$ 0-' ^GcM\GJ #*$ A: T: &<7 (-'&$'7<8*-'75-&$99 -&$% &<7 a#*7EF$'OF<7$'2P$*K.'/75-&$99:

6.1.3 Mehrdimensionaler Fluiddynamik-Modul für ATHLET

RN% &*$ 5$F%&*5$'7*-'<9$ V*5.9<8*-' A#$*OF<7*/$% V8%)5.'/$' 5*8 ^GcM\G #*%& &<7]-&.9 RM'T[x+P^ >1k$'8#*EL$98:

UF_7*L<9*7EF$ +%.'&9</$ &$% 5$F%&*5$'7*-'<9$' V*5.9<8*-' 8%<'7*$'8$% A#$*OF<7*/$% V8%)5.'/$' 5*8 &$5]-&.9 RM'T[x*78 $*' a#$* 2R9.*&]-&$99: W' $*'$5 a#$*2R9.*&]-&$99 #$%&$' &*$ T*9<'A/9$*EF.'/$' 6N%]<77$J W5O.97 .'& \'$%/*$ 6N% h$&$ UF<7$ 7$O<%<8 5-&$99*$%8: f$&$% V8%)5.'/7O%-A$77 L<'' <97 V.O$%O-7*8*-' 0-' b$99$'<.7K%$*8.'/$' <.6/$6<778 #$%&$': W' $*'OF<7*/$' V8%)5.'/$' F<8 5<' A#$* #7'89*EF$ b99'<.7K%$*8.'/$'C &*$ Y%.EL#99'J &*$ 7*EF 5*8 &$% VEF<99/$2 7EF#*'&*/L$*8 <.7K%$*8$' .'& G$5O$%<8.%#$99$'J &*$ 7*EF 5*8 &$% V8%)5.'/72 /$7EF#*'&*/L$*8 <.7K%$*8$': W' A#$*OF<7*/$' V8%)5.'/$' /*K8 $7 '-EF $*'$' &%*88$' ^.7K%$*8.'/78_O.7C &*$ a#*7EF$'OF<7$'#99'J &*$ 7*EF 5*8 &$5 I-9.5$'/$F<98 &$% $*'A$9'$' UF<7$' K$#$/$': Y*$7$ OF_7*L<9*7EF$' b$99$'<.7K%$*8.'/7/$7EF#*'&*/2 L$*8$' #$%&$' <.EF EF<%<L8$%*78*7EF$ +$7EF#*'&*/L$*8$' /$'<''8:

]<8F$5<8*7EF $%/$K$' 7*EF EF<%<L8$%*78*7EF$' +$7EF#*'&*/L$*8$' &.%EF $*'$ T$%$EF'.'/ &$% */$'#$%8$ &$% (-$66*A*$'8$'5<8%*e &$7 a#$*2R9.*&]-&$997: T$* 7-%/6B98*/$% OF_7*L<9*7EF$%]-&$99*$%.'/ 7*'& &*7 */$'#$%8$ %$$99 .'& 5*8 &$' EF<%<L8$%*78*7EF$' +$7EF#*'&*/L$*8$' *&$'8*7EF: Y*$ %$$99$' */$'#$%8$ S.'& &<7 0-9978B'&*/$ V_78$5 %$$99$% */$'0$L8-%$'X 78$99$' <.EF 7*EF$%J &<77 &<7 OF_7*L<9*7EF$]-&$99J 5<8F$5<8*7EF <97 ^'6<'/72 .'& P<'&#$%8O%-K9$5 /7F$'J 7<EF/$5B, /$78$998 *78 .'& &<77 &$% M)7.'/7O%-A$77 '*EF8 <.6 LN'789*EF$ -&$% '.5$%*7EF$ Y*66.7*-' <'/$#*$7$' *78:

Y<7 '.5$%*7EF$ M)7.'/70$%6<F%$' *5 RM'T[x]-&.9 5<EF8 $eO9*A*8 0-' &$' %$$99$' */$'#$%8$' SZF<%<L8$%*78*L$'X .'& */$'0$L8-%$' +$K%<.EF: Y*$ (-$66*A*$'8$'5<8%*e #*%& 7-*' A#$*]<8%*A$' A$%9$/8J &<77 &*$ $*'$ '.% &*$ O-7*8*0$' */$'#$%8$ $'8FB98 .'& &*$ <'&$%$ '.% &*$ '$/<8*0$' */$'#$%8$: Y*$ O-7*8*0$]<8%*e #*%& '.% 5*8 PNEL#B%87&*66$%$'A$' &$% M)7.'/70<%*<K9$' 5.98*O9*A*$%8J &*$ '$/<8*0$]<8%*e #*%& '.% 5*8 I-%#B%87&*66$%$'A$' &$% M)7.'/70<%*<K9$' 5.98*O9*A*$%8: Y<%<.7 $%/*K8 7*EF $*'J <.6 .'0$%7$8A8$5 +*88$%J 78<K*9$7 Y*66$%$'A$'0$%6<F%$'J &*$ 7- /$'<''8$ VO9*82Z-$66*E*$'8]<8%*e SVZ]X]$8F-&$ kP[ ]d>k:

]-&$99/9$*EF.'/$' 5*8 $*'$5 0-9978B'&*/$' V_78$5 %$$99$% */$'0$L8-%$' 7*'&J 5<8F$5<8*7EF /$7F'J 0-5 F_O$%K-9*7EF$' G_O: Y$7F<9K #$%&$' '.5$%*7EF$ M)7.'/70$%6<F%$'J &*$ $eO9*A*8$' +$K%<.EF 0-' &$' %$$99$' */$'#$%8$' .'& */$'0$L8-%$' 5<EF$'J <.EF F_O$%K-9*7EF$ M)7.'/70$%6<F%$' /$'<''8: ^'&$%$ I$%8%$8$% &*$7$% (9<77$ 7*'& &<7 !R9.e I$E8-% VO9*88*'/; kVG^ >1k -&$% &$% !^OO%-e*5<8$ P*$5<'' V-90$%; kG[‘ dkm ^.EF &*7 I$%6<F%$' 5<EF$' <K$% *5 M<.6$ * F%$7 M)7.'/7O%-A$77$7 0-' &$5]<8%*e7O9*88*'/ &$% VZ]]$8F-&$ +$K%<.EF: W5 \‘2 U%-h$L8 ^VG^P kVG^ >=k #.%&$' F_O$%K-9*7EF$ M)7.'/70$%6<F%$' <.6*F%$ */'.'/ A.% V*5.9<8*-' 5$F%&*5$'7*-'<9$% 8%<'7*$'8$% a#$*OF<7$'78%)5.'/$' .'8$%7.EF8: a.&*$7$5 a#$EL #.%&$' A#$*OF<7*/$ T$'EF5<%L G$786B99$ &$6*'*$%8: f$&$% &*7% 7*K' ^VG^P T$'EF5<%L G$786B99$ #<% &.%EF 8_O*7EF$ a#$*OF<7$'OFB'-5$'$ EF<%<L8$%*7*$%8C Y%.EL#99' .'& L*'$5<8*7EF$ b99'J UF<7$'NK$%/B'/$J +$/$'78%)5.'/J T$#$/.'/ 7EF<%6$% G%$''69BEF$'J L-5O%$77*K9$ SY<5O6X .'& '<F$A. *'L-5O%$77*K9$ Sb<77$%X a.78B'&$J 8F$%5*7EF$7 .'& 5$EF<'*7EF$7 D*EF8/9$*EF2 /$#*EF8J 78$*6$ o998%5$ *'6-9/$ 0-']<77$' 2 .'& \'$%/*$<.78<.7EF A#*7EF$' &$' UF<7$': *'$ #*EF8*/$ */$'7EF<68 &$% F_O$%K-9*7EF$' I$%6<F%$' *78 <.EF *F%$ RBF*/L$*8J ‘ ’78$8*/L$*8$' .'& 78$*9$ +%<&*$'8$' 7$F% /$'<. #*$&$%A./K': Y*$ '<EF/$%$EF'8' T$'EF5<%L G$786B99$ F<K$' /$A$*/8J &<77 &*$ $*'/$7$8A8$' F_O$%K-9*7EF$' I$%6<F%$' &$% ^VG^P U<%8'$% 7$F% /$%*'/$ '.5$%*7EF$ Y*66.7*-' <.6#$*7$' .'& 8%-8A&$5 78<K*9J /$'<.J $66*A*$'8 .'& %-K.78 7*'&: Y*$ F_O$%K-9*7EF$' M)7.'/70$%6<F%$' F<K$' $*'$' F-F$' P$*6$/%<& $%%$*EF8J 7*$ 7*'&*' &$% M</$J 8_O*7EF$ 5$F%&*5$'7*-'<9$ a#$*OF<7$'OFB'-5$'$ A.0$%9B77*/ A. K$%EF'' .'& 7*$ L)''$' K$* &$% 5$F%&*5$'7*-'<9$' ZRY V*5.9<8*-' 0-' a#$*OF<7$'78%)5.'/$' *' &$% P$<L8-%7*EF$%F$*8 $*'/$7$8A8 #$%&$': Y*$ PEF'$%/$K'*77$ &$% ^VG^P T$'EF5<%L G$786B99$ 5*8 &$5 RM‘T[xZ-&$ #.%&$' .'8$% k+P^ >@k 0$%)66$'89*EF8:

Y*$*5 RM‘T[xZ-&$ 0$%#$'&8 VZ]]$8F-&$ 0$%#$'&$8 K$* &$% [%87<OO%-e*5<8 *-' &$% 9-L<9$' +%<&*$'8$' $*' GIY I$%6<F%$' A#$*8$% [%&'.'/ kM\\h RN% &*$ a$*8*'8$/%<8*-' L-55 8 &<7 a$*8*'8$/%<8*-'70$%6<F%$' R\T\ kc[Ri1k A.5 *'7<8A: T$* &$% *5O9*A*8$' a$*8*'8$/%<8*-' &$% 7$F% 78$*6$' /$#)F'9*EF$' Y*66$%$'8*<92 /9$*EF.'/77_78$5$ #*%& $*' \e8%<O-9<8*-'70$%6<F%$' 0$%#$'&$8: Y<5*8 0$%K.'&$' *78 $*'$ <.8-5<8*7EF$ (-'8%-99$ &$7 A$*89*EF$' Y*7L%$8*7*$%.'/76$F9$%7: RN% $*'$ $66*A*$'8$ M)7.'/ #$%&$' &*$ a$*87EF%*88#$*8$.'& &*$ [%&'.'/ &$7 I$%6<F%$'7 <.8-5<8*7EF &$% U%-K9$59)7.'/ <'/$O<778J 7-&<77 0-5 ^'#$'&$% 0-%/$/$K'$' R$F9$%/%$'A$' $*'/$F<98$' #$%&$':

Y<7 a$*8*'8$/%<8*-'70$%6<F%$' R\T\ #*%& <.EF *' ^GcM\G $*'/$7$8A8: Y<77 K$*&$ U%-/%<55$J ^GcM\G .'& RM‘T[x&<7 /9$*EF$ a$*8*'8$/%<8*-'70$%6<F%$' 0$%#$'&$'J $%9$*EF8$%8 &*$ (-OO9.'/ K$*&$% U%-/%<55$ A. $*'$5 V*5.9<8*-'7O%-/%<55: T$* &$% (-OO9.'/ &$7 V_78$52Z-&$7 ^GcM\G 5*8 &$5 5$F%&*5$'7*-'<9$']-&.9 RM‘T[x 7*'&*5 b$7$'89*EF$' &%$* ^.6/<K$' A.9)7$':

a.'BEF78 K$')8*/8 5<' $*' W'8$%6<E$ 6N% &$' Y<8$'<.78<.7EF: c*$%K$* 7*'& &*$.'8$%7EF*$&9*EF$' Y<8$'78%.L8.%$' A. K$%NEL7*EF8*/$': ^.EF &*$.'8$%7EF*$&9*EF$' [%87<OO%-e*5<8*-'$' SO$%7$8A8$7J KA#: .'0$%7$8A8$7 +*88$%X 7O*9' F*$% $*'$ P-99$:

Y*$ A#$*8$ ^.6/<K$ *78 &*$ OF_7*L<9*7EF$ (-OO9.'/: Y*$ U%-/%<55$ 0$%#$'&$' .'8$%7EF*$&9*EF$]-&99: T$* a#$*OF<7$'78%)5.'/$' %$*EF8 &<7 VO$L8%.5 0-5 F-5-/$'$']-&$99 K*7 A.5 0-99 7$O<%*$%8$' a#$*2R9.*&]-&$99: *' #$*8$%$7 U%-K9$5 *78 &*$.'8$%7EF*$&9*EF$ Y*5$'7*-'<9*8B8 S1Y KA#: @YX &$% U%-/%<55$: ^KFB'/*/ 0-' &$% 0-%/$/K'$' 8$EF'*7EF$' (-'6*/.%<8*-' 5N77$' 7*''0-99$ I$%K*'&.'/$' /$7EF<66$' #$%&$'J &*$ *5 *'L9<'/ 5*8 &$' V8%)5.'/7O%-A$77$' 9*$/$': W'8$%O-9<8*-'72 .'& P$78%*L8*-'78$EF'*L$' #$%&$' F*$% $*'/$7$8A8:

Y*$ M)7.'/ &$% $%78$' K$*&$' ^.6/<K$' K$&*'/8 $*'$ OF_7*L<9*7EF 7*''0-99$ (-OO9.'/ K$*&$% U%-/%<55$.'& &$% V8%)5.'/7O%-A$77 #*%& *'7/$7<58J *5 P<F5$' &$% $*'/$7$8A8$' ^OO%-e*5<8*-'$'J %*EF8*/ #*$&$%/$/K': Y*$ '.5$%*7EF$ V*5.9<8*-' #*%& <K$% .: ‘: '-EF '*EF8 $66*A*$'8 7$*': Y*$ '.5$%*7EF$ M)7.'/ 0-' A$*8<KFB'/*/$' V8%)5.'/7O%-A77' .'8$%9*$/8 'B59*EF /$#*77$' V8<K*9*8B87L%*8$%*$': Y*7 $%A#*'/$' K$* $eO9*A*8$% a$*8*'8$/%<8*-'J &<77 &$% a$*87EF%*88 '*EF8 /%),$% 7$*' &<%6 <97 $*' K$78*558$% b$%8J &<7 7- /$'<''8$ Z-.%<'82M*5*8: Y<5*8 &$% V8%)5.'/7O%-A$77 $66*A*$'8 K$%$EF'$8 #$%&$' L<''J 5N77$' *5O9*A*8$ a$*8*'8$/%<8*-'70$%6<F%$' $*'/$7$8A8 #$%&$'J &: F: <.EF 6N% &<7 /$L-OO98 U%-/%<557_78$5 5.77 &*$ a$*8*'8$/%<8*-' *5O9*A*8 7$*': Y*$ &%*88$ S.'& 7EF#$%78$X ^.6/<K$ K78F8 <97- &<%*'J <.EF 6N% &*$ (-OO9.'/ $*'$' *5O9*A*8$' '.5$%*7EF$' M)7.'/7<9/-%*8F5.7 A. 6*'&$'J &$% &*$ +$7<587*5.9<8*-' 66L8*0 K$%EF'8:

RN% &*$ U%-/%<55$ ^GcM\G .'& RM‘T[x #.%&$ $*'$ $66*A*$'8$ *5O9*A*8$ (-OO9.'/778%<8$/*$ $'8#*EL$98 .'& 0$%*6*A*$%8 k+P^dik: Y$% *5O9*A*8$ (-OO9.'/7<9/-%*8F5.7 0$%#$'&$8 $*'$ a#*7EF$'7EF%*885$8F-&$J K$* &$% &*$ M)7.'/70$%6<F%$' &$% $*'A$9'$' U%-/%<55$ K$*K$F<98$' #$%&$': W'7/$7<58L-78$8 &*$ +$7<589)7.'/ '*EF8 0*$9 5$F% <97 &*$ <&&*$%8$ PEF'A$*8 6N% &*$ G$*97_78$5$: a.7B8A9*EF 5N77$' '.% L9$*'$ 9*'$<%$ +9$*EF.'/77_78$5$ <' &$' (-OO9.'/778$99$'

/$9)78 #$%&$':]*8 &*$7$% (-OO9.'/778%<8$/*$ #.%&$ $%6-9/%$*EF $*'$ +$/$'78%)5.'/ 0-' b<77$% .'& Y<5O6*5 P*'/%<.5 S‘UGR G$78 mP.' 1@km5*8 ^GcM\G k RM‘T[x 2 3Y /$%$EF'$8:

Y*$ A.LN'68*/$ \'8#*EL9.'/ A*$98 &<%<.6 <KJ &*$ @Y I$%7*-' &$7 RM‘T[xZ-&$7 5*8 ^GcM\G A. L-OO$9':]*8 &*7% \%#$*8$%.'/ *78 $7 &<'' 5)/9*EFJ '*EF8 '.% &$' P*'/%<.5 A#$*&*5$'7*-'<9 A. 7*5.9*$%$'J 7-'&$%' &$% /$7<58$ P$<L8-%&%.ELK$FB98$% L<'' &<'' &%$*&*5$'7*-'<9 *' $*'$ V*5.9<8*-'7%$EF'.'/ $*'K$A-/$' #$%&$': T*7 A.% U%-&.L8%$*6$ 5N77$' h$&-EF '-EF .'8$%7EF*$&9*EF78$ VA$'<%*$' S*'A$9$66$L8$.'&*'8$/%*$%8$7 V_78$50$%F<98$'X '<EF/$%$EF'$8 #$%&$'J .5 &*$ 0$%7EF*$&$'$' V8%)5.'/7A.78B'&$<' &$' (-OO9.'/778$99$' '.5$%*7EF 7*EF$% A. KF%%7EF$':

Y*$ &%$*&*5$'7*-'<9$ V*5.9<8*-' 0-' a#$*OF<7$'78%)5.'/$' $%6-%&$%8 <K$% <.EF #$*8$%$]-&99'8#*EL9.'/$': Y*$ V8%)5.'/7K*9&L<%8$' <.7 &$' $*'&*5$'7*-'<9$' V*5.9<8*-'$' L)''$' *' 5$F%&*5$'7*-'<9$' V*5.9<8*-'$' '*EF8 0$%#$'&$8 #$%&$': Y*$ V8%)5.'/7A.78B'&$ L)''$'J <.EF K$* 5$F%&*5$'7*-'<9$% V*5.9<8*-'J '*EF8 *5 5$% <.7 &$' \%F<98.'/7/9$*EF.'/$' <99$*' *&$'8*6*A*$%8 #$%&$': c*$%A. *78 $*'$ #$*8$%$]-&$99/%),$ '-8#$'&*/J &*$ UF<7$'8%$''69BEF$: *'$ G%<'7O-%8/9$*EF.'/ 6N% &*$ (-'A$'8%<8*-' &$% UF<7$'8%$''69BEF$ #*%& A.7B8A9*EF 5-&$99*$%8 .'& A.7<55$' 5*8 &$' \%F<98.'/7/9$*EF.'/$' /$9)78: T$* &$%]-&$99*$%.'/ $%#$*78 7*EF #*$&$% &*$ F_O$%K-9*7EF$ */$'7EF<68 &$7 +%.'&/9$*EF.'/77_78$57 <97 0-%8$*9F<68J #$*9 &*$ G%<'7O-%8/$7EF#*'&*/L$*8 &$% UF<7$'8%$''69BEF$ $*'$ &$% ZF<%<L8$%*78*L$' *78: Y*$ %$EF8$ V$*8$ &$% G%<'7O-%8/9$*EF.'/ K$7EF%$*K8 &*$ ś&$%.'/ &$% UF<7$'8%$''69BEF$ <.6 +%.'& 0-' I$%&<5O6.'/ .'&k-&$% (-'&$'7<8*-' .'& <.6 +%.'& &$% <.6 &*$ UF<7$'8%$''69BEF$ #*%L$'&$' (%B68$: Y*$ (-'A$'8%<8*-' &$% UF<7$'8%$''69BEF$ *78 &<%NK$% F*'<.7 $*' #*EF8*/$% U<%<5$8$% 6N% &*$ a#$*OF<7$'5-&$99*$%.'/: Y*$ a#*7EF$'OF<7$'%$*K.'/ .'& &*$ ^.78<.7EF8$%5$ 6N%]<77$.'& \'$%/*$ A#*7EF$' &$' UF<7$' K$* (-'&$'7<8*-'72 .'& I$%&<5O6.'/70-%/B'/$' FB'/$' 0-' &*$7$5 U<%<5$8$% <K:

\eO$%*5$'8$99$]$77.'/$' &$% UF<7$'8%$''69BEF$ K$7EF%B'L$' 7*EF K*7F$% <.6 T9<7$'78%)5.'/$': Y*$7$ \eO$%*5$'8$ SA: T: G[URM[b kUP^>@kX #$%&$' <.EF A.% I<9*&*$%.'/ &$% G%<'7O-%8/9$*EF.'/ 6N% &*$ UF<7$'8%$''69BEF$ F$%<'/$A-/$': a.% I<9*&*$%.'/ *5 T$%$*EF &$% G%-O6$'78%)5.'/ 7*'& VO%<_eO%*5$'8$ SGc^WJ G[VôDX /$$*/'$8: ‘'A.%$*EF$'&$ eO%*5$'8$99$ Y<8$' /*K8 $7 K*7F$% *' &$' T$%$*EF$' &<A#*7EF$'J F*$% 5N77$' '-EF ^'78%$'/.'/$' .'8$%'-55$' #$%&$':

*' #$*8$%$7 #*EF8*/$7 R$9& *' &$% a#$*OF<7$'5-&$99*$%.'/ *78 &*$ G.%K.9$'AJ &: F: &*$ \'8#*EL9.'/ 0-' G%<'7O-%8/9$*EF.'/$' 6N% &*$ 8.%K.9$'8$ L*'$8*7EF$ \'$%/*$.'& &$%$' Y*77*O<8*-' 6N% a#$*OF<7$'78%)5.'/$':

6.1.4 Verhalten neuerer Brennstäbe

W' &$.87EF$' ($%'L%<68#$%L$' L-55$' A.'$F5$'& T%$''$9$5$'8$ A.5 *'7<8AJ &*$ 7*EF &.%EF 9B'/$%$ V8<'&A$*8$' *5 ($%'J F)F$%$ ^KK%B'&$J /$B'&$%8$ T%$''78-66A.7<55$'7$8A.'/$' S] [XJ /$B'&$%8$ cN99%-F%9$/*$%.'/$' S]=J a*%9-X -&$% <.EF &.%EF F)F$%$ V8<K9B'/$'9$*78.'/$' <.7A$*EF'$': W''$%F<9K &$% [\ZY #*%& *' 0$%7EF*$&$'$' ^%K$*87/%.OO$' &*7L.8*$%8J *'#*$#$*8 &*$ K78F$'&$ U%<e*7 &$% M[Z^2 .'& PW^2+%$'A#$%82V$8A.'/ .'8$% T$%NEL7*EF8*/.'/ &$%]<8$%*<90$%B'&$%.'/ '-EF A.9B77*/ *78: Y*$ [\ZY2\eO$%8$'8</.'/ *5 D-0$5K$% 3>>@ kIWG>@k A$*/8$ &*$ D-8#$'&*/L$*8 '$.$% I$%7.EF$ A.% 9<'/6%*78*/$' (NF9K<%L$*8 &$7 ($%'7 &.%EF &<7 /$B'&$%8$]<8$%*<90$%F<98$':

W' ^GcM\G #*%& K*7F$% 6N% &*$ T$%$EF'.'/ &$7 bB%5$NK$%/<'/7L-$66*A*$'8$' *5 VO<98 A#*7EF$' U$99$8 .'& cN99%-F%J '$K$' &$% +<7A.7<55$'7$8A.'/J '.% &*$ 8F$%5*7EF$ Y$F'.'/ 0-' U$99$8 .'& cN99%-F% K$%NEL7*EF8*/8: ^.,$%&$5 K78F8 L$*'$ PNEL#*%L.'/ A#*7EF$' &$% ^.7&$F'.'/ &$7 cN99%-F%7 ST<99--'*'/X .'& &$% R9.*&&_'<5*L: Y*$7 *78 &<'' A.9B77*/J #$'' &<7 T<99--'*'/ A. L$*'$% 7*/''6*L<'8$' T9-EL<&$ 6NF%8:]*8 &$5 *'7<8A '$.$% cN99%-F%5<8$%*<9*$' L<'' h$&-EF .'8$% '578B'&$' <.EF K$* ^.79$/.'/778)%6B99$' &<7 T<99--'*'/ /%),$%$ ($%'K$%$*EF$ .56<77$'J #<7 6N% &$' D<EF#$*7 $*'$% <.7%$*EF$'&$' ($%'LNF9.'/A. K$%NEL7*EF8*/$' *78:

a.% \%5*889.'/ &$7 VEF<&$'.56<'/7 K$* (NF95*88$90$%9.7878)%6B99$' SM[Z^X #.%&$ &<7 PEF'O%-/%<55 G\VU^2P-& $'8#*EL$98 S7*F (<O*8$9 !T%$''78<K0$%F<98$';X: Y<5*8 78$F8 $*']-&$99 A.% I$%6N/.'/J 5*8 &$5 8%<'7*$'8$ VO<98/<76%$*7$8A.'/J T<99--'*'/ .'& cN99%-F%K$%78$' <.EF 6N% '$.$ cN99%-F%5<8$%*<9*$' .'& .'8$% T$%NEL7*EF8*/.'/ 0-' c-EF<KK%<'&2\66$L8$'J A: T: P*5 \66$E8 S$%F)F8$% ^KK%<'& *' &$% P<'&A-'$XJ K$%EF'8 #$%&$' L<'': I-5 ^KK%<'& <KFB'/*/$ ^'6<'/7O<%<5$8$% L)''$' 5*8 &$5 U%-/%<55 GP^DV'P^D'V kM^V>1k $%A$./8 #$%&$':

RN% &*$ b$*8$%$'8#*EL9.'/ 0-' ^GcM\G *78 0-%/7F$'J &*$]-&99 6N% &$' VO<982 bB%5$NK$%/<'/ .'& 6N% &<7 cN99%-F%0$%F<98$' &.%EF *'A$95-&$99$ 0-' G\VU^2P-& A. $%#$*8$%': RN% &*$ PNEL#*%L.'/ A#*7EF$' T%$''78<K0$%F<98$' .'& R9.*&&_'<5*L #*%& &<7]-&$99 0-' ^GcM\G2ZY NK$%'-55$':

6.1.5 Kopplung mit anderen Programmen

V_78$52Z-&$7 #$%&$' '*EF8 '.% A.% V*5.9<8*-' &$% GF$%5-F_&%<.9*L &$7 '.L9$<%$' Y<5O6$%A$./.'/77_78$57 7-'&$%' <.EF 6N% &*$ ^'9</$'7*5.9<8*-' $*'/$7$8A8: W' ^GcM\G 7*'& &*$]-&.9$ 6N% &*$ GF$%5-2R9.*&&_'<5*L SGRYXJ &$' T%$''78<K Sc\Z'XJ &*$ U.'L82 .'& 1Y2D$.8%-'$'L*'$8*L 7-#*$ 6N% &*$ M$*82 .'& V8$.$%.'/78$EF'*L S+ZV]X $*'/$K.'&$': ^.,$%&$5 L<'' ^GcM\G 5*8 &$5 @Y2(*'$8*L2U%-/%<55 ó^T[kóTT[x.'& &$5 3Yk@Y 2R9.*&5-&.9 RM'T[x/$L-OO$98 #$%&$': HK$% &$' ^'<9_7$7*5.9<8-% 7*'& /$L-OO98 P$EF'.'/$' 0-' ^GcM\G .'& &$5 Z-'8<*'5$'8 Z-&$ V_78$5 Z[Z[VjV 5)/9*EF: Y<%NK$% F*'<.7 7*'& 6N% &*$ V*5.9<8*-' 0-' V8)%6B99$' 5*8 ($%'A$%78)%.'/ #$*8$%$]-&.9$.'& U%-/%<55$ *' ^GcM\G2ZY $*'/$K.'&$' #-%&$':

RN% &*$ (-OO9.'/ .'8$%7EF*$&9*EF$% U%-/%<55$.'&]-&.9$ L)''$' 0$%7EF*$&$'$ G$EF'*L$' 0$%#$'&$8 #$%&$'C

- ^99/5*'$ (-OO9.'/ NK$% Y<8$'K<'L7_78$5$SPVjVGJ VW+^MXJ

- *'8$%'$ (-OO9.'/ NK$% O%-/%<55*$%8$J O%-K9$5-%*$'8*$%8$ VEF'*8878$99$':

T$* &$% *'8$%'$' (-OO9.'/ L<'' &$% Y<8$'<.78<.7EF h$ '<EF ^%8 &$% PNELL-OO9.'/ .'8$%7EF*$&9*EF -%/<'*7*$%8 #$%&$':

W78 &*$ PNELL-OO9.'/ 7EF#<EF S^GcM\GkZ[Z[VjVX -&$% NK$% $*' a$*8/9*$& /$&B5O68 S^GcM\Gkó^T[kóTT[XJ *78 $*'$ $eO9*A*8$ (-OO9.'/ <.6 a$*87EF%*88$K$'$ 5)/9*EFJ &: F: &$% Y<8$'<.78<.7EF $%6-9/8 A.5 \'&$ &$7 a$*87EF%*887: c<8 &<7 6NF%$'&$ U%-/%<55 ^GcM\G $*'$' /%),$%$' a$*87EF%*88 <97 ó^T[kóTT[x #$%&$' &*$ GRY2Y<8$' 6N% &*$ a$*87EF%*88$ &$% (*'$8*L *'8$%O-9*$%8: '5 (-'0$%/$'AO%-K9$5$ A. 0$%5$*&$'J*78 $7 h$&-EF*: ^99/:)L-'-5*7EF$%J &$' ^GcM\G2a$*87EF%*88 A. K$/%$'A$':

Y*$ (-OO9.'/ A#*7EF$' &$% ^GcM\G2GRY .'& &$5 T%$''78<K2 .'& V8%.L8.%5-&$99 c\Z' *78 7$5*2*5O9*A*8: Y<K$* 6-9/8 c\Z' &$' G$*9A$*87EF%*88$' &$% GRYJ .5 &$' '<EF6-9/$'&$' G$*9A$*87EF%*88 &$% GRY 5*8 <L8.99' ^'6<'/7K$&*'/.'/$' A. 0$%7-%/$': Y*$ b<77$%78-66$%A$./.'/ &.%EF &*$ cN99%-F%-e*&<8*-' #*%& K$* &$% T$%$EF'.'/ &$% f<E-K*2]<8%*e K$%NEL7*EF8*/8: SY*7 (-OO9.'/ #*%& <.EF 6N% &<7 T%$''78<K5-&$99 5*8 ($%'A$%78)%.'/ <'/$#$'&$8:X

Y*$ (-OO9.'/ A#*7EF$' &$% ^GcM\G2GRY .'& RM'T[x78 0-99 2*5O9*A*8J &: F: 7*$ $%6-9/8 <.6 &$% \K$'$ &$% Y*66$%$'8*<9/9$*EF.'/77_8$5$k+P^ >1k:

Y*$ ^%8 &$% (-OO9.'/ &$% M$*82 .'& V8$.$%.'/78$EF'*L S+ZV]X 5*8 &$% GRY .'& c\Z' L<'' &.%EF &$' ^'#$'&$% &$6*'*$%8 #$%&$' -&$% #*%& *'8$%' '<EF &$5]<, &$% PNELL-OO9.'/ -%/<'*7*$%8:

Y*7 O%-K9$5-%*$'8*$%8$ (-OO9.'/778%<8$/*$ F<8 A.5 a*$9J K$* 5)/9*EF78 /$%*'/$5 PEF'<.6#<'& &*$ (-OO9.'/7&<8$' 7- A. K$78*55$'J &<77 &<7 *5O9*A*8$ M)7.'/70$%6<F%$' &$% GRY '*EF8 /$78)%8 .'& -O8*5<9$ a$*87EF%*88#$*8$' $%5)/9*EF8 #$%&$':

Y*$ (-OO9.'/$' A#*7EF$' &$' 0$%7EF*$&$'$' U%-/%<55$' .'&]-&.9$' 5N77$' &$']-&$99$%#$*8$%.'/$' .'& ^'6-%&$%.'/$' $'87O%$EF$'& #$*8$% $'8#*EL$98 .'& -O8*5*$%8 #$%&$': Y*$ [O8*5*$%.'/ &$% (-OO9.'/$' K$*'F<98$8 <.EF &*$ '578$99.'/ <.6 '$.$ V-68#<%$2G$EF'-9-/*$' SA: T:]$77</$U<77*'/W'8$%6<E$S]UWX .'& &*$ U<%<99$9*7*$%.'/ 0-' U%-/%<557_78$5$':

6.1.6 Zusammenfassung und notwendige Modellentwicklung zum Forschungsbereich „Stör/Unfallanalyse Kühlkreislauf“

^.EF K$* &$5 K*7F$% $%%$*EF8$' F-F$' \'8#*EL9.'/778<'& #$%&$' &*$ F*$% K$7EF%*K'$' P$EF$'O%-/%<55$ #$*8$%F*' 7_78$5<8*7EF 0$%K77%8 .'& '$.$' ^'6-%&$%.'/$'J &*$ 7*EF <.7 &$% K%$*8$' ^'#$'&.'/ &$% P$EF$'O%-/%<55$ $%/$K$'J $'87O%$EF$'& <.7/$K<.8: Y<K$* 78$F8 $*'$ %$<9*78*7EF$%$ T$7EF%$*K.'/ K$78*558$% V8)%6<997p'A$'J &*$ $*'$ $%F)F8$ ^.77</$7*EF$%F$*8J $*'$ F)F$%$ %B.59*EF$ ^.69)7.'/ -&$% $*'$ $'/$%$ PNELL-OO9.'/ 5*8 &$% D$.8%-'$'L*'$8*L $%6-%&$%'J *5 I-%&$%/%.'&: ^.6/%.'& &$% .56<77$'&$' V_78$57*5.9<8*-' .'& /N'78*/$% PEF'A$*8$'J #$%&$' &*7 V_78$52Z-&$7 '-EF 9<'/6%*78*/ &*$ #*EF8*/78$' ^'<9_7$#$%LA$./$*5 P<F5$' &$% P$<L8-%7*EF$%F$*876-%7EF.'/7$*':

DK' &$' O%-/%<558$EF'*7EF$' \%#$*8$%.'/$' *78 A.% \%F)F.'/ &$% ^.77</$7*EF$%F$*8 $*'$ #7'89*EF$]-&990%K77%.'/ 6N% L-5O9e A#$*OF<7*/$ V8%)5.'/76-%5$' '-8#$'&*/: Y<K$* 7*'& &*$ ^%K$*8$' 6N% ZRY2Z-&$7 A.% R-%5.9*$%.'/ $*'$% \%F<98.'/7/9$*EF.'/ 6N% &*$ a#*7EF$'OF<7$'69BEF$ A. K$%NEL7*EF8*/$':

W' ($%'L%<68#$%L$' L-55$' A.'$F5$'& T%$''$9$5$'8$ A.5 *'7<8AJ &*$ 7*EF &.%EF 9B'/$%$ V8<'&A$*8$' *5 ($%'J F)F$%$ ^KK%B'&$J /$B'&$%8$ T%$''78-662 A.7<55$'7$8A.'/$' S][XJ /$B'&$%8$ cN99%-F%9$/*$%.'/$' S]=J a*%9-X -&$% <.EF &.%EF F)F$%$ V8<K9B'/$'9$*78.'/$' <.7A$*EF'$': \'87O%$EF$'& 5N77$' &*$]-&99 &$% V_78$52Z-&$7 #$*8$%$'8#*EL$98 #$%&$':

T<7*$%$'& <.6 &*7' \%L$''8'*77$' $%/$K$' 7*EF 6N% &*$ '-8#$'&*/$ b$*8$%$'8#*EL9.'/0-' ^GcM\G6-9/$'&$ ^%K$*87O.'L8$C

- I$%K$77$%.'/ &$%]-&$99*$%.'/ &$7]<77$'2J \'$%/*$2 .'& W5O.97<.78<.7EF7 K$* a#$*OF<7$'78%)5.'/J
- I$%K$77$%.'/ &$% %B.59*EF$' ^.69)7.'/ 5$F%&*5$'7*-'<9$% $*'2 .'& 5$F%OF<7*/$% V8%)5.'/$'Q b$*8$%$'8#*EL9.'/ &$% A$*89*EF$' \'8#*EL9.'/ 0-' V8%)5.'/7K*9&$%' 6N% $*'&*5$'7*-'<9$ P-F%78%)5.'/Q O%-/%<55 58$EF'*7EF$ *'K*'&.'/ &$7 3Yk@Y2]-&.97 RM'T[xJ
- I$%K$77$%.'/ &$%]-&$99*$%.'/ &$7 T%$''78<K0$%F<98$'7 K$*5 *'7<8A 0-']*7EF-e*&$'J K$* F-F$5 ^KK%<'& .'& '$.$' cN99%-F%5<8$%*<9*$' 5*8 T$%NEL7*EF8*/.'/ &$% .'5*88$9K<%$' PNEL#*%L.'/ <.6 &*$ R9.*&&_'<5*LJ
- %$<9*78*7EF$ T$%$EF'.'/ &$7 D.L9*&*'0$'8<%7 .'8$% T$%NEL7*EF8*/.'/ $*'$7 /$B'&$%8$' T$8%*K7 -&$% '$.$% T%$''$9$5$'8$J
- U%-/%<55-O8*5*$%.'/J o<9*8B877*EF$%.'/ .'& I$%K$77$%.'/ &$% T$'.8A$%-K$% 2 69BEF$J
- I$%LN%A.'/ &$% PEF'A$*8 &.%EF W5O9$5$'8*$%.'/ 0-']$8F-&$' A.% U<%<99$9*7*$%.'/ &$7 P$EF$'O%-/%<557:

6.2 Simulation der Vorgänge im Reaktordruckbehälter mit Kernzerstörung

Y$% I$%9<.6 $*'$7 O-78.9*$%8$' 7EF#$%$' ''6<997 *' M$*EF8#<77$%%$<L8-%$'J $*'/$9$*8$8 &.%EF $*'$ R%$*9$/.'/ &$7 ($%'7 .'& /$6-9/8 0-' $*'$% $'87O%$EF$'&$' ^.6F$*A.'/J *78 /$L$''A$*EF'$8 &.%EF

- &*$ [e*&<8*-' &$% ($%'5<8$%*<9*$' ?*'7K$7-'&$%$ &$% a*%E<9-_2cN99%-F%$?J
- &*$ a$%78)%.'/ &$7 ($%'7? ($%'7EF5$9A$' .'& 20$%9</$%.'/ ?J

- &<7 I$%F<98$' &$% VEF5$9A$.'& &77' (NF9K<%L$*8 *5 .'8$%$' U9$'.5 &$7 P$<L8-%&%.ELK$FB98$%7J

- &<7 I$%7</$' 0-' (-5O-'$'8$'J *'7K$7-'&$%$ &$7 P$<L8-%&%.ELK$FB98$%7J /$L-OO$98 5*8 &$5 ^.78%</ &$% ($%'7EF5$9A$ 7-#*$ &<7 VO<98O%-&.L8O$%F<98$' #BF%$'& &*$7$% U%-A$77$:

Y*$ ^K9B.6$*5 P$<L8-%&%.ELK$FB98$% K$78*55$'7-5*8 .:<:&$' O%*5B%$' o998%5 6N% VO<98O%-&.L8$.'& b<77$%78-66 *5 V*EF$%F$*87K$FB98$%: Y<K$* .'8$%9*$/$' &*7 U%-A77 $*'$% I*$9A<F9 0-' OF_7*L<9*7EF$' .'& EF$5*7EF$' UFB'-5$'$'J &*$ 7-#-F9 0-' &$% V8)%6<997$p$'A<97<.EF 0-' &$5 P$<L8-%8_O< KFB'/$' L)''$':

Y$% ^K9<.6 7EF#$%$% ''6B99$ *5 U%*5B%7_78$5 #*%& 7$*8 NK$% &%$*,*/ f<F%$'J /$78N8A8 <.6 eO%*5$'8$99$ ^%K$*8$'J <K$% <.EF <.6 &*$ \%L$''8'*77$J &*$ <.7 ^'<9_7$' &$7 G]W232''6<997 *5 f<F%$ 1dd /$#-''$' #$%&$' L-''8$'J .'8$%7.EF8: PEF'2 O%-/%<55$ K$6*'&$' 7*EF 7$*8F$% *' &$% \'8#*EL9.'/ .'& I<9*&*$%.'/ A.% ^'<9_7$ 0$%7EF*$&$'78$% V8)%6<997p'A$': Y<K$* 78F' 6N% &$8<*99*$%8$ ^'<9_7$' &$7 A$*89*EF$' ^K9<.67 7-#*$ &$7 o$998$%57 <.7/$#BF98$% ''6<997$p$'A$' *' M$*EF8#<77$%%$<L8-%$' #$*8/$F$'& 5$EF<'*78*7EF$ V_78$57E-&$7 #*$ &*$ &$.87EF$ \'8#*EL9.'/ ^GcM\G2ZYJ &*$ 6%<'A)7*7EF$ WZ^P\kZ^Gc^P\ -&$% &*$ 'V2<5$%*L<2 '*7EF$ P\M^U=kVZY^U SVZY^UVW]X A.% I$%6N/.'/: Y*$7$ 7-99$' &*$ T$#$%8.'/ &$% b*%L7<5L$*8 0-' D-86<99O%-A$&.%$' .'&]<,'<F5$' &$7 <'9</$'*'8$%'$' D-86<992 7EF.8A$7 78N8A$' 7-#*$ K$* O%-K<K*9*78*7EF$' V*EF$%F$*87<'<9_7$' SUV^X &$% V8.6$ 3 $*'$%7$*87 &$% (<9*K%*$%.'/ .'& <'&$%$%7$*87 &$% Y.%EF6NF%.'/ 0-' T$'EF5<%L2 %$EF'.''/$' 6N% W'8$/%<9E-&$7J #*$A:T:^VG\ZJ &*$'$':

Y<7 I$%78B'&'*7 &$% &$' ''6<99 EF<%<L8$%*7*$%$'&$' U%-A$77$ *78 A.% T$.%8$*9.'/ '<EF6-9/$'&$% V8)%6<99OF<7$' 7-#*$ A.% R789/.'/ /$$*/'8% ^EE*&$'8]<'</$5$'8 V8%<8$/*$' .'& A.%]*'&$%.'/ &$% V8)%6<996-9/$' '-8#$'&*/J .'& &*$7 '*EF8 '.% 6N% 9<.6$'&$J 7-'&$%' <.EF 6N% 6-%8/$7EF%*88$'$J A.LN'68*/$ ^'9</$':

W5 R-9/$'&$' #$%&$' &*$ K$78*55$'&$' UFB'-5$'$ #BF%$'& &$% 0$%7EF*$&$'$' V8<&*$' &$7 ''6<99<K9<.67 .'& &$%$' '57$8A.'/ *']-&$99$.'& ^'#$'&.'/ *' V8)%6<99<'<9_7$2Z-&$7J &*$ *' &$' #$*8$%$' (<O*8$9' &$8<*99*$%8 &*7L.8*$%8 #$%&$'J $*'9$*8$'& K$7EF%*K'C

Kernzerstörung – Kernschmelzen und Kernverlagerung

Y*$ ($%'A$%78)%.'/ #*%& *' A#$* UF<7$' .'8$%8$*98: Y*$ 6%NF$ UF<7$ KA*EF'$8 &*$ T$7EFB&*/.'/ &$% (-'8%-9978BK$ K*7 F*' A.5 VEF5$9A$' .'& I$%9</$%' 5$8<99*7EF$']<8$%*<97: Y*$ 7OB8$ UF<7$ #*%& EF<%<L8$%*7*$%8 &.%EF &<7 VEF5$9A$' L$%<5*7EF$% V8%.L8.%$'J &$' I$%9.78 &$% ($%'78%.L8.%k2/$-5$8%*$.'& $*'$% I$%9</$%.'/ &$% VEF5$9A$*' &<7 .'8$%$ U9$'.5 &$7 P$<L8-%&%.ELK$FB98$%7:

Y*$ **frühe Phase** &$% ($%'A$%78)%.'/J &*$ &.%EF $%78$ VEF5$9A$K*9&.'/$' 5$8<99*7EF$% (-5O-'$'8$' K$* #$*8/$F$'&$5 \%F<98 &$% T%$''$9$5$'8/$-5$8%*$ K$78*55 8 #*%&J *78 OFB'-5$'-9-/*7EF /.8 0$%78<'&$' .'& <.EF F*'7*EF89*EF &$%]-&$99*$%.'/ *' &$' Z-&$7 /.8 K$7EF%*K': D<EF &$5 G]W232''6<99 #.%&$' '<8*-'<9 .'& *'8$%'<8*-'<9 0$%78B%L8 eO%*5$'8$99$ ^%K$*8$' <.6 &*$7$5 V$L8-% &.%EF/$6NF%8: V-*78 $*' #*EF8*/$7 \%/$K'*7 &$7 0-' 1dinK*7 1dd@ &.%EF/$6NF%8$' Z[P^ 2U%-/%<557J &<77 7*EF VEF5$9A$' <.6/%.'& $.8$L8*7EF$% b$EF7$9#*%L.'/$' A#*7EF$' &$' 0$%7EF*$&$'$']<8$%*<9*$' &$.89*EF .'8$%F<9K &$% VEF5$9A8$5O$%<8.%$' &$% $*'A$9'$' (-5O-'$'8$' K*9&$' kc\PdIk: W' &$%A$*8 9<.6$'&$' U%-/%<555' #*$ A:T: &$% ó\DZc 2 I$%7.EF7%$*F$ #*%& &<7 ^K7EF%$EL0$%F<98$' $*'$7 NK$%F*8A8$' P$<L8-%L$%'7 .'8$%7.EF8 kc[ ]>Ik: a.LN'68*/$ ^%K$*8$' #$%&$' 7*EF &$5 I$%F<98$' '$.$%J <KK%<'&-O8*5*$%8$%]<8$%*<9*$' ScN99%-F%$J T%$''78-66$X #*&5$' kIWG>@k:

Y*$ **späte Phase** &$% ($%'A$%78)%.'/ *78 /$L$''A$*EF'$8 &.%EF &$' I$%9.78 &$% T%$''$8$5$'8/$-5$8%*$ <.6/%.'& &$% T*9&.'/ .'& I$%9</$%.'/ L$%<5*7EF$% VEF5$9A$': *'$ VEF5$9A$L%.78$ L<'' $*'$' VEF5$9A$O--9 KA#: $*' VEFN88K$88 *5 ($%'K$%$*EF F<98$': Y*$ /$'$%99 UFB'-5$'-9-/*$ &*7% UF<7$ *78 <.EF <.6/%.'& $e8$'7*0$% ^'<9_7$' &$7 G]W232''6<997 0$%78<'&$': Y*$]-&$99*$%.'/ .'& '57$8A.'/ *' $'87O%$EF$'&$' Z-&$7 *78 '-EF '*EF8 <K/$7EF9-77$' .'& +$/$'78<'& 9<.6$'&$% ^L8*O*8B8$':

Y*$ ($%'0$%9</$%.'/ *' &<7 .'8$%$ U9$'.5 *78 K$78*558 &.%EF $*'$ 7.LA$77*0$ -&$% L-FB%$'8$ I$%9</$%.'/ &$% VEF5$9A$J (%.78$'K*9&.'/ .'& ^K9<8*-' 0-' V8%.L8.%$': b$'' 7*EF *5 .'8$%$' U9$'.5 b<77$% K$6*'&$8J L)''$' $eO9-7*0$ VEF5$9A$2 (NF95*88$92b$EF7$9#*%L.'/$' '*EF8 0-9978B'&*/ <.7/$7EF9-77$' #$%&$': RN% &*$ ($%'0$%9</$%.'/ *''7 .'8$%$ U9$'.5 *78 &*$ eO%*5$'8$99$ Y<8$'K<7*7 7$F% K$/%$'A8Q &$% <L8.$99$ V8<'& &$7 b*77$'7 K<7*$%8 F<.O87BEF9*EF <.6 &$% ^'<9_7$ &$7 G]W232 ''6<997: Y</$/$' /<K .'& /*K8 $7 #$98#$*8 $*'$ P$*F$ eO%*5$'8$99$% U%-/%<555$ A.% VEF5$9A$2 (NF95*88$92b$EF7$9#*%L.'/: [K#-F9 $*' <K7EF9*$,$'&$7 \%/$K'*7 *'7K$2

7-'&$%$ A. 5<e*5<9$' (-'0$%7*-'7%<8$' 0-' 8F$%5*7EF$% *' 5$EF<'*7EF$ \'$%/*$.'& A.5 *'69.77 &$% VEF5$9A$A.7<55$'7$8A.'/ 6$F98J F<K$' A:T: &*$ &$.87EF$' T\PY^2I$%7.EF$ /A*/8J &<77 7$9K78 K$* L-'7$%0<8*0$' ^''<F5$' $*' I$%7</$' &$7 PYT*'6-9/$0-' Y<5O6$eO9-7*-'$' O%<L8*7EF<.7/$7EF9-77$' #$%&$' L<'':

D-EF $%F$K9*EF$% R-%7EF.'/7K$&<%6 K78F8 F*'7*EF89*EF &$% T$7EF%$*K.'/ &$7 a$*8O.'L8$7 &$7 HK$%/<'/7 0-' $*'$% V8<K/$-5$8%*$ A. $*'$5 VEFN88K$88 -&$% VEF5$9A$O--9J &$% V8-66#$%8$ &$% L-5O9$e$']<8$%*<9*$' 7-#*$ &$% Z-%*.52 ZF<%<L8$%*78*L< K$* \%%$*EF$' &$7 .'8$%$' U9$'.57:

Schmelzeverhalten und -kühlbarkeit im unteren Plenum

Y<7 I$%F<98$' .'& *'7K$7-'&$%$ &*$ (NF9K<%L$*8 &$% VEF5$9A$ *5 .'8$%$' U9$'.5 #$%&$' &.%EF &*$ VEFN88K$88K*9&.'/ 7$9K78J &$' bB%5$8%<'7O-%8 *5 VEFN88K$88J &*$ U--92 .'& (%.78$'K*9&.'/J &*$ (-'0$L8*-' .'& VEF*EF8$'K*9&.'/ *5 VEF5$9A$O--9 .'& //6: &.%EF &*$ T*9&.'/ $*'$7 VO<98$7 A#*7EF$' U--9L%.78$.'& PYT2b<'& K$78*558: a. &$' $*'A$9'$' UFB'-5$'$' #.%&$' A<F9%$*EF$ \eO$%*5$'8$ &.%EF/$6NF%8J 7-F<K$' A:T: &*$ *' P.779<'& &.%EF/$6NF%8$' [\ZY2U%-/%<55$ P^VUM^I .'&]^VZ^W.'&WW #$%80-99$ W'6-%5<8*-'$' NK$% O%-8-8_O*7EF$ ($%'7EF5$9A$' /$9*6%8: Y*$]-&$99*$%.'/ .'& ‘57$8A.'/ *' V8)%6<99<'<9_7$2Z-&$7 *78 +$/$'78<'& 9<.6$'&$% ^L8*O*8B8$':

Komponentenversagen und Schmelzeaustrag

T$* .'A.%$*EF$'&$% (NF9.'/ &$% VEF5$9A$ KA#: &$7 VEFN88K$88$7 0-' *''$' -&$% <.,$'J L<'' &$% PYT 0$%7</$' .'& &*$ VEF5$9A$ *' &$' V*EF$%F$*87K$FB98$% /$9<'/$': Y<K$* L)''$' 7-#-F9 F-F$ 8F$%5*7EF$.'& 5$EF<'*7EF$ T$<'7O%.EF.'/$' <97 <.EF .'8$% ‘578B'&$' $*' GF$%5-7EF-ELJ 0$%.%7<EF8 &.%EF &*$ *'7O$*7.'/ 0-' D-8LNF9#<77$% -&$% &.%EF &*$ ^.,$'LNF9.'/J A.5 I$%7</$' &$7 T$FB98$%7 6NF%$': Y$% a$*8O.'L8 .'& &$%]-&.7 &$7 I$%7</$'7 &$% PYT2(<9-88$ S9-L<9 -&$% /9-K<9X 7*'& &$%A$*8 '-EF #$*8/F'& .'L9<% .'& 78<%L 0-5 Y$7*/' &$7 PYT <KFB'/*/: \%/$K'*77$ A:T: &$% I$%7.EF7O%-/%<55$ McRk[McR S‘V^X -&$% R[P\I\P SVEF#$&$'X #$%&$' <L8.$99 A.% \'8#*EL9.'/ $'87O%$EF$'&$% Y$8<*9E-&$7 /$'.8A8: Y*$ ^%K$*8$' A.5 PYT2 I$%7</$' K$* ($%'7EF5$9A.'6B99$' #$%&$' &$8<*99*$%8 *5 (<O*8$9 !P$<L8-%&.ELK$FB98$%

K$* ($%'7EF5$9A$'; K$7EF%*$K$'J &$7F<9K #*%& &<%<.6 *' &*$7$5 (<O*8$9 '*EF8 #$*8$% $*'/$/<'/$':

Y$% ^.78%</ &$% 6$*' 6%</5$'8*$%8$' VEF5$9A$ *' &$' V*EF$%F$*87K$FB98$% #*%& *5 &$.87EF$' YWVZ[2U%-/%<55 .'8$%7.EF8: W' W'8$/%<9E-&$7 #*$]\MZ[P -&$% ^VG\Z 7*'&$*'6<EF$ O<%<5$8%*7EF$]-&99A.5 VEF5$9A$<.78%</*5O9$5$'8*$%8:

Y.%EF &*$ F-F$' T$<'7O%.EF.'/$' 7*'& '$K$' &$5 PYT '<8N%9*EF <.EF P-F%9$*8.'/$'J #*$ &$% F$*,$ V8%<'/ -&$% &*$ I-9.5$'<.7/9$*EF79$*8.'/J 7-#*$ &*$ Y<5O6$%A$./$%F$*A%-F%$ 0$%7</$'7/$6BF%&$8:

VEF9*$,9*EF K*%/8 &<7 I$%7</$' &$% (-5O-'$'8$' &*$ +$6<F% &$7 M.68$*'K%.EF7 *' &<7 U%*5B%7_78$5 5*8 0$%78B%L8$% [e*&<8*-' .'& a$%78)%.'/ 0-' *5 ($%'K$%$*EF 0$%K9*K'$' 5$8<99*7EF$' (-5O-'$'8$' .'& *'8$'7*0$% VO<98O%-&.L86%$*7$8A.'/ SA: T: P.8F$'*.5X: a.LN'68*/$ I$%7.EF$*5 P<F5$' &$% U%-/%<55$ó\DZc SY$.87EF9<'&X .'& UF$K.7SR%<'L%$*EFX #$%&$' A.%M)7.'/ &*7% U%-K9$5$K$*8%</$' .'& $*'$T<7*7 6N% &*$ #$*8$%$]-&99'8#*EL9.'/ K*9&$':

Spaltproduktverhalten

Y*$ VO<98O%-&.L86%$*7$8A.'/ K$/9$*8$8 <99$ UF<7$' $*'$7 7EF#$%$' ''6<997 *5 U%*5B%7_78$5: Y<K$* #*%& &<7 VO<98O%-&.L80$%F<98$' &.%EF $*'$ I*$9A<F9 0-' U%-A$77$' .'& UFB'-5$'$' K$78*55 8J #*$A: T:

- &$% R%$*7$8A.'/ <.7*'8<L8$5 T%$''78-66 K$* I$%7</$' &$% cN99%-F%$J
- &$% R%$*7$8A.'/ <.7 VEFN88K$88$' -&$% VEF5$9A$7$$'J
- &$% b$EF7$9#*%L.'/$' A#*7EF$' *'8<L8$5 T%$''78-66J VEFN88K$88$' -&$% VEF5$9A$.'& &$5 (NF95*88$9J
- &$% ^.68$*9.'/*' &*$ 0$%7EF*$&$'$' UF<7$' S5$8<99*7EF ? L$%<5*7EFX #BF%$'& &$7 VEF5$9A$'7 KA#: &$% b*$&$%$%78<%%.'/ -&$% &$% (%.78$'K*9&.'/7-#*$
- &$% R%$*7$8A.'/ K$* 78<%L -e*&*$%$'&$' ' 5/$K.'/7K$&*'/.'/$':

a.% ''8$%7.EF.'/ &$7 VO<98O%-&.L80$%F<98$'7 7*'& &<F$% .'8$%7EF*$&9*EF78$ I$%7.EF7%$*F$'J #*$ A: T: VG[P]J P'V\GJ c\I^kI\PZ[PV -&$%]^VZ^ A.%

T$%NEL7*EF8*/.'/ &$% 0*$%B98*/$' P<F5$'K$&*'/.'/$' &.%EF/$6NF%8 #-%&$' .'& <.EF #$*8$%F*' '-8#$'&*/:

bBF%$'& A.% R%$*7$8A.'/ 69NEF8*/$% VO<98O%-&.L8$ <.7 T%$''78BK$' <'/$5$77$'$ Y<8$'K<'L$' $e*78*$%$' .'& &*$7$ <.EF *' &$' V8)%6<99<'<9_7$2Z-&$7 /.8 K$7EF%*K' #*%&J 7*'& &*$ 0$%6N/K<%$' Y<8$' A.5 R%$*7$8A.'/70$%F<98$' #$'*/$% 69NEF8*/$% VO<98O%-&.L8$.'& ($%'5<8$%*<9*$' <.7 $*'$5 A$%78)%8$' ($%' 78<%L $*'/$7EF%B'L8 .'& &*$]-&$99*$%.'/*' V8)%6<99<'<9_7$2Z-&$7 +$/$'78<'& 9<.6$'&$% ^L8*0*B8$':

W' &$' 6-9/$'&$' (<O*8$9' #*%& &$8<*99*$%8$% <.6 &*$ $*'A$9'$' UF<7$' $*'$7 V8)%6<997 5*8 ($%'7EFB&$' $*'/$/<'/$' .'& &$% V8<'& &$% \'8#*EL9.'/ &<%/$78$998:

6.2.1 Einleitungsphase des auslegungsüberschreitenden Störfalls

a. T$/*'' <.79$/.'/7NK$%7EF%$*8$'&$% V8)%6B99$J &*$ *5 7OB8$%$' I$%9<.6 A. ($%'7EF5$9A$' 6NF%$' L)''$'J 78$F8 $*'$ *'9$*8.'/7OF<7$ SR%-'8 \'&X: Y*7 UF<7$ #*%& 0-' &$' M$EL5<77$'78%)5$'J &$% \'$%/*$2 .'& b<77$%0$%8$*9.'/ *5 '.L9$<%$' Y<5O6$%A$./.'/77_78$5 /$O%B/8 .'& *78 K$78*55$'& 6N% &$' a$*8O.'L8 &$% ($%'6%$*9$/.'/J 6N% 5)/9*EF$ b*$&$%<.66N990-%/B'/$.'& <97 #7'89*EF$ P<'&K$2 &*'/.'/ 6N% &$' 7OB8$%$' ''6<99<K9<.6 6N% &*$ c)F$ &$% D<EFA$%6<9979$*78.'/0-' &$% &*$ ($%'<.6F$*A.'/7%<8$ <KFB'/8: Y<7 a$*86$'78$% A#*7EF$' T$/*'' &$% Y<5O6NK$%F*8A.'/ <5 ($%'<.78%*88J &*$ 5$778$EF'*7EF $%6<778 #$%&$' L<''J .'& &$5 \%%$*EF$' 0-' $8#< 1:=>> (S1:3>> fZXJ &$5 T$/*'' &$% G$5O$%<8.%$7L<9<8*-' &.%EF &*$ cN99%-F%-e*&<8*-'J L<'' $'87EF$*&$'& 7$*' 6N% &*$ T$#$%8.'/0-' D-86<997EF.8A5<,'<F5$':

Y$7F<9K #$%&$' #BF%$'& &$% *'9$*8.'/7OF<7$ <' &*$ PEF'O%-/%<55$ K$AN/9*EF &$% GF$%5-F_&%<.9*L &*$ /9$*EF$' ^'6-%&$%.'/$' /$78$998 #*$ <' &*$ V_78$52Z-&$7J &*$ 6N% T$782\78*5<8$2^'<9_7$' 0-' ^.79$/.'/778)%6B99$' 0$%#$'&$8 #$%&$': PEF'2 O%-/%<55$ #*$ ^GcM\G2ZYJ WZ^P\kZ^Gc^P\ .'& P\M^UkVZY^U $%6N99$' &*7 ^'6-%&$%.'/J &< 7*$ <.6 &$' *'8$'7*0 0<9*&*$%8$' GF$%5-F_&%<.9*L2]-&$99$' &$% T$782 \78*5<8$2Z-&$7 <.6K<.$': T$* W'8$/%<92Z-&$7 #*$ ^VG\Z .'&]\MZ[PJ &*$ $*'6<EF$%$ GF$%5-F_&%<.9*L2]-&$99$ 0$%#$'&$'J 7-998$' &*$ *'/<K$&<8$'7B8A$ &.%EF T$'EF5<%L$EF'.'/$' A. T$782\78*5<8$2Z-&$7 p<9 *6*A*$%8 #$%&$':

*' I$%/9$*EF 0$%7EF*$&$'$% P$EF'.'/$' A.5 ''6<99 *' G]W23 kRWZ >I<k F<8 /A*/8J &<77 &*7 UF<7$ 5*8 <.7%$*EF$'&$% HK$%$*'78*55.'/ 5*8 &$' *' &$% ^'9</$ /$55$77$'$' Y<8$' .'& &$% /$7EFB8A8$' b<77$%78-662\%A$./.'/ /$%$EF'$8 #$%&$'

L<'': b $*8$%$ \'8#*EL9.'/7<%K$*8$' K$7EF%B'L$' 7*EF <.6 &*$ $'87O%$EF$'&$ *'K*'&.'/ 0-' 0$%K$77$%8$']-&99' &$% T$782\78*5<8$2Z-&$7:

6.2.2 Kernschädigung

Y*$ A.% ($%'A$%78)%.'/ 6NF%$'&$' U%-A77 9<77$' 7*EF .'8$%8$*9$' *' &*$ UF<7$ &$% ($%'7EFB&*/.'/ 5*8 #$*8/$F$'&$5 \%F<98 &$% -%*/*'<9$' ($%'/$-5$8%*$.'& &$% ($%'A$%78)%.'/ 5*8 &$% ^.69)7.'/ &$% T%$''78<K/$-5$8%*$.'& 7.LA$77*0$% '5#<'&9.'/*' $*' Y$K%*7K$88 -&$% $*'$' VEF5$9A$7$$:

Brennstabverhalten

Y*$ T%$''78<K7EFB&*/.'/ K$/*''8 5*8 &$5 ^.6K9BF$' S!T<99--'*'/;X .'& T$%78$' &$7 cN99%-F%7 K$* P$&.L8*-' &$7 V_78$5&%.EL7*5 (NF9L%$*79<.6:a.% ZF<%<L8$%*7*$%.'/ &$7 T%$''78<K0$%F<98$'7 #$%&$' 'K' &$' /%.'&9$/$'&$' 8F$%5-F_&%<.9*7EF$' P<'&K$&*'/.'/$' .'& &$' 8F$%5*7EF$']<8$%*<9$*/$'7EF<68$' 5*8 78$*/$'&$' G$5O$%<8.%$' A.'$F5$'& OF_7*L-2EF$5*7EF$ b$EF7$9#*%L.'/$' #*EF8*/:a. &$' 9$8A8$%$' /$F)%8 &*$ [e*&<8*-' &$% <.6 a*%L-'*.5 K<7*$%$'&$' cN99%-F%5<8$%*<9*$'J &$%$' b$EF7$9#*%L.'/ 5*8 W'E-'$9*' ^K78<'&7F<98$%' <.6 &$% cN99%-F%<.,$'7$*8$.'& &$' 0$%7EF*$&$'$' T%$''78-66$' S'[3J][¥k <.6 &$% W''$'7$*8$:Y*$ $.8$L8*7EF$' b$EF7$9#*%L.'/$' 6NF%$' A.5 ^.68%$8$' 0-' VEF5$9A$' &$.89*EF .'8$% &$' VEF5$9A8$5O$%<8.%$' &$% $*'A$9'$']<8$%*<9*$'kc\Pdlk:

Oxidation und Wasserstofffreisetzung

[K$%F<9K 0-' 1:>>> (#*%& &.%EF &*$ [e*&<8*-' &$% 5$8<99*7EF$' cN92 .'& V8%.L8.%#$%L78-66$*5 ($%' 5$%L9*EF b<77$%78-66 .'& \'$%/*$ 6%$*/$7$8A8J #-&.%EF 7*EF &*$ ($%'<.6F$*A.'/ K$7EF9$.'*/8:Y*$ VEF.8A#*%L.'/ &$% /$K*9&8' [e*&7EF*EF8$' 6NF%8 A. $*'$% P$&.L8*-' &$% P$<L8*-'7%<8$J &*$ 5*8 $*'$5 O<%<K-9*7EF$' ^'7<8A K$7EF%*K' #$%&$' L<'': Y*$ a*%L<9-_-e*&<8*-' #*%& A.'BEF78 &.%EF &<7 Y<5O6<'/$K-89*5*8*$%8 .'& 7OB8$% &.%EF &$' I$%K%<.EF &$% 5$8<99*7EF$' UF<7$S 2a%X: [K$%F<9K 0-' E<:1:i>> ($%F)F8 7*EF &*$ P$<L8*-'7%<8$ <.6/%.'& $*'$% UF<7$'B'&$%.'/ *5 [e*&:Y*7 UFB'-5$'$ L)''$' 5*8 &$' &$%A$*8*/$' Z-&$7 <&Bp<8 5-&$99*$%8 #$%&$'kc\P d@kJkVZc>lk:

DK' &$% [e*&<8*-' *' $*'$% b<77$%&<5O6<85-7OFB%$ 5.77 <.EF &<7 *'78%)5$' 0-' M.68 <.7 &$5 V*EF$%F$*87K$FB98$% K$%NEL7*EF8*/8 #$%&$': Y*$ K$* &$% M.68-e*&<8*-' /$K*9&$8$' [e*&7EF*EF8$' 7EFN8A$' &<7]$8<99 &$.89*EF #$'*/$%: R$%'$% #*%& K$* /$%*'/$' V<.$%78-66<'8$*9$' *' &$% M.68 a*%L-''*8%*& *5 [e*& /$K*9&$8J #-&.%EF &*$ V8<K*9*8B8 &$7 cN99%-F%7 &$.89*EF 0$%%*'/$%8 #*%&: ^97 (-'7p'A *78 K$*5 R9.8$' &$7 ($%'$7 $*'$ $%F)F8$ VEF<&$'7<.7K%$*8.'/ 5*8 ^.78%</ 0-' U<%8*L$9' *' &$' (NF9L%$*79<.6 A. $%#<%8$': Y*$ ^.7#$%8.'/ &$7 *5 I$%7.EF7O%-/%<55 M^Z[ ]\P^ &.%EF/$6NF%8$' I$%7.EF7ó\DZc 21> So2M1X*78 F*$%A. '-EF '*EF8 <K/$7EF9-77$':

Wechselwirkung Abstandhalter / Hüllrohr

T$%$*87 .'8$%F<9K &$% VEF5$9A8$5O$%<8.% &$% FB.6*/ 6N% ^K78<'&7F<98$% 0$%#$'&$8$' D*EL$92M$/*$%.'/ W'E-'$9 SE<: 1:d>> (X 6*'&$8 $*'$ 9-L<9$ $.8$L8*7EF$ b$EF7$9#*%L.'/ 5*8 &$5 a*%L<9-_ &$7 cN99%-F%7 78<88: Y*$ VEF.8A#*%L.'/ &$7 a*%L-'-e*&7 6NF%8 A. $*'$% A$*89*EF$' I$%A)/$%.'/ &*7% b$EF7$9#*%L.'/J h$&-EF #*%& $*'$ 9-L<9$ U$%6-%<8*-' '*EF8 0$%F*'&$%8: Y*$7$ 6NF%8 A. $*'$% 6%NFA$*8*/$' R%$*7$8A.'/ 5$8<99*7EF$% VEF5$9A$:

Brennstoffauflösung durch Zirkonium

]*8 &$5 \%%$*EF$' &$% VEF5$9A8$5O$%<8.% &$7 a*%L<9-_7 S3:1@> (X K$/*''8 &*$ ^.69)7.'/ &$% ' [32U$99$87 &.%EF V<.$%78-662 KA#: a*%L-'&*66.7*-': V-9<'/$ /$'N/$'& b<77$%&<5O6 $*'$ <.7%$*EF$'& F-F$ V<.$%78-66L-'A$'8%<8*-' <' &$% cN99%-F%<.,$'7$*8$ /<%<'8*$%8J 6NF%8 &*$7$% U%-A$77 A. $*'$% Sa%2'2[X VEF5$9A$ 5*8 5$8<99*7EF$5 ZF<%<L8$% *''$%F<9K &$% a*%L-'-e_&FN99$: T$* %$&.A*$%8$5 Y<5O6<'/$K-8 #*%& '$K$' &$% U$99$8<.69)7.'/ <.EF &*$ 7EFN8A$'&$ a*%L-'-e*&FN99$ &.%EF V<.$%78-66&*66.7*-' <'/$/%*66$': Y$% *'69.77 &$7 ^KK%<'&$7 *78 &$%A$*8 '*EF8 p<'8*6*A*$%K<%J <.7 0$%7EF* $&$'$' \eO$%*5$'8$' SUF$K.7 RUGJ R%<'L%$*EFX /*K8 $7 h$&-EF c*'#$*7$ <.6 $*'$ a.'<F5$ &$% T%$''78-66<.69)7.'/ 5*8 &$5 ^KK%<'& kV\D >3k:

Hüllrohrversagen und Abfließen metallischer Schmelze

P$&.A*$%8 &*$ 5$8<99*7EF$ VEF5$9A$ &*$ [e_&7EF*EF8&*EL$ -&$% #*%& *'6-9/$ &$7 G$5O$%<8.%<'78*$/7 NK$% 3:@=> (F*'<.7 &*$ [e_&7EF*EF8 *'78<K*9J 0$%7</8 &<7 cN99%-F%

5$EF<'*7EF .'& 7$8A8 VEF5$9A$ 6%$*: Y*$ $*'/$7EF9-77$'$ VEF5$9A$ 0$%9</$%8 7*EF $'89<'/ &$% cN99%-F%-K$%69BEF$ '<EF .'8$' K*7 A. $*'$% ($%'F)F$J &$%$' G$5O$%<8.% &$% V-9*&.78$5O$%<8.% &$% VEF5$9A$ $'87O%*EF8: W' ^'<9-/*$ A.5 ^K69*$,$' 0-' ($%A$'#<EF7 #*%& '.% 0-' $*'$% G$*9K$'$8A.'/ &$7 cN99%-F%.56<'/7 <.7/$/<'/$': Y*$ VEF5$9A$ #*%& '<EF *F%$% R%$*7$8A.'/ #$*8$% -e*&*$%8: ^' &$% \%78<%%.'/778$99$ K*9&$8 &*$ <LL.5.9*$%8$ VEF5$9A$ $*'$ 9-L<9$ T9-EL<&$J &*$ 7*EF <.6/%.'& &$% D<EFA$%6<997#B%5$.'& &$% 7EF9$EF8$%$' (NF9K<%L$*8 #*$&$% <.6F$*A8:

Keramisches Schmelzen und Brennstabversagen

]*8 &$5 T$/%*66 T%$''78<K0$%7</$' #*%& &$% L-5O9$88$ I$%9.78 &$% V8<K/$-5$8%*$ KA*EF'$8J &:F: &.%EF $.8$L8*7EF$ b$EF7$9#*%L.'/ A#*7EF$' &$' P78' &$7 cN99%-F%$7 Sa%[3X .'& &$' U$99$87 S'[3X 0$%69N77*/8 &$% T%$''78<K 9-L<9J 7-&<77 &*7% '*EF8 9B'/$% 7$*'$ 8%</$'&$ R.'L8*-' 6N% &*$ &<%NK$% 9*$/$'&$' V8<KK$%$*EF$ $%6N99$' L<'': Y*$ MB'/$ &$% 0-5 T%$''78<K0$%7</$' K$8%-66$'$' V8<K7$/5$'8$ *78 &$%A$*8 <.6/%.'& eO%*5$'8$99$% Y<8$' '*EF8 $e<L8 K$L<''8J <97 .'8$%$ +%$'A$ #*%& &<F$% &$% 0$%8*L<9$ ^K78<'& A.5 &<%NK$% 9*$/$'&$' '-EF '*EF8 /$7EF5-9A$'$' ^K78<'&7F<98$% </$'-55$': ^97 \e8%$56<99 #*%& *' $*'*/$' Z-&$7 &$% (-99<O7 &$7 /$7<58$' &<%NK$% 78F'&$' V8<K$7 .'8$%78$998:

W' &$' 6%<'A)7*7EF$' UF$K.7 RUG 2 \eO$%*5$'8$' #.%&$ $*'$ &$.89*EF '*$&%*/$%$ I$%7</$'78$5O$%<8.% /$/$'NK$% &$5 UF<7$'&*</%<55 0-' '[3.'& a%[3/$6.'&$'J #<7 <.6 $*'$' ^KK%<'&$*'69.77 -&$% <.6 $*'$' '*EF88F$%5*7EF$' \66$L8 SA:T: I$%9</$%.'/ 0-' 6$*' 6%</5$'8*$%8$' U$99$8O<%8*L$9'*5 P*'/7O<98X F*'#$*78:

Brennstabverhalten beim Quenchen

Y$% T$/%*66 !o$'EF$'; K$7EF%$*K8 &<7 ^K7EF%EL' &$ 7 P$<L8-%L$%'$7 &.%EF b<77$%$*'7O$*7.'/: Y*$ *'7O$*7.'/ L<'' $'8#$&$% <.8-5<8*7EF &.%EF &<7 P$<L8-%7EF.8A7_78$5 -&$% &.%EF <'9</$'*'8$%'$D-86<9955<,'<F5$' <L8*0*$%8 #$%&$':

b*$ <.7 eO%*5$'8$99$' ''8$%7.EF.'/$' SM[RGJ Z[P^J ó\DZcX K$L<''8J FB'/8 &*$ P$<L8*-' &$% T%$''$9$5$'8$.'& V8%.L8.%$' *5 ($%' 78<%L 0-5 K*7F$%*/$' ''6<99O$%9<.6 .'& &<5*8 0-' &$% I-%7EFB&*/.'/ &$% ($%'7 .'& &$% 5<e*5<9$' G$5O$%<8.% <K: ''8$%F<9K $*'$% 5<e*5<9$' ($%'8$5O$%<8.% 0-' 3:1>> (L<''

#$*8/$F$'& $*' I$%F<98$' #*$*5 ^.79$/.'/7K$%$*EF S1 :=>> (X .'8$%78$998 #$%&$': Y*$ &.%EF [e*&<8*-' 6%$*/$7$8A8$ \'$%/*$ #*%& 7EF'$99 &.%EF &$' b<77$%&<5O6 <97 bB%5$7$'L$ <K7-%K*$%8J &*$ 6%$*/$7$8A8$ b<77$%78-665$'/$ *78 /$%*'/: W' &*$7$5 T$%$*EF L)''$' &*$ &$%A$*8*/$' &$8<*99*$%8$' .'& *'8$/%<9$' Z-&$2V_78$5$ &$' R9.82 .'& ó \DZc 2U%-A$77 F*'%$*EF$'& /.8 K$7EF%$*K$' kc \P >3kJkc [ ] >Ik:

[K$%F<9K &*$7$% G$5O$%<8.% *78 &$% *'69.77 &$7 ($%'A.78<'&$7 S5$8<99*7EF$ VEF5$9A$J T9-EL<&$'J VEFN88K$88J $8E:X $%L$''K<%J .'& &*$ *'7O$*7$%<8$ K$78*5 58 &$' ^K9<.6 .'& &*$ (-'7p'A$' &$7 R9.80-%/<'/$7 kc \P >Ik: W5 \e8%$56<99 0$%&<5O68 &*$ $*'/$7O$*78$ b<77$%5$'/$ 0-9978B'&*/J .'& &$% Y<5O6 #*%& 0-' &$% [e*&<8*-' 0$%K%<.EF8J 7-&<77 '.% '-EF b<77$%78-66 *' &$' V*EF$%F$*87K$FB98$% /$9<'/8: c*$%A. #$%&$' '-EF I$%7.EF$*5 I$%7.EF7O%-/%<55 M^Z [ ] \P^ &.%EF/$6NF%8 ó \DZc 211 So 2M3X kc \P >Ik:

Steuerstabverhalten (AgInCd und B_4C)

Y<7 ^K7-%K$%5<8$%*<9 &$% Y%.EL#<77$%78$.$%78BK$ ^/2W'2Z& 7EF5*9A8 K$* E<: 1:>>> (<.6J #BF%$'& &<7 ^K7-%K$%5<8$%*<9 T|Z &.%EF b$EF7$9#*%L.'/ 5*8 &$5 \&$978<F9FN99%-F% <K 1:=>> (0$%69N77*/8 #*%&:

Wechselwirkung Hüllrohr/Führungsrohr (Ag, In, Cd) und Hüllrohr/Absorber (B_4C)

Y$% O%*5B%$ VEFB&*/.'/75$EF<'*75.7 K$%.F8 <.6 &$% b$EF7$9#*%L.'/ A#*7EF$' &$5 \&$978<F9 &$% cN99%-F%$.'& &$5 a*%L<9-_ &$% RNF%.'/7%-F%$ KA#: &$% T%$''$9$5$'8LB78$' *5 VbP S7:.:X -K$%F<9K 0-' 1:3=> (: Y<7 K$7EF%B'L8$ Y<5O6<'/$K-8 *5 P*'/%<.5 A#*7EF$' cN992 .'& RNF%.'/7%-F% 6NF%8 '.% A. &N''$' [e*&7EF*EF8$'J &*$ &*7 b$EF7$9#*%L.'/ '*EF8 K$F*'&$%':

Oxidation, Erzeugung von Oxidationsprodukten

D<EF &$5 I$%7</$' &$% [e*&7EF*EF8 .'& &$5 ^.769*$,$' &$% ^K7-%K$%7EF5$9A$ L-558 &*7 *' (-'8<L8 5*8 &$5 b<77$%&<5O6 .'& #*%& -e*&*$%8: bBF%$'& *5 YbP &<7 ^K7-%K$%5<8$%*<9 ^/2W'2Z& L-5O9$88 0$%69N77*/8 *78J 0$%K9$*K$' *5 VbP2V8$.$%78<K '-EF P$785<77$' <' T|Z: Y*$ [e*&<8*-' 7$8A8 b<77$%78-66J Z [J Z [3J 7-#*$ T3 [@J &<7

*' (-'8<L8 5*8 Y<5O6 A. cT[3 %$</*$%8J 6%$*: Y< F*$%K$* b<77$%&<5O6 0-' <.,$' &.%EF &*$ I$%7</$'7)66'.'/ $'8/$/$' &$% V8%)5.'/7%*EF8.'/ &$% P$<L8*-'7O%-&.L8$ 78%)58J *78 &*7% ^'8$*9 9*5*8*$%8:]$8F<' #*%& <.6/%.'& &$% F-F$' G$5O$%<8.%$' *5 ($%'K$%$*EF '*EF8 /$K*9&$8J 7-'&$%' 78%-5<K *' LB98$%$' T$%$*EF$' &$7 -K$%$' U9$'.57.'& &$7 (NF9L%$*79<.6$7:

Versagen des Führungsrohres und Abfließen metallischer Schmelze

Y*$ VEF5$9A$ <.7 V8<F9 .'& ^K7-%K$%5<8$%*<9 9)78 &<7 a*%L<9-_ &$7 RNF%.'/7%-F%$7 <.6 .'& 6NF%8 -K$%F<9K 0-' 1:==> (A.% U$%6-%<8*-' &$% [e_&7EF*EF8: T$* &$5 YbP V8$.$%78<K 6NF%8 &$% *'8$%'$ Y%.EL<.6K<. 0-%#*$/$'& &.%EF &<7 (<&5*.5 A. $*'$5 &.%EF Y%.EL /$8%*$K$'$' ^.769.77 &$% V8<F92^K7-%K$%7EF5$9A$:

Wechselwirkung der Absorbermaterialien mit benachbarten Brennstäben

bBF%$'& K*7F$% '.% &*$ b$EF7$9#*%L.'/$' *''$%F<9K &$7 T%$''2 KA#: ^K7-%K$%78<K7 K$8%<EF8$8 #.%&$'J /*K8 $7 K$* K$78*55 8$' VA$'<%*$' &.%EF Y%.EL /$8%*$K$'$' ^.78%</ 0-' /$7EF5-9A$'$5 ^K7-%K$%5<8$%*<9 $*'$ b$EF7$9#*%L.'/ 5*8 &$' K$'<EFK<%8$' V8BK$' -&$% V8%.L8.%5<8$%*<9*$': +$9<'/8 ^K7-%K$%7EF5$9A$ <.6 &*$ [K$%69BEF$ K$'<EFK<%8$% T%$''78BK$J 7- #*%& &-%8 &*$ V<.$%78-66A.6.F% .'8$%K.'&$' .'& &*$ [e*&7EF*EF8&*EL$ %$&.A*$%8 K*7 &.%EF $.8$L8*7EF$ b$EF7$9#*%L.'/ &<7 a*%L<9-_ 0$%69N77*/8 #*%&: \K$'7- #$%&$' ‘ [32U$99$87 &.%EF V8<F92^K7-%K$%7EF5$9A$ #$*8 .'8$% *F%$% VEF5$9A8$5O$%<8.%<'/$/%*66$'.'& <.6/$7EF5-9A$':

SWR-Komponenten (Brennelementkasten, Absorberelement)

Y*$ VbP V8$.$%78<KL-5O-'$'8$'J &<7 ^K7-%K$%2(%$.A .'& &$% T%$''$9$5$'8L<78$' ST\2(<78$'X 0$%F<98$' 7*EF BF'9*EF #*$ &$% YbP2T1Z V8$.$%78<KJ h$&-EF *78 &$% V8<F9<'8$*9 /%),$%J #-&.%EF &*$ /$7<58$ T1Z2]<77$ &.%EF b$EF7$9#*%L.'/ 5*8 &$5 cN99%-F%78<F9 0$%69N77*/8 #$%&$' L<'': Y*$ $'87O%$EF$'&$' G$5O$%<8.%$' 7*'& 6N% &*$7$ b$EF7$9#*%L.'/ 0$%/9$*EFK<%Jh$&-EF $'86B998 &*$ VEF.8A#*%L.'/ &$7 a*%L-'-e*&7 &$7 RNF%.'/7%-F%$7J &< &$% T\2(<78$' $*'$' /%),$%$' 9<8$%<9$' ^K78<'& 0-5 ^K7-%K$%$9$5$'8 F<8: ^.6/%.'& &$% &*EL$%$' T\2(<78$'#<'& .'& &$% &*EL$%$' [e*&7EF*EF8 <.6/%.'& &$% 9B'/$%$' V8<'&A$*8 *5 ($%' L<'' $*'$ ^.7#*%L.'/ &$%

6%$*/$7$8A8$' V8<F92^K7-%K$%7EF5$9A$ <.6 &*$ T%$''$9$5$'8$ #$*8/$F$'& <.7/$7EF9-77$' #$%&$':

Status der Code-Validierung

Y*$ &$8<*99*$%8$ Z-&$ I<9*&*$%.'/ $%6-9/8$ <'F<'& *'8$%'<8*-'<9$% V8<'&<%&O%-K9$5$ &$% [\ZYJ*' &$% Z[P^ ^'9</$ SWVU2@1JWVU2@=X 7-#*$ *' &$% ó\DZc ^'9</$ SWVU 2I=X: b*EF8*/78$ I-%<.77$8A.'/ *78 F*$%A. &*$ V$/5$'8*$%.'/ &$% K$-K<EF8$8$' U%-A$77$.'& *F%$%)%89*EF$' \'8#*EL9.'/: +$'$%$99 #*%& h$&-EF &*$ 6%NF$ ($%'7EF5$9AOF<7$ /.8 '<EF/$K*9&$8J h$&-EF '.% <.6 (-5O-'$'8$'$K$'$J &: F: T%$''78<KJ ^K7-%K$%78<KJ $8E:: (-5O-'$'8$'NK$%/%$*6$'&$]-&99 A: T: 6N% ^K7-%K$%78BK$ 7*'& 9$&*/9*EF *' &$% Y*7L.77*-':

T$*5 R9.8$' $*'$7 G$*9A$%78)%8$' ($%'$7 #*%& &$%A$*8 &*$ Y<8$'K<7*7 0$%O-9978B'&*/8: Y*$ /$L-OO$98$' Z-&$7 ^GcM\G2ZYJ WZ^P\kZ^Gc^P\J VZY^UkP\M^U 7*'& F*$% <.6/%.'& *F%$% I<9*&*$%.'/7K<'&K%$*8$ <.7 &$' ^.79$/.'/778)%6B99$' *5 I-%8$*9: [K$%F<9K $*'$% 5<e*5<9$' ($%'8$5O$%<8.%0-' 3:@>> (0-%&$5 R9.8$' 7*'&h$&-EF &*$ ''7*EF$%F$*8$' <.6/%.'& .'K$L<''8$% T9-EL<&$78%.L8.%$' .'& [K$%69BEF$'%<.F*/2 L$*8$' 7- /%-,J &<77 &*$7$% I-%8$*9 0$%7EF#*'&$8: Y*$ b<77$%78-666%$*7$8A.'/ #*%& &<'' <.EF /$/$'NK$% &$' eO%*5$'8$99$' b$%8$' .'8$%7EFB8A8J #<7 <.6 $*' '-EF 0-%F<'&$'$7 Y$6*A*8*' &$% ($''8'*7 &$7A. +%.'&$9*$/$'&$']$EF<'*75.7 &$.8$8:

6.2.3 Kernzerstörung

]*8 A.'$F5$'&$5 ^.75<, &$7 ($%'7EF5$9A$'7J &$% I$%9</$%.'/ 0-' VEF5$9A$.'& &$% T*9&.'/ 0-' T9-EL<&$' &.%EF #*$&$%$%78<%%8$7]<8$%*<9*' '-EF LNF9$%$' T$%$*EF$' 0$%B'&$%8 7*EF &*$ /$-5$8%*7EF$ V8%.L8.% &$7 ($%'7A. $*'$5 L-5O9e' +$K*9&$ <.7]<8$%*<9K%.EF78NEL$'J /$7EF9-77$'$' (%.78$'2T$%$*EF$'J 69*$,$'&$% .'& <.6 7-9EF$' T9-EL<&$' 7*EF 7<55$9'&$% VEF5$9A$: Y<&.%EF 0$%B'&$%8 7*EF &*$ a./B'/9*EFL$*8 6N% &*$ Y<5O678%)5$.'& K$* $*'$5 R9.8$' <.EF 6N% &$' b<77$%A.78%-5: (NF9.'/7K$&*''.'/$' 7-#*$ c32\%A$./.'/ #$%&$' &<&.%EF K$$*'69.778 .'& #*%L$' 7*EF <.6 &*$ #$*8$%$ \'8#*EL9.'/ <.7:]*8 A.'$F5$'&$% ^.6F$*A.'/ 8%*88 A.5 5$8<99*7EF$' VEF5$9A$' SO-% <99$5 a%2VEF5$9A$' .'& ^.67EF5$9A$' 0-' '[3 &.%EF a%C !5$8<99*7EF$; '2a%2[2VEF5$9A$X 0$%78B%L8 L$%<5*7EF$7 VEF5$9A$' F*'A.J &: F: ^.67EF5$9A$' 0-' a%[3.'& '[3J 7$O<%<8.'&*'W'8$%<L8*-':

T$AN/9*EF &$% 6%NF$%$' UF<7$' &$7 ($%'7EF5$9A$'7 .'& &$% ($%'7EFB&*/.'/ /$98$' &*$ F<.O87BEF9*EF$' 7*EF$%F$*878$EF'*7EF$' R%</$78$99.'/$' &$5 *'7$8A$' .'& &$% I$%5$*&.'/ 0-' VEFB&*/.'/$'J #*$ &$5 cN99%-F%O$%7</$'J &$% T%$''78-66<.69)7.'/ .'& &$% VO<98O%-&.L86%$*7$8A.'/ 7-#*$ &$5 T$/*'' 78<%L$% [e*&<8*-' .'& b<77$%78-66$%A$./.'/: T$* &$' 7OB8$%$' UF<7$' &$% ($%'A$%78)%.'/ &-5*'*$%8 &*$ R%</$78$99.'/J -K KA#: K*7 A. #$9EF$5 a$%78)%.'/7/%<& $*'$ (NF9.'/ .'& PNELF<98.'/ &$% VEF5$9A$ *5 ($%' '-EF 5)/9*EF *78J #$'' $*'$ ^L8*O*$%.'/ &$% b<77$%$*'7O$*7.'/ /$9*'/8J -&$% '<EF #$9EF$% a$*8 .'& *' #$9EF$% ^%8 $*' ^.769*$,$' <.7&$5 ($%' <.68%*88:

Y*$ ^%8 &$7 ^.769*$,$'7 &$% VEF5$9A$ <.7 &$5 ($%' K$78*558 ZF<'E$' &$% (NF9K<%L$*8 -&$% a$*8$' &$% PNELF<98.'/ *5 .'8$%$' U9$'.5 &$7 P$<L8-%2 &%.ELK$FB98$%7: R9*$,8 &*$ VEF5$9A$ *' R-%5 '*EF8 A. &*EL$% VEF5$9A$78%<F9$' NK$% $*'$ 9B'/$%$ Y<.$% *' P$78#<77$% *5 .'8$%$' U9$'.5 $*'J 7-L<'' &*$ VEF5$9A$ F% 6%</5$'8*$%$' .'& LNF9K<%$ VEFN88.'/$' K*9&$' <97 K$* $*'$5 ^.769*$,$' *' $*'$5 /%-,$' VEF#<99 '<EF /%-,69BEF*/$%$5 I$%7</$' $*'$% (%.78$ *5 ($%': \'87EF$*&$'& 6N% &*$ F<.O87BEF9*EF$ V*EF$%F$*876%</$ &$% (NF9K<%L$*8 .'& PNELF<98.'/ *78 <97-J #*$ 0*$9 /$7EF5-9A$'$]<77$ 7*EF *5 ($%' <LL.5.9*$%$' L<'' .'& #*$ &*7 7EF9*$,9*EF <.769*$,8:

]*8 &$% T$8-'.'/ &*7% NK$%/%$*6$'&$' R%</$' .'& ''8$%7.EF.'/7A*9 #*%& $*'$ <&Bp<8$J A*$9-%*$'9*$%8$]-&$99*$%.'/ &$% L-5O9e' U%-A77 $%9$*EF8$%8: Y$8<*97 &$7 +$7EFF'7 7*'& #$'*/$% #*EF8*/ <97 *' &$' U%-A$77$' <'/$9$/8$ 78<%L$ G%$'&7J #$9EF$ &*$ VEF5$9A$2^LL.5.9<8*-' *5 ($%' .'& &<7 ^.769*$,$' K$78*55$': Y*$7$ 7*'& .:': K$%$*87 *' $%F$K9*EF$5]<,$ &.%EF &*$ \'8#*EL9.'/ &$% (NF9.'/ 6$78/9/8: V-L<'' <KFB'/*/ 0-' (NF9$66$L8$' S\'8#*EL9.'/ &$7 b<77$%78<'&$7X $*' 78<%L$% -&$% 7EF#<EF$% G%$'& A.% T*9&.'/ $*'$7 /%-,$' VEF5$9A$7$$7 K78F$'J h$#$*97 <K$% 5*8 &$5 BF'9*EF$' \66$L8 $*'$7 ^.769*$,$'7 &$% VEF5$9A$ *' K$/%$'A8$5 V8%-5 <.7 &$5 ($%': T$* $*'$5 78<K*9$' VEF5$9A$7$$ *78 'B59*EF $*' ^.769*$,$' <.6/%.'& &$%*''$%$' bB%5$78%-50$%8$*9.'/ 0-5 -K$%$' P<'& F$% A. $%#<%8$': T$* $*'$5 #$*8/$F$'&$' Y.%EF69*$,$' 0-' VEF5$9A$ -F'$ 78<%L$' ^.678<. 5.77 &<7 ^.769*$,$' '<EF .'8$' &</$/$' #$*8/F'& &$5 VEF5$9AO%-A$77 6-9/$': b$9EF$7 I$%F<98$' 7*EF $*'78$998 .'& -K A#*7EF$' &*$7$' \e8%$5$' /%-,$% VO*$9%<.5 6N% I<%*<'8$' $e*78*$%8J FB'/8 0-' &$' I$%9</$%.'/7O%-A$77$' *5 0$%7</$'&$' ($%' *' b$EF7$9#*%L.'/ 5*8 &$% (NF9.'/7$'8#*EL9.'/ <K: Y*$ 7$*89*EF$ ^.7K%$*8.'/ &$% VEF5$9A$ *5 I$%/9$*EF A.% I$%9</$%.'/ '<EF .'8$' 7O*$98 &<K$* $*'$ #7'89*EF$ P-99$: Y<&.%EF #$%&$' I$%7</$'7O6<&$ 8F$%5*7EF 0-%/$O%B/8 .'& &<5*8])/9*EFL$*8$' .'& +%$'A$' &$%

^.7K*9&.'/ $*'$7 /%-,$' V$$7 <.6 $*'$% 78<K*9$' (%.78$ -&$% $*'$7 ^.678<.7 0-' VEF5$9A$ K$* #$'*/ 78<K*9$% (%.78$: Y*7 R%</$78$99.'/$' 7O*$98$' A: T: K$* ^'<9_7$' A.5 PNELF<98$L-'A$O8 &.%EF ^.,$'LNF9.'/ K$*5 P$<L8-%L-'A$O8 ^Unn> $*'$ #7'89*EF$ P-99$ kGc\ dh

Modellierung der fortschreitenden Kernzerstörung

Y$% Y$8<*99*$%.'/7/%<& &$7]-&$997 A.5 ($%'0$%7</$' *78 <' &$% T$<'8#-%8.'/ &$% -K*/$' R%</$' A.-%*$'8*$%$': \% FB'/8 &<F$% <K 0-' &$% V8B%L$ &$% G%$'&7 .'& \66$L8$ KA#: &$5 VO*$%%<.5 A#*7EF$' V$$2T*9&.'/ .'& L-'8*'.*$%9*EF$5 ^.769*$,$': c*'7*EF89*EF &$% A.'$F5$'& L-5O9$e$' V8%.L8.%$' &$7 ($%'7 #BF%$'& 7$*'$7 I$%7</$'7 *78 $*']-&$99 <'/$5$77$'J &<7 &*$ VEF5$9A2 .'& I$%9</$%.'/7O%-A$77$ *5 9-L<9$']*88$9 K$7EF%$*K8J <97 U%-A77 *' $*'$% O-%)7$' V8%.L8.%J *5 +%$'A6<99 $*'$% VEFN88.'/: Y<K$* *78 &*$ \'878$F.'/ 0-' Y.%EF9B77*/L$*8$' KA#: 9-L<9$' I$%8$*9.'/$' &$% U-%-7*8B8 *' ^KFB'/*/L$*8 0-5 ^K9<.6 &$7 I$%7</$'7 A. $%6<77$': ^.7 PNELL-OO9.'/$' L)''$' 7*EF 0$%78B%L8$ G%$'&7 $%/$K$'J #$9EF$ &*$ Y$8<*99*$%.'/7<'7O%NEF$ %$&.A*$%$':

Y<7]-&$99]\V[Z[S]\98*'/ <'& V[9*&*6*E<8*-' -6 Z[%$ 5<8$%*<9X #.%&$ A.% V*5.9<8*-' &$% 6-%8/$7EF%*88$'$' ($%'7EFB&*/.'/ .'& ($%'A$%78)%.'/ $'8#*EL$98 kT‘\>1kJ kT‘\>Ik .'& *' ^GcM\G2ZY $*'/$K<.8: *'$ 0$%/9$*EFK<%$]-&$99*$%.'/ #*%& *' WZ^P\ &.%EF/$6NF%8 kRWZ>1k: W' ^GcM\G2ZY #.%&$ <99$%&*'/7*5 ‘'8$%7EF*$& A. WZ^P\ $*' 6-%87EF%$*8$'&$%J K$%$*EF7#$*7$% HK$%/<'/ A#*7EF$' &$5 R%NFOF<7$'5-&$99 S6%NF$ UF<7$' &$7 ($%'0$%7</$'7C ($%'7EFB&*/.'/ K$* '-EF #$*8/F'& *'8<L8$% T%$''78<K2V8%.L8.%X .'& &$5 VOB8OF<7$'5-&$99 &$7 ($%'0$%7</$'7]\V[Z[%$<9*7*$%8: Y*$7$]-&$99*$%.'/ K$&<%6 0-% <99$5 '-EF &$% eO%*5$'8$99$' HK$%O%N6.'/J &*$ *5 P<F5$' &$% MWI\2\eO$%*5$'8$ k\UU>3k 0-%/7F$' *78: D-8#$'&*/$ HK$%O%N6.'/$' .'& .: ‘: Y$8<*99*$%.'/$' K$8%66' 0-% <99$5 &*$ P$*K.'/ &$% VEF5$9A$ <' &$% V8%.L8.% 7-#*$ bB%5NK%/B'/$.'& &*$ T$7EF%$*K.'/ &$% VEF5$9A2 .'& \%78<%%.'/7O%-A77 *' ^KFB'/*/L$*8 0-' &$%]<8$%*<9A.7<55$'7$8A.'/:

W5 HK$%/<'/ A#*7EF$' ($%'7EFB&*/.'/ .'& ($%'A$%78)%.'/ K$78F' ‘'7*EF$%F$*8$' *'7K$7-'&$%$ K$AN/9*EF U%-A$77$' &$7]<8$%*<90$%7</$'7J #*$ &$% R%</5$'8*$%.'/ 0-' R$7878-66 <.6/%.'& 8F$%5*7EF$% VO<''.'/$' SA: T: <.6/%.'& $*'$% b<77$%2

$*'7O$*7.'/ #*$ K$* G]WX -&$% $*'$7]<8$%*<9L-99<O7 NK$% $'878<'&$'$' c-F9%B.5$'J .'& $*'$% &<%<.7 %$7.98*$%$'&$' T*9&.'/ 0-' VEFN88.'/$':

Bildung und Verhalten eines Schmelzesees im Kern

Y*$ T*9&.'/ $*'$7 VEF5$9A$7$$7 *5 ($%' FB'/8 0-' &$% T*9&.'/ $*'$% <.7%$*EF$'& 78<%L$' (%.78$ <K: W5 ''8$%7EF*$& A. WZ^P\ #*%& *']\V[Z[&<7 ^'6%*$%$' &$% VEF5$9A$ '*EF8 *5 9-L<9$' 8F$%5*7EF$' +9$*EF/$#*EF8 K$7EF%*K': Y.%EF T$%NEL7*EF8*/.'/ $*'$7 8$*9#$*7$' \%78<%%$'7 *']\V[Z[J K<7*$%$'& <.6 .'8$%7EF*$&9*EF$' G$5O$%<8.%$' 0-' R$7878-66 .'& VEF5$9A$J L<'' O%*'A*O*$99 $*' 6%NF$%$7 \%78<%%$' .'& T9-EL*$%$' &$7 VEF5$9A$69.77$7 '<EF .'8$' <.68%$8$'J <K$% <.EF $*'$ %B.59*EF 0$%8$*98$%$.'& 7- .: ': #$'*/$% 78<K*9$ (%.78$'K*9&.'/: V-9EF$ \66$L8$ L)''8$' 6N% &*$ V$$2T*9&.'/ *5 ($%' K$&$.87<5 7$*':

Y*$ \e*78$'A .'& Y*EL$ $*'$% (%.78$ .5 $*'$' V$$ *78 7EF9*$,9*EF K$78*5 58 &.%EF &*$ bB%5$78%)5$ <.7 &$5 V$$.'& &*$ bB%5$<K6.F%: Y*$ bB%5$78%)5$ <.7 &$5 V$$ 7*'& *5 P<F5$' $*'$%]-&$99*$%.'/ &$7 +$7<58<K9<.67 #*$ *']\V[Z['*EF8 &*%$L8 <.7 $*'$%]-&$99*$%.'/ &$% D<8.%L-'0$L8*-' *5 V$$ K$%$EF$'K<%: Y<%<' 7EF$*8$%' /$/$'#B%8*/ '-EF 7$9K78 <.6#B'&*/$ V$O<%<82]-&$99$: I$%$*'6<EF$'& #.%&$ &<F$% $*'$ T$7EF%$*K.'/ NK$% &*$ P<'&2+%$'A7EF*EF8 *' ^'L-OO9.'/ <' &*$ HK$%F*8A.'/ *5 V$$ /$#BF98 SBF'9*EF A. RM'xT^WD kT[D d=k .'&]IWG^ kV\c dkXJ &*$ OF_7*L<9*7EF$ +%.'&AN/$ <KK*9&$8J <K$% &$% ^'O<77.'/ <' eO%*5$'8$99$ Y<8$' K$&<%6: Y<7]-&$99 7-99 &*$ bB%5$78%)5$ A.5 P<'& 69$e*K$9 K$%$EF'$'J <KFB'/*/ 0-' &$% HK$%F*8A.'/ *5 V$$.'& &$% /$-5$8%*7EF$' P<'&2(-'6*/.%<8*-'J &*$ 7*EF *5 I$%9<.6 &$% V$$2 \'8#*EL9.'/ *5 ($%' $*'78$998: Y*$ I-%/$7EF*EF8$ 0-' ^.6F$*A.'/$'J VEF5$9A$69N77$' .'& b<77$%78<'&7$'8#*EL9.'/ /$F8 &<%*' .'& *' &*$]<8$%*<9A.78B'&$ <.,$%F<9K &$7 V$$7 $*' .'& L<'' 7*EF <.6 $*' I$%7</$' &$% (%.78$.'& ^.769*$,$' &$% VEF5$9A$ <.7#*%L$': Y< &*$ \'8#*EL9.'/ &$% (%.78$'&*EL$ <' &$% V$$2T$%<'&.'/ 7-#*$ &<%<.7 6-9/$'& I$%7</$'7-%8$J 2A$*8$' .'& 2<%8$' F*$%&.%EF K$78*5 58 7*'&J #<% $7 '-8#$'&*/J $*'$ 7O$A*$99$ Y8L8*-' &$7 P<'&$7 .'& 7$O<%<8$ T$78*5 5.'/ &$% (%.78$'&*EL$ $*'A.6NF%$': G%-8A&$5 0$%K9$*K$' O%*'A*O*99 ''7*EF$%F$*8$' NK$% &<7 ^.769*$,$' &$% VEF5$9A$ A: T: F*'7*EF89*EF &$% \'8#*EL9.'/ &$% +%),$ &$% g66'.'/ .'& &$% V8%<F9K*9&.'/ '<EF Y.%EF69*$,$' .'& ^.67EF5$9A$' &$% .'8$%$' +*88$%O9<88$: c*$% 7*'& ''7*EF$%F$*8$' #*$&$% &.%EF O<%<5$8%*7EF$ I<%*<8*-'$' A. NK$%K%NEL$' .'& *' *F%$5 \66$L8 $*'A.7EFB8A$': b*EF8*/ *78 $7J &*$ &-5*'<'8$' OF_7*L<9*7EF$' U%-A77J &*$ $*'$% 6.'&*$%8$' T$7EF%$*K.'/ A./B'/9*EF 7*'&J 0-' &$' .'7*EF$%$' T$%$*EF$' A.

8%$''$' S7:<: P[^^] kGc\dIkX: RN% &*$ VEF5$9A$78%<F92T*9&.'/ K$&$.8$8 &*$7J 5*8 &$%]-&$99*$%.'/ <.6 &$' T$%$*EF &$7 (%.78$'<.67EF5$9A$'7 S*'7K$7-'&$%$C <5 -K$%$' P<'& &$7 V$$7 -&$% .'8$'X*' ^KFB'/*/L$*8 0-' &$% \'8#*EL9.'/ <KA.FK': Y<%<.7 $%/$K$' 7*EF /%.'&7B8A9*EF$ (-'7p'A$' F*'7*EF89*EF &$7 ^.769*$,$'7 S<5 P<'& 5*8 <995BF9*EF$% G$'&$'A &$% \%#$*8$%.'/ '<EF .'8$' .'& /$%*'/$% ^.778%)52 /$7EF#*'&*/L$*8J*5 I$%/9$*EF A.$*'$5 I$%7</$'<5 V$$2T-&$'X:

*' #$*8$%$% .'7*EF$%$% UFB'-5$'2 .'&]-&$992T$%$*EF K$78$F8*' &$5 ^.68%8' 0-' VEF*EF8.'/$'*5 VEF5$9A$7$$J K$7-'&$%7 $*'$% &$% L$%<5*7EF$' VEF5$9A$ 9$8A89*EF NK$%7EF*EF8$8$' 5$8<99*7EF$' VEF5$9A$7EF*EF8J -&$% 0'8.99% VEF*EF8.'/$' <.6/%.'& 0-']*7EF.'/79NEL$': c*$%&.%EF L)''$' A:T: &.%EF R-L.77*$%.'/7$66$L8$ 9-L<9 0$%78B%L8$ -&$% /$'$%$99 0$%B'&$%8$ %B.59*EF$ I$%8$*9.'/$' &$% bB%5$78%)5$ <.68%8':

Y$% $%%$*EF8$ V8<'&*78J &<77]\V[Z[*' $*'$% $%#$*8$%8$' R<77.'/ $*'7EF9*$,9*EF &$7 VEF5$9A$7$$2]-&$997*' ^GcM\G2ZY $*'/$K<.8*78:Y<5*8 L)''$' VA$'<%*-2<KFB'/*/ VEF5$9A$2^'7<55 9.'/$' *5 ($%' 7-#*$ ^.769*$,0-%/B'/$ K$%$EF'$8 #$%&$'J *' PNELL-OO9.'/ 5*8 &$% ^.7&<5O62\'8#*EL9.'/ .'& .'8$% T$%NEL7*EF8*/.'/ <.EF 0-' b<77$%$*'7O$*7.'/$': D-EF '-8#$'&*/$ HK$%O%N6.'/$' .'& b$*8$%$'8#*EL9.'/$' K$8%$66$'J A.7B8A9*EF A.&$' L-'78*8.8*0$' +$7$8A$' 6N% &*$ VEF5$9A$78%)5.'/ 7-#*$ 6N% VEF5$9A2 .'& \%78<%%.'/7O%-A$77$J &<7 0$%$*'6<EF8$ V$$2]-&$99 .'& &*$ T$7EF%$*K.'/ &$7 I$%7</$'7 .'& ^.769*$,$'7J &*$ b<77$%78-66K*9&.'/ <.7 &$% P$<L8*-' 5*8 5$8<99*7EF$' ^'8$*9$'J &*$ VO<98O%-&.L86%$*7$8A.'/ <.7 &$% VEF5$9A$.'& &*$ $'87O%$EF$'&$' G%<'7O-%8O%-A77*5 R9.*&:

Kühlbarkeit des zerstörten Kerns

a. h$&$% UF<7$ &$7 ''6<99<K9<.67 5.77 .'8$%7.EF8 #$%&$' L)''$'J -K K$* $*'$% b<77$%2*'7O$*7.'/ &*$ (NF9K<%L$*8 #*$&$%F$%/$78$998 #$%&$' L<'' -&$% #*$ $*'$ 7-9EF$ *'7O$*7.'/ &$' #$*8$%$' I$%9<.6 K$$*'69.778:a.7<55$' 5*8 &$' ZF<'E$'J $*'$ *'7O$*7.'/ #BF%$'& &*7% UF<7$ &$% ($%'A$%78)%.'/ A.%$<9*7*$%$'J K$78*55 8 &*$ (NF9K<%L$*8 0-' ($%'A.78B'&$' &*$ ZF<'E$' &$% PNELF<98.'/ &$% VEF5$9A$ *5 ($%':

T$*5 G]W2‘ ’6<99 #.%&$ 8%-8A b<77$%$*’7O$*7.’/ ’.% $*’$ K$/%$’A8$ (NF9.’/ $%%$*EF8: Y$% VEF5$9A$7$$ *5 ($%’ K%$*8$8$ 7*EF .’8$% b<77$% <.7J K*7 A.5 ^.769*$,$’ 0-’ VEF5$9A$.’8$% b<77$%: W’#*$#$*8 &<%<.7 /$’$%99% <.6 $*’$ D*EF8LNF9K<%L$*8 &$7 ($%’A.78<’&$7 5*8 VEF5$9A$7$$ /$7EF9-77$’ #$%&$’ L<’’J K9$*K8 ’-EF -66$’ SA: T: V8%.L8.%L-99<O7 <97 ‘%7<EF$ 6N% (%.78$’0$%7</$’ kP\W>IkX:

‘5 7-9EF$ R%</$’ A. L9B%$’ .’& &*$ (NF9K<%L$*8 #BF%$’& &$% ($%’A$%78)%.’/J <97-<.EF K$* a.78B’&$’ 5*8 /$7EF5-9A$’$’ ^’8$*9$’J .’8$%7.EF$’ A. L)’’$’J #.%&$ &$% *5 (\VV2P<F5$’ $’8#*EL$98$]-&.9 b^T\ Sb^8$%T\&X A.% (NF9K<%L$*8 0-’ O-%)7$’ V8%.L8.%$’ 5*8]\V[Z[A.]\b^ /$L-OO$98:]\b^ #.%&$ 6N% &$’ ($%’ *’ ^GcM\G2 ZY *5O9$5$’8*$%8: ^.EF F*$%A. K78F8 *’7K$7-’&$%$ ’-EF T$&<%6 <’ HK$%O%N6.’/$’ 7-#*$ b$*8$%$’8#*EL9.’/7K$&<%6 /$5B, &<K$* 6$78/$78$998$% Y$6*A*8$: *’ I$%/9$*EF &$%]-&$99$J <.EF <.6 &$% T<7*7 0$%/9$*EF$’&$% P$EF.’/$’ 6N% %$9$0<’8$ VA$’<%*$’J *78 *5 P<F5$’ &$7 \‘2D$8A#$%L$7 V^PD\G 0-%/$7F’ .’& 7-99 #7’89*EF A.% \%<%K$*8.’/ $*’$% <&Bp<8$’J <.77</$ 2 .’& $e8%<O-9<8*-’76BF*/$’]-&$99*$%.’/ <.EF 6N% &$’ $.%-OB*7EF$’ W’8$/%<9E-&$ ^VG\Z K$*8%</$’: ^97 eO%*5$’8$99$ T<7*7 7*’& /$/$’#B%8*/ 0-% <99$5 &*$ Uc\T‘V2 SR%<’L%$*EFX .’& MWI\2I$%7.EF$ k\UU>3k A. ’$’’$’:

V-#-F9 &*$ 9<’/6%*78*/$ (NF9K<%L$*8 $*’$% A.’BEF78 <K/$LNF98$’ O-%)7$’ V8%.L8.% -&$% VEFN88.’/ .’8$% D<EF#B%5$2R%$*7$8A.’/ L<’’ 5*8]\b^ .’8$%7.EF8 #$%&$’ <97 <.EF &<7 R9.8$’ F$*,$%J .: ‘: 8$*9#$*7$ /$7EF5-9A$’$% V8%.L8.%$’: Y*$]-&$99*$%.’/72 7EF#$%O.’L8$.’& &<5*8 <.EF 0$%K.’&$’$])/9*EFL$*8$’ &$% 0$%$*’6<EF8$’ T$7EF%$*K.’/ $%/$K$’ 7*EF <.7 &$’ <97 $’87EF$*&$’& <’/$7F’$’]$EF<’*75$’C Y-5*’<’A &$% R9.*&%$*K.’/ <’ &$% O-%)7$’ V8%.L8.% K$* /9$*EFA$*8*/$% T$&$.8.’/ &$% W’8$%OF<7$’2P$*K.’/ A#*7EF$’ b<77$% .’& Y<5O6 .’& &<5*8 &$7 +$/$’2 -&$% +9$*EF78%-55.78$%7 6N% &<7 *’&%*’/$’ &$7 b<77$%7 Sb<77$%A.6.F%X *5 I$%/9$*EF A. <’&$%$’ T$*8%B/$’ *’ &$’ W5O.97/9$*EF.’/$’J +%$’A6B99$ $*’$%7$*87 &$7 I-%<.77EF%$*8$’7 $*’$% 7EF5<9$’ o$’EF6%-’8 ’<EF]<,/<K$ &$% P$*K.’/ -&$% <’&$%$%7$*87 &$7 o$’EF$’7 ’<EF]<,/<K$ &$% V*$&$L.%0$*’ $*’$5 K%$*8$’ T$%$*EF F*’8$% &$% b<77$%6%-’8J *’&%*’/$’ &$7 b<77$%7 NK$% .’8$%$ T$%$*EF$ <.6/%.’& $*’$% &.%EF I$%&<5O6.’/ $%A$./8$’ D<8.%L-’0$L8*-’ S3Y2\66$L8$X: Y*$ ^.,$’LNF9.’/ $*’$7 VEF5$9A$7$$7 *5 ($%’ 7O*$98 7EF9*$,9*EF $*’$ $’87EF$*&$’&$ P-99$ 6N% &<7 ^.68%8’ $*’$7 8F$%5*7EF$’ I$%7</$’7 &$% (%.78$.’& &$7 ^.769*$,$’7:

Y*$ [e*&<8*-’ 0$%K9*$K$’$% 5$8<99*7EF$% ^’8$*9$ L<’’ &.%EF &<7 R9.8$’ 0$%78B%L8 #$%&$’: T$* F-F$’ G$5O$%<8.%$’ 8%$*K8 &<7 /%-,$ Y<5O6<’/$K-8 <.7 %<7EF$%

I$%&<5O6.'/ &*$ [e*&<8*-' .'& b<77$%78-66O%-&.L8*-'J #-K$* &$% $'878<'&$'$ b<77$%78-66 *' <'&$%$' T$%$*EF$' $*'7EF%B'L$'& #*%L8 S!78$<5 78<%0<8*-'Xq Y*$ [e*&<8*-' #*%L8 &.%EF *F%$' $e-8F$%5$' \66$L8 &$% ^KLNF9.'/ $'8/$/$' .'& L<'' <97 R-9/$ &$7 R9.8$'7 7-/<% A$*8#$*7$ ^.6F$*A.'/$' K$#*%L$': ^'&$%$%7$*87 #*%L8 &<7 o$'EF$' &$% [e*&<8*-' $'8/$/$': Y*$ T$&$.8.'/ &$% +$/$'$66$L8$ A.% ^KLNF9.'/ *78 '-EF 6N% %$9$0<'8$ VA$'<%*$' A. .'8$%7.EF$'J K$0-% #$*8$%$ Y$8<*99*$%.'/$' *5 [e*&<8*-'72 -&$% o$'EF 2]-&$99 A. K$78*55$' 7*'&:

6.2.4 Rekritikalität

W' &$' ^'<9_7$' A. <.79$/.'/7NK$%7EF%$*8$'&$' V8)%6B99$' 5*8 ($%'7EF5$9A$' #*%& &*$ R%</$ '<EF $*'$% 5)/9*EF$' P$L%*8*L<9*8B8 *: ^99/: '*EF8 /$78$998J &< ($%'7EF5$9A$' '.% <97 R-9/$ $*'$% /%),$%$' ($%'6%$*9$/.'/ .'& &<5*8 -F'$ <.7%$*EF$'&$ D$.8%-'$'2 5-&$%*$%.'/ <.68%8' L<'': T$* &$% *'7O$*7.'/ 5*8 D-8LNF9#<77$% #*%& *5 YbP $*'$ <.7%$*EF$'& F-F$ T-%*$%.'/ .'8$%78$998J 7-&<77 $*' #*$&$% L%*8*7EF #$%&$' <.7/$7EF9-77$' #$%&$' L<'':

*'$ ^.7'<F5$ 78$998 &$% R<99 &<%J *' &$5 *' $*'$5 VbP &*$ <.7%$*EF$'&$ D-82 .'& D<EFLNF9.'/ 7-#$*8 .'8$%K%-EF$' #*%&J &<77 &$% RN9978<'& .'8$% ($%'-K$%L<'8$ <K6B998J 7-&<77 $7 A.% ^.6F$*A.'/ &$% T%$''78BK$ L-55$' L<'': ''8$% &*7' '578B'&$' L<'' $7 <.EF A.5 ^K7EF5$9A$' &$% ^K7-%K$%$9$5$'8$ L-55$'J 7-&<77 &<7 b*$&$%<.66N99$' A.% P$L%*8*L<9*8B8 6NF%$' L<'': ^'<9_7$' k(\Pdik 5*8 &$% ^''<F5$ *'8<L8$% ($%'/$-5$8%*$ A$*/8$'J &<77 .'8$% &*$7$' '578B'&$' '-EF 3>v &$% D$''9$*78.'/ $%A$./8 #$%&$' L)''8$' .'& &<5*8 &*$ W'8$/%*8B8 &$7 V*EF$%F$*87K$FB98$%7 /$6BF%&$8 #B%$: +%.'&7B8A9*EF #*%& h$&-EF &<7 I$%/*68.'/77_78$5 <L8*0*$%8J &$77$' b*%L.'/ 9<'/6%*78*/ A.% ''8$%L%*8*L<9*8B8 6NF%$' 7-99:

''8$%7.EF.'/$' A.% P$L%*8*L<9*8B8 0-' 7-9EF$' ($%'A.78B'&$' #.%&$' /$'$%*7EF &.%EF/$6NF%8 kab\ >1k: Y$%<%8*/$ a.78B'&$ 7-998$' 6N% T%$''$9$5$'8$ 5*8 F)F$%$% ^'%$*EF$%.'/*' *'A$9.'8$%7.EF.'/$' $%'$.8 K$8%<EF8$8 #$%&$':

6.2.5 Schmelzerückhaltung im RDB

Y*$ 7OB8$' UF<7$' 0-' ''6B99$' 5*8 ($%'A$%78)%.'/ #$%&$' &.%EF &<7 I$%F<98$' &$% VEF5$9A$ *5 .'8$%$5 U9$'.5 S'UX .'& &*$ W'8$/%*8B8 &$7 PYT2T-&$'7 /$O%B/8: W5

R-9/$'&$' #$%&$' &*$ #7'89*EF$' U%-A$77$ K$7EF%*$K$' .'& 7EF#$%O.'L85B,*/ &$% V8<'& &$%]-&99'8#*EL9.'/ <'F<'& &$% ^%K$*8$' &$7 W(\ &<%/$78$998:

Verlagerung ins untere Plenum und Wechselwirkung mit Restwasser

Y<7 U-8$'A*<9 A.% T*9&.'/ 0-' VEFN88.'/$' *5 P$78#<77$% &$7 'U *78 6N% &*$ ''6<992 .'& V*EF$%F$*87<'<9_7$ #*EF8*/: +$/$'NK$% $*'$% &*%$L8$' T*9&.'/ $*'$7 VEF5$9A$7$$7 K$*5 *'69*$,$' 0-' VEF5$9A$ *' &<7 'U $e*78*$%8 $*' $%F$K9*EF $%#$*8$%8$7 (NF9.'/7 0-8$'A*<9: Y<5*8 $%/*K8 7*EF $*'$ I$%9B'/$%.'/ &$% A$*89*EF$' R%*78$' K*7 A.% VEF5$9A$7$$2T*9&.'/ .'& K*7 A.5 I$%7</$' &$7 PYT 7-#*$ 6N% &*$ Y.%EF6NF%.'/ 0-' D-86<997EF.8A5<,'<F5$':

Y<7 ^.769*$,$' 0-' VEF5$9A$ <.7 $*'$5 VEF5$9A$7$$ *5 ($%' $%6-9/8 '<EF K*7F$%*/$' P$EF'.'/$' 0-%%<'/*/ <5 -K$%$' V$$2P<'& .'& &<5*8 *' K$/%$'A8$5 V8%-5: Y*$7$% L<'' 7$*89*EF '<EF .'8$' /$%*EF8$8 7$*' -&$% 7*EF NK$% &*$.'8$%$ +*88$%O9<88$ $%/*$,$' .'& 0$%8$*9$': W' K$*&$' RB99$' L<'' $*' $*'2 -&$% 5$F%78%<F9*/$7 ^.769*$,$' <'/$'-55$' #$%&$': b*%& $*'$ K$/%$'A8$ V8%<F9&*EL$ 0-' K*7 E<:1>E5 <'/$'-55$'J 7- L)''$' 7*EF '<EF &$' R^P[2\eO$%*5$'8$' k]^+ ddk /%),$%$ ^'8$*9$ 6%</5$'8*$%8$% VEF5$9A$ 0-' 5$F%$%$']*99*5$8$% U<%8*L$9&.%EF5$77$% $%/$K$': ^.EF $*' /%),$%$%J 7$*8#B%87 NK$% &$' ($%'2T_O<77 <K69*$,$'&$% VEF#<99 *78 5)/9*EFJ #$'' &*$ (%.78$ /%-,69BEF*/ <.6K%*EF8 kP\W>Ik:

W' &$% h$8A*/$']-&$99*$%.'/79*'*$ *' (\VV .'& A. ^GcM\G2ZY #*%& &<0-' <.7/$/<'/$'J &<77 7*EF &*$ VEF5$9A$ <97 $*'A$9'$% V8%<F9 -&$% 5$F%78%<F9*/ *' &<7 P$78#<77$% &$7 'U $%/*$,8: *' BF'9*EF$7]-&$99 A.% b$EF7$9#*%L.'/ 5*8 b<77$% *5 'UJ &<7 &*$ V8%<F96%</5$'8<8*-' <97 I-%<.77$8A.'/ A.% T*9&.'/ 0-' VEFN88.'/$' K$*'F<98$8J #.%&$ 6N% WZ^P\kZ^Gc^P\ $'8#*EL$98 kWZ^>@k: Y</$/$' #$%&$' *' &$' W'8$/%<9E-&$7]^^UJ]\MZ[P .'& VZY^UkP\M^U 7-9EF$ ^.6K%$EFO%-A$77$.'& &<7 6-9/$'&$ I$%F<98$' 0-' VEFN88K88' *5 'U '*EF8 K$7EF%*$K$': ^97 R-9/$ &$% I$%9</$%.'/ #*%& 0*$95$F% &*%$L8 $*' VEF5$9A$7$$ <'/$'-55$':

Bildung von Schüttungen im unteren Plenum

W' $*'$% <&Bp<8 &$8<*99*$%8$'J 5)/9*EF78 0$%$*'6<EF8$']-&$99*$%.'/ 7*'& &*$ U%-A77 &$% R%</5$'8*$%.'/ .'& T*9&.'/ 0-' VEFN88.'/$' A. 7*5.9*$%$': W' &$%]-&$99*$%.'/ &$% V8%<F96%</5$'8<8*-' /$F8 $7 A.'BEF78 &<%.5J &$' $'87EF$*&$'&$' OF_7*L<9*7EF$']$EF<'*75.7A. $%6<77$':W' $*'$% $%78$' UF<7$ &$7 *'8<.EF$'7*' b<77$% K$#*%L$'J K$* '-EF %$9<8*0 &N''$5 Y<5O66*95J &$% P$9<8*078%-5 0-' .5/K'&$5 b<77$% .'& VEF5$9A$78%<F9 $*' b$99$'#<EF78.5 <.6 &$5 V8%<F9 7-#*$ &*$ ^K78%$*6./0-' b$99$' <97 VEF5$9A$8%-O6$':]*8 A.'$F5$'&$% Y*EL$ &$% Y<5O6A-'$ KA#:$*'$% &<5O6%$*EF$']$F%OF<7$'A-'$ <.7 b<77$%J Y<5O6 .'& VEF5$9A$8%-O6$' *78 &<'' $*'$ Y-5*'<'A &$7 Y<5O678%-57 $'89<'/ &$7 VEF5$9A$78%<F97 <97 6%</5$'8*$%$'&$% V8%-5 <'A.'$F5$': Y*$]-&$99*$%.'/ &$% R%</5$'8<8*-' 0-' VEF5$9A$78%<F9$' L-558 '*EF8 -F'$ $*'$ ^'O<77.'/ 0-' U<%<5$8$%' <.7J &*$ <'F<'& &$% eO%*5$'8$99$' P$7.98<8$ 0-%A.'$F5$'*78:

W5 0$%$*'6<EF8$']-&$99 .'& (\VV2]-&.9 W(\f\G #*%& $*' \66$L8 &$7 %<&*<9$' +$7EF#*'&*/L$*87O%-6*97 .5 &$' V8%<F9 &.%EF $*'$' $5O*%*7EF$' P$&.L8*-'76<L8-% <.6 &*$ 5*889$%$ +$7EF#*'&*/L$*8 *5 78%<F9'<F$' Y<5O678%-5 $%6<778: Y*$7$% Y<5O678%-5 $'89<'/ &$7 V8%<F97 #*%& &.%EF &<7 78%<F9'<F$ <e*<9$ Y%.EL/$6B99$ F$%0-%/$%.6$'J #$9EF$7 7*EF 9$8A89*EF <.7 &$5 K$78*55$'&$' F_&%-78<8*7EF$' +$6B99$ *' &$% +$5*7EF7B.9$ &$% ‘5/$K.'/ $%/*K8:

W' PEF'E-&$7 #*$ f^V]WD\ k][P>Ik -&$%]Z@Y k^G(>IkJ &*$ $*']-&$99 A.% V8%<F96%</5$'8<8*-' $'8F<98$'J #*%& /$/$'#B%8*/ *' $*'$5 0$%$*'6<EF$'&$' ^'7<8A &*$ Y<5O6/$7EF#*'&*/L$*8 <.7 &$5 8%$*K$'&$' +$6B99$ $*'$% B.,$%$' b<77$%7B.9$ K$78*558: Y<5*8 K9$*K8 &*$ R%</5$'8*$%.'/ <K$% O%<L8*7EF .'<KFB'/*/ 0-' &$' +$5*7EF2T$&*'/.'/$': Y</$/$' *78 K$* $*'$5 F-F$' Y<5O6/$F<98 *' &$% /<'A$']*7EF.'/ $*'$ $%F$K9*EF$ P$&.L8*-' &$% R%</5$'8*$%.'/ A. $%#<%8$': W' '$.$%$' P$EF'.'/$' k^G(>Ik #.%&$' &<F$% &*%$L8]*88$9.'/7<'7B8A$ 6N% Y*EF8$.'& +$7EF#*'&*/L$*8*5 78%<F9'<F$' +$5*7EF $*'/$6NF%8:

Y$% 7*EF $*'78$99$'&$ Y<5O6/$F<98 *' &$%]*7EF.'/ *78 '*EF8 '.% $'87EF$*&$'& 6N% &*$ R%</5$'8*$%.'/ $*'$7 VEF5$9A$78%<F97J 7-'&$%' <.EF F*'7*EF89*EF &$% ^KLNF9.'/ &$% 6<99$'&$'J <.7 &$% R%</5$'8<8*-' $'878<'&$'$' G%-O6$': Y*7 5N778$' K*7 A.% ^K7$8A.'/ <5 PYT2T-&$' $*'$ 78<K*9$ (%.78$ K*9&$'J .5 &*$ \'878$F.'/ $*'$% VEFN88.'/ A. $%5)/9*EF$': ^'&$%'6<997 $%/$K$' 7*EF 5*'&$78$'7 69N77*/$ ^'8$*9$ -&$% L-5O<L8*$%8$ T$%$*EF$: *' F-F$% Y<5O6/$F<98 %$&.A*$%8 &*$ ^KLNF9.'/ .'& #*%L8 &<F$%

7-#-F9 &$% T*9&.'/ LNF9K<%$% VEFN88.'/$' <97 <.EF 5)/9*EF$' Y<5O6$eO9-7*-'$' $'8/$/$':

W5 P<F5$' &$7 V\P\D^2U%-h$L87 &$% [\ZY #<% <.7 0$%/9$*EF$'&$' P$EF'.'/$' 0$%7EF*$&$'$% Z-&$7J *'7K$7-'&$%$ A. R^P[2M3iJ $%L$''K<%J &<77 &$% K$%EF'8$ Y<5O6/$F<98 /$'$%$99 A. F-EF *78 kT'\>@k:])/9*EF$ '%7<EF$ *78 $*'$ A. 9<'/7<5$ Y<5O6<K6.F% #$/$' A. /%-,$% W'8$%OF<7$'%$*K.'/ A#*7EF$' Y<5O6 .'& b<77$%: Y*$]-&99 A.% W'8$%OF<7$'%$*K.'/ .'& A. $'87O%$EF$'&$' V8%)5.'/75.78$%' 7*'& '-EF 5*8 /%-,$' ''/$'<.*/L$*8$' K$F<68$8 .'& A$*/$' '-EF $%F$K9*EF$' HK$%O%N6.'/72 .'& Y$8<*99*$%.'/7K$&<%6:

I-' 7*EF$%F$*878$EF'*7EF$% T$&$.8.'/ 7*'& <97 R-9/$ &$% R%</5$'8<8*-' <.,$%&$5 I$%&<5O6.'/77O*8A$' *' &$%]*7EF.'/7OF<7$ 7-#*$ $*'$ 0$%78B%L8$ [e*&<8*-' 5$8<99*7EF$% ^'8$*9$ 5*8 $'87O%$EF$'&$% b<77$%78-66$%A$./.'/: W5 VEFN88K$882]-&$99 b^T\7*'& &*$ [e*&<8*-'J b<77$%78-66$%A$./.'/ .'& 28%<'7O-%8 K$%$*87 K$%NEL7*EF8*/8:

Kühlbarkeit von Schüttungen im unteren Plenum, Bildung eines Schmelzesees

D<EF &$% T*9&.'/ $*'$% VEFN88.'/ <5 PYT2T-&$'J .:': 5*8 L-5O<L8$' .'& /$7EF5-9A$'$' ^'8$*9$'J #*%& &$%$' (NF9K<%L$*8 A.5 A$'8%<9$' GF$5<J 7-#-F9 F*'7*EF89*EF I$%A)/$%.'/$' K*7 A. $*'$% VEF5$9A$7$$2T*9&.'/ <97 <.EF F*'7*EF89*EF &$% (NF9.'/7EF<'E$'J <KFB'/*/ 0-' 0$%9</$%8$% VEF5$9A$5<77$.'& #*$&$% %$<9*7*$%8$% *'7O$*7.'/ 0-' b<77$%: Y<7 U-8$'A*<9 F*$%A. 0-% ^.7K*9&.'/ $*'$7 /%-,$' VEF5$9A$7$$7 *78 A. $%L.'&$'J .5 &*$ <.7 $*'$% b<77$%$*'7O$*7.'/ %$7.98*$%$'&$' ZF<'E$' <.EF '-EF*' $*'$% 7-9EF$' 7OB8$' ''6<99OF<7$ $*'7EFB8A$' A. L)''$':

b*$ 7EF-' K$*5 78<%L K$7EFB&*/8$' -&$% A$%78)%8$' P$<L8-%L$%' *78 &*$ (NF9K<%L$*8 $*'$% O-%)7$' V8%.L8.%-&$% VEFN88.'/ <.EF*5 'U$'87EF$*&$'&0-' &$' T$&*'/.'/$' 6N% &<7 *'&%*'/$' 0-' 0-%F<'&$'$5 b<77$%*' &*$ VEFN88.'/ <KFB'/*/: P$78#<77$% -&$% *' &$' PYT $%'$.8 $*'/$7O$*78$7 b<77$% 9*$/8 F*$%K$* '<EF ^K7$8A.'/ &$% VEFN88.'/ *55$% <97 NK$%7EF*EF8$8$% b<77$%2U--9 0-%: Y<7 *'69*$,$' 0-' b<77$% NK$% '*$&%*/$ VEFN88.'/7K$%$*EF$ K$/N'78*/8 <K$% &*$ (NF9K<%L$*8: \7 *78 '.% *5 P<F5$' 0-' 5$F%&*5$'7*-'<9$']-&$99$' $%6<77K<%: Y*$ (NF9K<%L$*8 #.%&$ &<F$% *' 6%NF$%$']-&$99$' .'8$%7EFB8A8: *'$ T$/%$'A.'/ &$% (NF9K<%L$*8 *78 &<'' /$/$K$'J #$'' K$* F-F$% Y<5O6O%-&.L8*-' '*EF8 5$F% /$'N/$'& b<77$% '<EF69*$,$' KA#:

Y<5O6 <K69*$,$' L<'' .'& &<5*8 $*' 78<8*-'B%$% a.78<'& &$% VEFN88.'/ '*EF8 5$F% 5)/9*EF*78: Y<'' 7$8A8 ^.7&<5O6$' 5*8 &$% T*9&.'/0-' G%-EL$'78$99$' $*':

'5 &*$ V8%)5.'/7K$&*'/.'/$' 6N% L-5O9eJ <.EF F8%-/$'$ T$%$*EF$.'& I$%&*EF8.'/$' $'8F<98$'&$ VEFN88.'/72(-'6*/.%<8*-'$' %$<9*78*7EF A.$%6<77$'J *78 &$% 7$*89*EF$ b<77$%2a.78%-5 *' .'8$%$ VEFN88.'/7K$%$*EF$ 5*'&78'7 &.%EF $*' 3Y2]-&$99 A. K$7EF%$*K$': Y<7 32R9.*&2]-&$99 &$% V8%)5.'/ 5.77 7-#-F9 +9$*EF78%-52 <97 <.EF +$/$'78%-55.78$% K$*'F<98$': Y<7 b^T\2 KA#:]\b^2]-&$99J &<7 A.'BEF78 6N% &$' P$<L8-%L$%' $'8#*EL$98 #.%&$J K$%NEL7*EF8*/8 &*7 '-8#$'&*/$' ^'6-%&$%.'/$': Y<K$* #.%&$' *' b^T\ $%F$K9*EF$ I$%$*'6<EF.'/$' K$AN/9*EF &$% +%.'&/9$*EF.'/$' 0-%/$'-55$'J A: T: I$%'<EF9B77*/.'/$' 8%<'7*$'8$% .'& L-'0$L2 8*0$% G$%5$*' &$' W5O.97/9$*EF.'/$'J #<7 5*8 &$% Y-5*'<'A &$% &.%EF U<%8*L$9 KA#: 6$78$]<8%*e K$&*'/8$' P$*K.'/ &$% a#$*OF<7$'78%)5.'/ K$/%N'&$8 #$%&$' L<'': 5'9*EF$]-&99'8#*EL9.'/$' #$%&$' <.EF 6N% WZ^P\kZ^Gc^P\ kRWZ >Ik &.%EF2 /$6NF%8:

^.6/%.'& &$% %$9<8*0 '*$&%*/$' R<99F)F$'*5 P$78#<77$% &$7 'U*78 K$*5 \'878$F$'0-' VEFN88.'/$' 5*8 U<%8*L$9' F)F$%$% G$5O$%<8.%$' A. %EF'': *'$ A.'BEF78 0-9978B'&*/$ ^KLNF9.'/ *78 F*$% '*EF8 A. $%#<%8$': \7 *78 &<'' 0-' F$*,$'J %<7EF <.7&<5O6$'&$' VEFN88.'/$' <.7A./$F$'J*' &*$ b<77$% $%78 #*$&$% $*'&%*'/$' 5.77J .5 $*'$ #*%L.'/70-99$ (NF9.'/ $*'A.9$*8$': Y$7F<9K #$%&$' *' b^T\ .'&]\b^ .'8$%7EF*$&9*EF$ G$5O$%<8.%6$9&$% 0-' R$7878-66J VEF5$9A$J b<77$% .'& Y<5O6 K$7EF%*$K$'J 7-&<77 &*$ $'87O%$EF$'&$' bB%5$78%)5$ L-%%$L8 &<%78$99K<% 7*'&: Y*$ (-%%$9<8*-'$' A.% T$%$EF.'/ &$% bB%5$NK$%/<'/7A<F9$' .'& A.5 P$*K.'/72 &%.EL<K6<99 7*'& h$&-EF 5*8 /%-,$' ''7*EF$%F$*8$' K$F<68$8J 7-&<77 F*$%A. $*' 0$%78B%L8$% I$%6*L<8*-'7K$&<%6 K$78$F8:

*' $%F$K9*EF$7 (NF9.'/7O-8$'A*<9 K78F8 <K$% <.EF '-EF K$* \e*78$'A 0-' G%-EL$'A-'$' *' &$% VEFN88.'/ NK$% $*'$' LNF9$'&$' Y<5O678%-5J #$'' b<77$% .'8$% &*$7$ a-'$' 0-%&%*'/$' L<'' S7:<: kRWZ >IkX:

T*9&$' 7*EF <.6 +%.'& .'/$'N/$'&$% bB%5$<K6.F% /%),$%$ VEF5$9A$7$$' <.7J 5.77 <.EF &$% bB%5$8%<'7O-%8 &.%EF /%-,%B.5*/$ (-'0$L8*-' *' &$% VEF5$9A$ K$%NEL7*EF8*/8 #$%&$':

*'$ /$7EF9-77$'$ T$F<'&9.'/ &$% I-%/B'/$ *5 'U #*%& $*'$%7$*87 &.%EF *'K$A*$F.'/ &$7 b^T\2]-&$997 6N% &*$ VEFN88.'/*' W(\]Wx.'& <'&$%$%7$*87 &.%EF

&*$ '-EF *' T$<%K$*8.'/ K$6*'&9*EF$ (-OO9.'/ 0-' W(\]Wx5*8]\V[Z[$%5)/9*EF8 #$%&$':]*8 &$5 0-%/7F$'$' *'K<. &*$7$7 +$7<585-&$997 I\Z[6N% &*$ U%-A77 *5 'U*' ^GcM\G2ZY .'& &*$ ^'L-OO9.'/ <' &*$ GF$%5-F_&%<.9*L 0-' ^GcM\G #*%& &<'' $*'$ +$7<58K$7EF%$*K.'/ &$% U%-A77 .'8$% *'K$A*$F.'/ 0-' *'7O$*7.'/$' 0-' b<77$% .'& &$% V_78$5A.78B'&$ $%5)/9*EF8:]*8 VEF5$9A$7$$2T*9&.'/ .'& P$<L8-%&%.ELK$FB98$%2I$%7</$' 7*'& <97 VEF'*8878$99$ 6N% R-9/$O%-A$77$ *5 V*EF$%F$*87K$FB98$% <.EF I$%7</$'7A$*8$' .'& 2<%8$' 7-#*$ VEF5$9A$2 .'&]<8$%*<9A.78B'&$ $'8F<98$':

Schmelzepool im unteren Plenum des RDB, Außenkühlung und RDB-Versagen

T$AN/9*EF $*'$7 <.7/$K*9&$8$' /%-,$' VEF5$9A$7$$7 S*5 +%$'A6<99 &<7 /<'A$ ($%'*'0$'8<% .56<77$'&X *5 'U K$78$F8 &*$ $'87EF$*&$'&$ R%</$78$99.'/ .'& &<5*8 <.EF]-&$99<.6/<K$ &<%*'J &*$ I$%8$*9.'/ &$7 bB%5$NK$%/<'/7 $'89<'/ &$% '5/%$'A.'/ &$7 V$$7 .'& &<5*8 &*$ 8F$%5*7EF$ T$9<78.'/ &$% PYT2b<'& A. K$78*55$': Y<K$* *78 <.EF #BF%$'& &$% VEF5$9A0%9</$%.'/ $*'$ 8F$%5*7EF$ VEF#BEF.'/ .'& \%-7*-' &$% PYT2b<'& &.%EF &*%$L8$ *'#*%L.'/ L-5O<L8$%J .'6%</5$'8*$%8$% VEF5$9A$78%<F9$' <.6 &$' PYT2T-&$' A. K$%NEL7*EF8*/$': Y*$7$ 8%8' <.6J #$'' L$*' -&$% A. #$'*/ P$78#<77$% 0-%9*$/8 -&$% 7*EF 7$F% &*EL$ VEF5$9A$78%<F9$' $%/$K$': Y<7 I$%7</$' &$7 PYT L<'' &.%EF $*'$ #*%L7<5$ ^.,$'LNF9.'/ 0$%A)/$%8 -&$% <.EF 0$%5*$&$' #$%&$': ^.EF 5)/9*EF$ (NF9$66$L8$ NK$% &N''$ VO<98$ A#*7EF$' /$7EF9-77$'$' -&$% O-%)7$' (%.78$' .'& &$% PYT2b<'& L)''$' A.%]*'&$%.'/ &$% 8F$%5*7EF$' T$9<78.'/ K$*8%</$':

Y*7 U%-A77 7-99$' 5*8 &$5 &$8<*99*$%8$' I\Z[2]-&$99 kT'\>Ik -&$% &$5 0$%$*'6<EF8$' ^WY^2]-&$99k]'\>1k 7*5.9*$%8 #$%&$':

*'$ %$<9*78*7EF$ T$78*55.'/ &$% VEF5$9A$L-'0$L8*-' .'& &$% I$%8$*9.'/ &$7 bB%5$NK$%/<'/7 $'89<'/ &$% '5/%$'A.'/ &$7 V$$7 7EF$*'8 /$/$'#B%8*/ <.EF 5*8 <.6#B'&*/$' ZRY2T$%$EF'.'/$' L<.5 5)/9*EF: Y<F$% *78 F*$%6N% #*$&$% $*' 0$%$*'6<EF8$7]-&$99 <.6 T<7*7 &$% +%$'A7EF*EF8K$8%<EF8.'/ .'& *' ^'L-OO9.'/ <' $*'$' <e*<9$' I$%9<.6 &$% V$$2HK$%F*8A.'/ 0-%/$7F': D<EF eO%*5$'8$99$% ^'O<77.'/ $%9<.K8 &*$7$7]-&$99 &*$ T$%$EF'.'/ &$% bB%5$78%)5$ '<EF <.,$' *' ^KFB'/*/L$*8 0-' &$% HK$%F*8A.'/ &$7 V$$7 .'& &$% RN99F)F$: '5 &*7 0$%$*'6<EF8$]-&$99*$%.'/ <KA.7*EF$%'J K9$*K8 $7 0-' W'8$%77J &*$ I$%8$*9.'/ &$% bB%5$78%)5$

<.7 &$5 V$$ <.EF *' V$O<%<85-&$99$' A. .'8$%7.EF$' SA: T: kbWM>1kXJ <.EF #$''
/$/$'#B%8*/ '.% K$/%$'A8<.77</$6BF*/$ T$7EF%$*K.'/$' 5)/9*EF 7*'&:

b*%& *5 8F$%5-EF$5*7EF$' +9$*EF/$#*EF8 <' &$% W''$'7$*8$ $*'$% (%.78$ .5 $*'$'
VEF5$9A$7$$ &*$ M*p*&.7 2G$5O$%<8.% $'87O%$EF$'& &$% a.7<55$'7$8A.'/ &$%
VEF5$9A$ <'/$'-55$' kV\W>>kJ 7- 78$998 7*EF &*$ (%.78$'&*EL$ *' $*'$5 78<8*-'B%$'
-&$% p<7* 278<8*-'B%$' a.78<'& $'87O%$EF$'& &$% bB%5$A.6.F% <.7 &$% VEF5$9A$.'&
&$% bB%5$<K6.F% '<EF <.,$' $*':W5 (-'8<L8 5*8 &$5 PYT #*%& &<K$* &*$ PYT2b<'&
7-#$*8 <.67EF5$9A$' K*7 $*' +9$*EF/$#*EF8 $%%$*EF8 *78J &: F: &*$ 9-L<9$' bB%5$78%)5$
<K/$6NF%8 #$%&$': Y*$ W'8$/%*B8 &$7 PYT L<'' &<'' <'F<'& 0-' V8<K*9*8B87L%*8$%*$' 6N%
&*$ 0$%K9$*K$'&$ b<'&&*EL$ K$.%8$*98 #$%&$': Y*7% G$*9 &$%]-&$99*$%.'/ *78 6N% ^WY^
0-%/7F$':

Y*$ (-OO9.'/ 5*8 ^WY^ 7EF9*$,8 &<K$* <.EF 5)/9*EF$ (NF9$66$L8$ NK$% &N''$ VO<98$
A#*7EF$' &$% (%.78$.'& &$% PYT2b<'&J *' &*$ b<77$% $*'&%*'/$' L<''J $*': *'
$'87O%$EF$'&$7]-&$99 #.%&$ <.EF *' b^T\ *'8$/%*$%8: Y*$ VO<98K*9&.'/ #*%& *' &*7'
]-&99' <99$%&*'/7 '*EF8 K$7EF%*K': ^'/$7*EF87 &$% ‘ ’7*EF$%F$*8$' F*$%K$* 7*'&
<K7-9.8$ V*EF$%F$*87<.77</$' -&$% 2L-'A$O8$ <.6 &$% T<7*7 &*$7$7]$EF<'*75.7 7$F%
6%</9*EF: Y*$ a*$97$8A.'/ K$* &$%]-&$99*$%.'/ L<'' &<F$% '.% &<%*' K$78F'J 5)/9*EF$
T$*8%B/$ A.% VEF5$9A$%NELF<98.'/ $%L$''K<% A. 5<EF$': Y<A. 7*'& ^.7&$F'.'/ .'&
Y*EL$ &$% VO<98$ A. O<%<5$8%*$%$':

\7 *78 <.,$%&$5 0-%/7F$'J &*$ 8F$%5-5$EF<'*7EF$ b*%L.'/ <.6 &*$ PYT2b<'&J
#$9EF$ 9$8A89*EF $*' I$%7</$' &.%EF (%*$EF&$F'.'/ K$&*'/8J 5*8 &$5 *' ^WY^
0$%#$'&8' 78%.L8.%&_'<5*7EF$' U%-/%<55 ^VG[P A. $%5*88$9' k]‘\>1k:
‘ ’8$%78N8A.'/ &<A. L<'' 0-' &$8<*99*$%8$' U%-/%<55$' #*$ ^YWD^ k+P\ ddk .'&
^DVjV kbWM>1k /$#-''$' #$%&$' S7*F <.EF (<O*8$9 !P$<L8-%&%.ELK$FB98$% K$*
($%'7EF5$9A$';X: Y*$ T%.EF78$99$ $%/*K8 7*EF 0-%#*$/$'& <.7 &$% 8F$%5*7EF$'
T$9<78.'/:

T$AN/9*EF &$7 I$%F<98$'7 &$7 VEF5$9A$7$$7 .'& &$% bB%5$78%-50$%8$*9.'/ <5 P<'&
7*'& F8%-/$'$ VEF5$9A$A.78B'&$ 0-' K$7-'&$%$% T$&$.8.'/: ^.6/%.'& EF$5*7EF$%
P$<L8*-'$' L<'' $7 A.]*7EF.'/79NEL$' .'& &<%<.7 %$7.98*$%$'&$% UF<7$'7$O<%<8*-'
.'& VEF*EF8$'K*9&.'/ L-55$': Y*7 K$$*'69.778 &*$ bB%5$78%-50$%8$*9.'/ <5 P<'&:
T$7-'&$%7 /%<O*$%$'& *78 &*$ T*9&.'/ 5$8<99*7EF$% VEF*EF8$'J &*$ A. $*'$% R-L.77*$%.'/
0-' bB%5$78%)5$' <' &$' P<'& 5*8 0$%78B%L8$% 9-L<9$% ^.67EF5$9A#*%L.'/ 6NF%$' .'&
$*' 6%NFA$*8*/$7 9-L<9$7 PYT2I$%7</$' K$#*%L$' L)''$': W5 I\Z[2]-&$99 7*'&

M)7.'/7<'7B8A$ 6N% &*$ b*%L.'/ 5$8<99*7EF$% HK$%7EF*EF8.'/$' $'8F<98$': \%#$*8$%.'/$' A. $*'$% <99/5*'$' \%6<77.'/ 0-' VEF*EF8.'/7$66$L8$' 7*'& 0-%/$7F'J '*EF8 <K$% &*$]-&$99*$%.'/ &$% VEF*EF8$'K*9&.'/ 7$9K78: b*$ 7EF-' 6N% &*$ VEF5$9A$*5 ($%'K$%$*EF 7-99$' 5)/9*EF$ \66$L8$.'8$% O<%<5$8%*7EF$' ^''<F5$' &$% VEF*EF8&*EL$ <'<9_7*$%8 #$%&$': Y*$7$ 7*'& /%.'&7B8A9*EF *' ^KFB'/*/L$*8 0-' &$' EF$5*7EF$' I-%/B'/$' .'& &$% \e*78$'A $'87O%$EF$'&$%]<8$%*<9OF<7$' <'A.'$F5$': b$*8$%$ \%L$''8'*77$ <.7]^VZ^ k]'\>@k NK$% &*$ VEF*EF8$'K*9&.'/ 7*'& A. K$%NEL7*EF8*/$':

6.2.6 Spaltproduktfreisetzung

Phänomenologische Beschreibung

Y*$ #BF%$'& &$7 T$8%*$K7 0-' ($%'L%<68#$%L$' &.%EF ($%'7O<98.'/ $'878$F$'&$' VO<98O%-&.L8$ SVUX K$$*'69.77$' &$' I$%9<.6 &$% ($%'A$%78)%.'/ ? A: T: &.%EF &*$ '50$%8$*9.'/ 0-' D<EFA$%6<997#B%5$p99' K$* $*'$5 VO<98O%-&.L88%<'7O-%8 *5 U%*5B%L%$*7J &*$ ^.6F$*A.'/ 0-' V8%.L8.%$' &.%EF <K/$9</$%8$ VU -&$% &*$ Y%.ELK$9<78.'/ &$% *' &$% 7OB8$' V8)%6<99OF<7$ &$' VEF5$9A$7$$ .5/K'&$' L$%<5*7EF$' (%.78$ &.%EF <.7/<7$'&$ VU ? .'& 78$99$' &$' O-8$'8*99' O%*5B%$' %<&*-<L8*0$' o998%5 6N% &$' V*EF$%F$*87K$FB98$% &<%:

Y<7 R%$*7$8A.'/70$%F<98$' <.7 *'8<L8$' T%$''2 .'& ^K7-%K$%78BK$'J /$6-9/8 0-' &$% R%$*7$8A.'/ <.7 VEFN88K88' .'& &<'' <.7 VEF5$9A$O--97 *5 ($%' FB'/8 0-' $*'$% I*$9A<F9 OF_7*L<9*7EF$% .'& EF$5*7EF$% U%-A77*' &$% R$7878-665<8%*e -&$% VEF5$9A$.'& &$% .5/K'&$' +<7<855-7OFB%$ S-e*&*$%$'&$ T$&*'/.'/$'XJ &$' b$EF7$9#*%L.'/$' A#*7EF$' *'8<L8$5 T%$''78-66J VEFN88K$88$' -&$% VEF5$9A$.'& &$5 (NF95*88$9 7-#*$ &$% ^.68$*9.'/ *' &*$ 0$%7EF*$&$'$' UF<7$' S5$8<99*7EF? L$%<5*7EFX #BF%$'& &$7 VEF5$9A$'7 KA#: &$% b*$&$%$%78<%%.'/ -&$% &$% (%.78$'K*9&.'/<K:

Y*$ VU L)''$' *' 0$%7EF*$&$'$J *F%$ R9NEF8*/L$*8 EF<%<L8$%*7*$%$'&$ (<8$/-%*$' S(9<77$'X $*'/$-%&'$8 #$%&$': \'87O%$EF$'& &$% <'/$#$'&8' [%&'.'/7L%*8$%*$' 2 A: T: Y<5O6&%.EL -&$% V*$&$O.'L8$ &$% $9$5$'8<%$' P$*'78-66$J T$%NEL7*EF8*/.'/ EF$5*7EF$% b$EF7$9#*%L.'/$' -&$% <.EF $%#<%8$8$% S'9*EFL$*8$' *5 OF_7*L<9*7EF 2 EF$5*7EF$' I$%F<98$' .'& &$5 Y$8<*99*$%.'/7/%<& &$% (<8$/-%*7*$%.'/[1] 2 L)''$' F*$%

[1] A: G: $%6-9/8 $*'$ *'8$*9.'/*' K*7A.7*$K$' (<8$/-%*$'

&.%EF<.7 ‘ ’8$%7EF*$&$ *’ &$% *’-%&’.’/ <.68%$8$’J 7*$F$ A: T: kUM‘ >IkJ k([P ddkJ kP [+ d>kJ kTP [dkm b $%&$’ &*$ VU *’ &%$* (<8$/-%*$’ $’87O%$EF$’& &$% $%#<%8$8$’ 5’9*EFL$*8$’ *F%$7 OF_7*L< 9*7EF2EF$5*7EF$’ I$%F<98$’7 $*’/$-%&’$8J 7- %$7.98*$%8 <97 $*’ I-%7EF9</ kUM‘ >Ik

- M$*EF8 69NEF8*/$ 8J (%J fJ T%J Z7J PKJ Z.J V$J G$J VKJ ^/J
- 5*88$969NEF8*/$ T<J P.J V%J M<J jJ \.J Z$J]- .’&
- 7EF#$% 69NEF8*/$ PFJ U&J GEJ DKJ a%J DOJ U.J D&J U5J +&J GKJ Y_J c-J \%J G5J jKJ U%J ^5J Z5J V5J ‘Ja’J ^7J Z&J V’J +<J +$J W’:

Y*$ 8%$*K$’&$’ (%B68$ &$% R%$*7$8A.’/ <.7 &$5 T%$’’78-66 KA#: <.7 &$5 V8%.L8.%5<8$%*<9 7*’& *5 #$7$’89*EF$’ (-’A$’8%<8*-’72 .’& Y%.EL/%<&*$’8$’ <.7 &$5]<8$%*<9*’’$%$’ A.5 (NF95*88$9: Y$% V8-668%<’7O-%8 #*%& 7-5*8 &.%EF 6-9/$’&$ A: G: 7EF%*88#$*7$ <K9<.6$’&$ U%-A77 K$78*5 58:

- Y*$ <8-5<%$ Y*66.7*-’ *’’$%F<9K &$% ()%’$% &$% R$7878-6655<8%*e .’& A. &$’ (-%’/%$’A69BEF$’J Y*66.7*-’ *’’$%F<9K 0-’ +<7K9<7$’ *5 (-%’*’’$%$’J K$$*’69.778 &.%EF &*$ VU2U%-&.L8*-’ *5 (-%’J (-%’#<EF78.5J (-%’/%$’A$’0$%7<8AJ I$%69N77*/.’/ &$% (-%’-K$%69BEF$’ .’& M)7.’/7O-%/B’/$J
- &*$ ^.7K*9&.’/ &$7 (-%’/%$’A69BEF$’’$8A$7 .’& &$% U-%$’ A#*7EF$’ &$’ (-%’/%$’A$’J .:<:&.%EF ^’7<55 59.’/ .’& ^.7&$F’.’/0-’ +<7K9<7$’ 7-#*$
- &<7 a.7<55$’#<EF7$’ &$% +<7K9<7$’ .’& &<5*8 &*$ g66’.’/ 0-’ G%<’7O-%8O6<&$’ 6N% /<76)%5*/$ VU .’& /9$*EFA$*8*/$ Y*66.7*-’ 0-’ ^$%-7-9$’ $’89<’/ &$% (-%’/%$’A-K$%69BEF$’ .’& &<5*8 &$’ G%<’7O-%8 A.% [K$%69BEF$ &$7]<8$%*<97:

Y$% G%<’7O-%8O%-A$77 <.7 &$% T%$’’78-6655<8%*e <’ &<7 (NF95*88$9 L<’’ 7-5*8 *’ 7$*’$% +$7<58F$*8 <97 Y*66.7*-’ <.6/$6<778 #$%&$’J 7-&<77 &*$ R%$*7$8A.’/7%<8$.:<: K$78*5 58 #*%& &.%EF

- &*$ 66L8*0$’ Y*66.7*0*8B8$’ KA#: Y*66.7*-’7#*&$%78B’&$ &$% $*’A$9’$’ R%$*2 7$8A.’/7O6<&$J
- &*$ R%$*7$8A.’/7O6<&9B’/$’ .’& 2p$%7EF’*88$ 7-#*$
- &*$ 8%$*K$’&$’ (%B68$J /L’’A$*EF’$8 &.%EF &*$ h$#$*9*/$ R9NEF8*/L$*8:

Y*$ 66L8*0$' Y*66.7*0*8B8$' 7*'& <KFB'/*/ 0-' 5*8$*'<'&$% /$L-OO$98$' U%-A$77$' #*$

- <8-5<%$ Y*66.7*-'J
- T9<7$'#<EF78.5 .'& 2K$#$/.'/ *5 (-%'J (-%'/%$'A69BEF$'#<EF78.5J T9<7$'2 A.7<5 5$'#<EF7$' A#*7EF$' &$' (-%'/%$'A$'J
-]*L%-%*77K*9&.'/ 7-#*$
- (-%'/%$'A0$%69N77*/.'/ .'& ?0$%&<5O6.'/:

Y*$ 5<,/$K9*EF$' *'69.77/%),$' 7*'& F*$% &*$ G$5O$%<8.% .'& &$% ^//%$/<8A.78<'& SR$7878-66 -&$% VEF5$9A$X &$7 &.%EF#<'&$%8$']<8$%*<97:

Y*$ R%$*7$8A.'/7O6<&9B'/$' .'& 2p$%7EF'*88$ #$%&$' K$$*'69.778 &.%EF

- &*$ P*77K*9&.'/ *' .'& I$%69N77*/.'/ 0-' cN99%-F%$'J
- &*$ I$%7O%)&.'/72 .'& R%</5$'8*$%.'/70-%/B'/$ <.6/%.'& 0-' T%$''78-662 &$F.'/ -&$% 8F$%5*7EF$% VO<''.'/$'

.'& FB'/$' &<%NK$% F*'<.7 0-' &$% I-%/$7EF*EF8$ &$7 T%$''78-667 S^.6F$*A&<.$%J ^KK%<'&%<8$X <K:

Y*$ VO<98O%-&.L86%$*7$8A.'/ K$/9$*8$8 <99$ UF<7$' $*'$7 7EF#$%$' ‘'6<997 *5 U%*5B%7_78$5 k([Z>@k:]*8 A.'$F5$'&$% G$5O$%<8.% .'& ($%'A$%78)%.'/ ''*5 58 &*$ b*%L7<5L$*8 &$% *''$%$' T<%%*$%$' /$/$' &*$ R%$*7$8A.'/ 0-' VO<98O%-&.L8$' SVUXJ &: F: &*$ *'K*'&.'/ &$% VU*' &<7 (%*78<99/*88$% &$7 T%$''78-667 .'& <'&$%$% V8%.L8.%$' 7-#*$ &$% /<7&*EF8$ *'7EF9.77 *''$%F<9K &$% T%$''78<KFN99%-F%$J <K: T$/*''$'& 5*8 &$% V8$*/$%.'/ &$%]-K*9*8B8 &$% VU*''$%F<9K &$7 (%*78<99/*88$%7 5*8 &$% G$5O$%<8.%)66'$8 7*EF K$* $*'$5 W'8$/%*8B870$%9.78 &$% cN99%-F%$ $*' R%$*7$8A.'/7O6<& &$% VU*' &<7 (NF95*88$9: G%*88 $*'$ R%</5$'8*$%.'/ ''-EF 6$78$% ($%'K$78<'&8$*9$ A:T: &.%EF p$'EF*'&.A*$%8$ GF$%5-7O<''.'/$' K$*5 b*$&$%69.8$' &$7 ($%'7 <.6J 7- 0$%LN%A8 7*EF &$% b$/ &$% VU <.7 &$5 W''$%$' &$% T%$''78-665<8%*e <' &*$ 5<L%-7L-O*7EF$ [K$%69BEF$ &$7 R$7878-66$7J #<7 5*8 $*'$% V8$*/$%.'/ &$% R%$*7$8A.'/ 0$%K.'&$' *78: T$* A.'$F5$'&$% ($%'A$%78)%.'/ 5*8 I$%69N77*/.'/ &$7 T%$''78-667 .'& <'&$%$% V8%.L8.%$' B'&$%' 7*EF &*$ G%<'7O-%85$EF<'*75$'*' &$']<8$%*<9*$':Y*$ VU K$#$/$' 7*EF *' &$' 69N77*/$' UF<7$' &$.89*EF 7EF'$99$% <97 *' &$' (%*78<9978%.L8.%$' &$7 R$78L)%O$%7J 7-&<77 &*$ R%$*7$8A.'/7%<8$' <'78$*/$':

Stand der Modellentwicklung und Programmvalidierung

Y*$ K$* &$% Y*7L.77*-' &$7 \'8#*EL9.'/72 .'& I<9*&*$%.'/778<'&$7 5<,/$K9*EF A.K$%NEL7*EF8*/$'&$' &$8<*99*$%8$' U%-/%<5 57_78$5$ 6N% &*$ W'2I$77$92UF<7$ 7*'& &*$&$.87EF$ \'8#*EL9.'/ ^GcM\G2ZY kGP^ dkJ kV[D >3kJ &*$ 6%<'A)7*7EF$ WZ^P\3 .'&&*$ 'V2<5$%*L<'*7EF$ VZY^UkP\M^U=SVZY^UVW]X 7-#*$ &*$ W'8$/%<9E-&$7 ^VG\ZS6%<'A)7*7EF2&$.87EFX .'&]\MZ[P S'V2<5$%*L<'*7EFXJ #-K$* &*$]-&$99K<7*7 &$%Z-&$7 A:G: &.%EF<.7 5'9*EFL$*8$' <.6#$*78 .'& F*$% '.% 7 $F% 0$%LN%A8 <'F<'& &$%]-&$99$*' ^GcM\G2ZY .'& ^VG\Z &<%/$78$998 #*%&:

^GcM\G2ZY K$*'F<98$8 A.% T$%$EF'.'/ &$% VU2 .'& V8%.L8.%5<8$%*<96%$*7$8A.'/ <.7T%$''2 .'& ^K7-%K$%78BK$' '$K$' $*'$5 P<8$'/9$*EF.'/7<'7<8AJ &$% &*$/$K%B.EF9*EF$' 8$5O$%<8.%<KFB'/*/$' P<8$'/9$*EF.'/$' ? #*$ D'P\+ >8J Z[PV[PJ V^VZc^J Z[PV[P2]J U\GGW .'& [PDM ? A.% ^.7#<F9 78$998J <.EF Y*66.7*-'7<'7B8A$? #*$ Z[PV[P .'& Z[PV[P2]J IWZG[PW^J]WGP^ .'& D'P\+kZP2881n c*$%K$* #*%&*5]-&.9 RWUP\] A#*7EF$' VO<98O%-&.L8$'J T%$''78-66 .'& ^L8*'*&$' 7-#*$ V8%.L8.%5<8$%*<9*$' .'8$%7EF*$&$'J K$* &$%$' T$%$EF'.'/ *' &$%<L8.$99$' I$%7*-' &*$ ^KFB'/*/L$*8 0-5 h$#$*9*/$' U<%8*<9&%.EL 5*8 K$%NEL7*EF8*/8#$%&$' L<'':

Y*$ T$%$EF'.'/ &$% R%$*7$8A.'/ 0-' VU .'& V8%.L8.%5<8$%*<9 $%6-9/8*' ^VG\Z*' &$5]-&.9 \MV^ S<L8.99 I$%7*-' 3:1J kUM' >IkX: Y<7]-&.9 \MV^ K$%$EF'$8 &*$R%$*7$8A.'/7L*'$8*L 69NEF8*/$% VO<98O%-&.L8$ K$* cN99%-F%0$%7</$' .'& 6N% VEFN88K$88$'NK$% $*'$' Y*66.7*-'7<'7<8A ST--8F2R-%5.9*$%.'/X: T$* T%$''78-660$%69N77*/.'/ #*%&<'/$'-55$'J &<77 69NEF8*/$ VO<98O%-&.L8$ 0-9978B'&*/ 6%$*/$7$8A8 #$%&$': RN%5*88$969NEF8*/$ VU #*%& &*$ Y*66.7*-' *''$%F<9K &$% R$7878-6655<8%*e 0$%'<EF9B77*/8 .'&&*$ R%$*7$8A.'/ 0$%$*'6<EF$'& NK$% $*'$' I$%&.'78.'/7<'7<8A 0-' &$% (-%'-K$%69BEF$&$7 T%$''78-667 *' &*$ +<7OF<7$ K$7EF%*$K$': T<7*$%$'& <.6 8F$%5-EF$5*7EF$'^'7B8A$' A.%]*'*5*$%.'/ &$% 6%$*$' +*KK7 \'$%/*$ 6N% *&<9 M)7.'/$' $%6-9/8 &*$T$78*55.'/ &$% U<%8*<9&%NEL$ &$% h$#$*9*/$' VU: Y*$ T$7EF%$*K.'/ &$% R%$*7$8A.'/7EF#$% 69NEF8*/$% VU $%6-9/8 <'<9-/ .'8$% &$% ^''<F5$J &<77 &*$ R%$*7$8A.'/ 7EF#$%69NEF8*/$% VU 0-' *'8<L8$5 T%$''78-66 .'& VEFN88K88' &.%EF &*$ I$%69NEF8*/.'/ 0-''[3 K$78*558 #*%&: Y*$ R%$*7$8A.'/ 0-' V8%.L8.%5<8$%*<9 *78 *' &$% <L8.99'Z-&0%7*-' <.6 &*$ R%$*7$8A.'/ 0-' ^/J W' .'& Z& &$7 ^K7-%K$%78<K$7 .'& V' <.7&$' cN99%-F%$' K$/%$'A8: W' ^'9$F'.'/ <' &*$ \'8#*EL9.'/ 0-' P\M[V k([P ddkJkT\P>@kJ kT\P>@<k 0$%6N/8 ^VG\Z KA#: \MV^ *' &$% <L8.$99$' I$%7*-' kUM' >Ik '.'<.EF NK$% $*']-&$99 A.% T$%$EF'.'/ &$% VU2 .'& V8%.L8.%5<8$%*<96%$*7$8A.'/ <.7

($%'7EF5$9A$O--97 5*8 $*'$% I$%L'NO6.'/ $*'$7 G%<'7O-%8<'7<8A$7 S&*66.7*0$.'& L-'0$L8*0$ G%<'7O-%8O%-A77X 5*8 8F$%5-EF$5*7EF$' +9$*EF/$#*EF87<'<9_7$' 6N% *&<9 V_78$5$:

a.% ‘ '8$%7.EF.'/ &$7 VO<98O%-&.L8O$%F<98$'7 7*'& .'8$%7EF*$&9*EF78$ I$%7.EF7%$*F$'J #*$ A: T: ^ZPP2VGJ M[RG2RUJ [PDM W'2UWM\J UTRkVRYJ ^\ZM2TGRJ UF$K.7 RUJ VG[P]J P‘V\GJ V^VZc^Q c\I^kI\PZ[PV -&$%]^VZ^ A.% T$%NEL7*EF8*/.'/ &$% 0*$%B98*/$' P<F5$'K$&*'/.'/$' &.%EF/$6NF%8 #-%&$' k([P ddkJ kc[Z d=k .'& <.EF #$*8$%F*' A.% I$%0-9978B'&*/.'/ &$% 8F$%5-EF$5*7EF$' Y<8$'K<'L$' '-8#$'&*/: bBF%$'& A.% R%$*7$8A.'/ 69NEF8*/$% VO<98O%-&.L8$ <.7 T%$''78BK$' <'/$5$77$'$ Y<8$'K<'L$' $e*78*$%$' .'& &*$7$ <.EF *' &$' V8)%6<99<'<9_7$2Z-&$7 *: ^99/: /.8 K$7EF%*K' #*%& kZM\>@kJ k(M\>@kJ k^YP>@kJ 7*'& &*$ 0$%6N/K<%$' Y<8$' A.5 R%$*7$8A.'/70$%F<98$' #$'*/$% 69NEF8*/$% VO<98O%-&.L8$.'& ($%'5<8$%*<9*$' <.7 $*'$5 A$%78)%8$' ($%' *' &$% 7OB8$' V8)%6<99OF<7$ 78<%L $*'/$7EF%B'L8 k([P dh .'& &*$]-&$99*$%.'/ *' V8)%6<99<'<9_7$2Z-&$7 0$%K77%.'/7#N%&*/ .'& +$/$'78<'& 9<.6$'&$% ^L8*0*8B8$': a.5 G$*9 #*%& F*$% $*'$ $'/$ (-OO9.'/ A#*7EF$' ($%'2 A$%78)%.'/72 .'& VO<98O%-&.L86%$*7$8A.'/75-&99' '-8#$'&*/ #$%&$':

Y$% V8<8.7 &$% ‘57$8A.'/ &$% T$7EF%$*K.'/ &$% V8%.L8.%5<8$%*<96%$*7$8A.'/ *' &*$ Z-&$7J*5 b$7$'89*EF$' ^/J W' .'& Z& &$% ^K7-%K$%78BK$ 7-#*$ V' <.7 &$' a*%L<9-_2 cN99%-F%$' ? &<7 .:<: 6N% &$' G$99.%2G%<'7O-%8 0-' T$&$.8.'/ *78 ? 78$998 7*EF <97 '<F$A. 0$%/9$*EFK<% 5*8 &$5 &$% 7EF#$% 69NEF8*/$' VU &<%J &$'' <.EF F*$% 78%$.$' &*$ \%/$K'*77$ *5 I$%/9$*EF A. \eO$%*5$'8$' A:G: $%F$K9*EF: D*EF8 A.9$8A8 &*$ \%/$K'*77$ &$7 WVU2Im#$*7$' $*'$' 7.K78<'8*99$' \'8#*EL9.'/7K$&<%6 6N% &*$ V8%.L8.% 2 5<8$%*<96%$*7$8A.'/ <.6 kZM\>@k:

W' &$% R-9/$ &$%]-&$99$'8#*EL9.'/$' 6N% &*$ VU2 .'& V8%.L8.%5<8$%*<96%$*7$8A.'/$' .'& //6: '-8#$'&*/$% (-OO9.'/$' 5*8 <'&$%$' VOB8OF<7$'5-&99' 7*'& '-EF $%F$K9*EF$ I<9*&*$%.'/7<L8*0*8B8$' $%6-%&$%9*EF:

6.2.7 Spaltprodukt- und Aerosoltransport

a.% V*5.9<8*-' &$7 VO<98O%-&.L82 .'& ^$%-7-98%<'7O-%87 *5 '.L9$<%$' Y<5O6$%2 A$./.'/77_78$5 7*'& *' &*$ V_78$52Z-&$7 .'& W'8$/%<9E-&$7 .'8$%7EF*$&9*EF$ U%-/%<55$$*'/$K.'&$'C

- ^VG\Z .'& ^GcM\G2ZYC V[Uc^\P[Vk]WV >>kJ
-]\MZ[PC 6N% &<7 ^$%-7-90$%F<98$']\P[V k+\M i3k .'& 6N% &<7 I$%F<98$' &$% VO<98O%-&.L82YB5O6$ &*$]-&$99<'7B8A$ <.7 GP^U2]\MG kf[P i=kJ
- P\M^UkVZY^UC IWZG[PW^ kc\^ d3k:

W5 R-9/$'&$' 7-99$' h$&-EF '.% &*$ */$'7EF<68$' 0-' V[Uc^\P[V &*7L.8*$%8 #$%&$': Y<7 U%-/%<5 5 #.%&$ 0-' GP^U2]\MG <K/9*8$8 .'& #*%& *' R%<'L%$*EF #$*8$%$'8#*EL$98 .'& 0-% ^99$5 <'F<'& &$% UFK.7 2I$%7.EF$ 0<9*&*$%8: Y*$ '$.$ *' ^VG\Z *5O9$5$'8*$%8$ I$%7*-' A$*EF'$8 7*EF &.%EF $*'$ 0-9978B'&*/ NK$%<%K$*8$8$ Y<8$'K<7*7 6N% EF$5*7EF$ P$<L8*-'$' .'& $%F$K9*EF$ I$%K$77$%.'/$' *' &$% D.5$%*L S*5O9*A*8k$eO9*A*8X <.7: ^.,$%&$5 $'8FB98 7*$]-&99 A.% F-5-/$'$' .'& F8%-/$'$' D.L9$<8*-' &$7 Y<5O6$7 7-#*$ A.% 5$EF<'*7EF$' ^$%-7-92P$7.7O$'7*-': Y*$ EF$5*7EF$' P$<L8*-'$' *' &$% +<7OF<7$ #$%&$'J <.7/F'& 0-' &$% *5 ($%' K$78*5 58$' R%$*7$8A.'/ 0-' K*7 A.@I \9$5$'8$'J 5*8 c*96$ $*'$%]<8$%*<9&<8$'K<'L K$%$EF'$8J &*$ NK$% d>> +%.'&$9$5$'8$.'& I$%K*'&.'/$' .56<778: W'7/$7<58 #$%&$' K$*5 VO<98O%-&.L80$%F<98$' *5 U%*5B%L%$*7 '.' 1m0F_7*L<9*7EF$ U%-A77 K$%NEL7*EF8*/8C

- ^$%-7-9O%-A$77$C
  - V$&*5$'8<8*-'
  - M<5*'<%$ Y*66.7*-'
  - G.%K.9$'8$ Y*66.7*-'
  - G.%K.9$'8$ ^K9</$%.'/ S$&&_*5O<E8*-'X
  - a$'8%*6./<9<K7EF$*&.'/ SK$'&*5O<E8*-'X
  - GF$%5-0F-%$7*7
  - Y*66.7*-0F-%$7*7
  -]$EF<'*7EF$ P$7.7O$'7*-'
  - P$9<8*0/$7EF#*'&*/L$*8 &.%EF VEF#$%L%<68 S<$%-7-9 6<992K<ELX
  - ^//9-5$%<8*-' &.%EF]-9$L.9<%K$#$/.'/
  - ^//9-5$%<8*-' &.%EF VEF#$%L%<68
  - ^//9-5$%<8*-' &.%EF G.%K.9$'A:

- U%-A77 &$% /<76)%5*/$' \9$5$'8$.'& I$%K*'&.'/$'
  - c-5-/$'$D.L9$<8*-'
  - c8%-/$'$D.L9$<8*-'

- (-'&$'7<8*-' <' &$% b<'& .'& <' U<%8*L$9'
- V-%K8*-' <' &$% b<'&:

Y*$ '$.$ V[Uc\P'V2I$%7*-' #.%&$ <.EF *' ^GcM\G2ZY *5O9$5$'8*$%8J h$&-EF <K#$*EF$'& 0-' &$% Y<8$'K<'L78%.L8.% 0-' ^VG\Z 5*8 $*'$5 &*%$L8$' Y<8$'<.78<.7EF A#*7EF$' &$' $'87O%$EF$'&$']-&.9$' NK$% *'8$%'$ VEF'*8878$99$': *'*/$ ^%K$*87O.'L8$ L-''8$' '-EF '*EF8 <K7EF9*$,$'& K$<%K$*8$8 #$%&$' S^.7#*%L.'/ &$7 [e*&<8*-'7O-8$'A*<97 &$7 G%B/$%69.*&7 <.6 &*$ EF$5*7EF$' P$<L8*-'$'Q PNEL#*%L.'/ &$% D<EFA$%6<9979$*78.'/ 7.7O$'&*$%8$% .'& <K/$9</$%8$% VO<98O%-&.L8$ <.6 &*$ R9.*&8$5O$%<8.%X:

6.2.8 Zusammenfassung und notwendige Weiterentwicklung der Arbeiten zur „Simulation der Vorgänge im Reaktordruckbehälter mit Kernzerstörung“

bBF%$'& &*$ 6%NF$ UF<7$ &$% ($%'A$%78)%.'/ /.8 0$%78<'&$' *78 .'& $'87O%$EF$'&$]-&99*' &$' V8)%6<99<'<9_7$2Z-&$7 #$*8/F'&*5O9$5$'8*$%8 7*'&J 7*'& &*$ 7OB8$%$' UF<7$' OFB'-5$'-9-/*7EF A#<% /%.'&7B8A9*EF 0$%78<'&$'J $7 6$F9$' h$&-EF /%-,$'8$*97 K$9<78K<%$ Y<8$' .'& 0<9*&*$%8$]-&99: D-8#$'&*/$ b$*8$%$'8#*EL9.'/$' 7*'& &$7F<9K 0-% ^99$5 6N% &*$]-&99 &$% 7OB8$' V8)%6<99OF<7$ $%6-%&$%9*EF: Y<K$**78 A. K$%NEL7*EF8*/$'J &<77 <.6/%.'& &$% F-F$' (-5O9$e*8B8 &$% U%-A$77$.'& &$% ^K9<.67A$'<%*$' &*$ \'8#*EL9.'/ &$7 ($''8'*778<'&$7 A.% ($%'A$%78)%.'/ .'8$% &$' T$&*'/.'/$' $*'$7 7EF#$%$' ''6<997 <97 $*' $0-9.8*-'B%$% U%-A$77 0$%78<'&$' #$%&$' 5.77: Y*$ V*EF$%F$*8778<'&<%&7 F<K$' 7*EF &.%EF I$%K77%.'/$' &$% D-86<992 5<,'<F5$' KA#: &$7 ^EE*&$'8]<'</$5$'87J <.EF /$78N8A8 <.6 &*$ A.0-% K$7EF%*$K$'$' ^L8*0*B8$' A.% V*5.9<8*-' 7EF#$%$% ''6B99$J K$%$*87 7EF-'*' &$' K$*&$' 9$8A8$' f<F%A$F'8$' 7*/'*6*L<'8 $%F)F8: ''7*EF$%F$*8$' K$* &$' T$#$%8.'/7O%-A77' 0-' ''6<99<K9B.6$' A$*/$' <K$% <.EF $*'$' #$*8$%$' R-%7EF.'/7K$&<%6 <.6J #-&.%EF A. $%#<%8$' *78J &<77 &<7 P*7*L- &$7 T$8%*$K7 L$%'8$EF'*7EF$% ^'9</$' <97 \%/$K'*7 &*7% ^'78%$'/.'/$' <.EF LN'68*/ '-EF #$*8$% %$&.A*$%8 #$%&$' L<'':

Einleitungsphase

*' I$%/9$*EF 0$%7EF*$&$'$% P$EF'.'/$' A.5 ''6<99*' G]W23 F<8 /A*/8J &<77 &*7 UF<7$ 5*8 <.7%$*EF$'&$% HK$%$*'78*55.'/ 5*8 &$' *' &$% ^'9</$ /$5$77$'$' Y<8$'

.'& &$% /$7EFB8A8$' b<77$%78-662\%A$./.'/ /$%EF'8 #$%&$' L<'': b$*8$%$ \'8#*EL9.'/7<%K$*8$' K$7EF%B'L$' 7*EF <.6 &*$ $'87O%$EF$'&$ *'K*'&.'/ 0-' 0$%K$77$%8$']-&99' &$% T$782\78*5<8$2Z-&$7:

Kernschädigung

+$'$%$99 #*%& &*$ 6%NF$ ($%'7EF5$9AOF<7$ /.8 '<EF/$K*9&$8J h$&-EF '.% <.6 (-5O-'$'8$'$K$'$J #*$A: T: T%$''78<KJ ^K7-%K$%78<KJ T%$''$9$5$'8L<78$': (-5O-2 '$'8$'NK$%/%$*6$'&$]-&99 6N% &*$ b$EF7$9#*%L.'/ A#*7EF$' ^K7-%K$%5<8$%*<9*$' .'& &$' T%$''78BK$' 7*'& #$/$' &$% \.8$L8*L< 5*8 '*$&%*/$' VEF5$9A8$5O$%<8.%$' .'& &<5*8 6%NFA$*8*/$% VEF5$9AK*9&.'/ 0-' T$&$.8.'/ .'& &$7F<9K #$*8$% A. $'8#*EL$9':

T$*5 R9.8$' $*'$7 G$*9A$%78)%8$' ($%'$7 #*%& &$%A$*8 &*$ Y<8$'K<7*7 0$%O-9978B'&*/8: Y*$ /$L-OO$98$' Z-&$7 ^GcM\G2ZYJ WZ^P\kZ^Gc^P\J VZY^UkP\M^U 7*'& F*$% <.6/%.'& *F%$% I<9*&*$%.'/7K<'&K%$*8$ <.7 &$' ^.79$/.'/778)%6B99$' *5 I-%8$*9: [K$%F<9K $*'$% 5<e*5<9$' ($%'8$5O$%<8.% 0-' 3@>> (0-% &$5 R9.8$' 7*'& h$&-EF &*$ ''7*EF$%F$*8$' <.6/%.'& .'K$L<''8$% T9-EL<&$78%.L8.%$' .'& [K$%69BEF$'$66$L8$' 7-/%-,J &<77 &*7% I-%8$*9 0$%7EF#*'&$8: Y*$ b<77$%78-666%$*7$8A.'/ #*%& FB.6*/ /$/$'NK$% &$' eO%*5$'8$99$' b$%8$' .'8$%7EFB8A8J #<7 <.6 $*' '-EF 0-%F<'&$'$7 Y$6*A*8 *' &$% ($''8'*7 &$7 A. +%.'&$ 9*$/$'&$']$EF<'*75.7 &$.8$8 .'& &$' T$&<%6 '-8#$'&*/$% b$*8$%$'8#*EL9.'/ $%L$''$' 9B778:

b$/$' &$% $%F)F8$' R%$*7$8A.'/ %<&*-<L8*0$% V8-66$ K$* ''6B99$' 5*8 M.68$*'K%.EF .'& &$% '-EF /$%*'/$' eO%*5$'8$99$' \%6<F%.'/ 6N% 7-9EF$ ''6<99<K9B.6$ *78 <.EF F*$% &*$ b$*8$%$'8#*EL9.'/ &$%]-&99 A.% cN99%-F%-e*&<8*-' &%*'/$'& /$K-8$':

Kernzerstörung

W' &$' (<O*8$9' A.% ($%'A$%78)%.'/ SVOB8OF<7$' &$7 ($%'7EF5$9A$'7 .'& &$7 ($%'0$%7</$'7X .'& A.5 VEF5$9A0%F<98$' *5 'U &$7 PYT #.%&$' &*$ A$'8%<9$' V*EF$%F$*876%</$' .'& &*$ &<%<.6 K$A-/$'$ V8%<8$/*$ &$%]-&$99$'8#*EL9.'/ .'& &$% V8<'& &<%/$78$998:

a*$9 &$%]-&$99*$%.'/778%<8$/*$ *78 $7 <99/$5$*'J K$9<78K<%$ ^.77</$6BF*/L$*8 6N% &*$ V*EF$%F$*876%</$' A. $%%$*EF$' .'& $*'$' &<6N% <&Bp<8$' Y$8<*99 *$%.'/7/%<& 5*8 $'87O%$EF$'&$' VEF#$%O.'L7$8A.'/$' A. K$78*55$': ^.7 &$' V*EF$%F$*87A*9' 0-' (NF9K<%L$*8 .'& PNELF<98.'/ #.%&$' T$8-'.'/$' <K/9*8$8J &*$ <.EF 6N% &*$ '-8#$'&*/$ b$*8$%$'8#*EL9.'/ &$7 V_78$52Z-&$7 ^GcM\G2ZY /98'C

- VEF5$9A$2^LL.5.9<8*-'*5 ($%' .'& ^.769*$,0$%F<98$'J
- T*9&.'/ LNF9K<%$% VEFN88.'/$' *5 'UJ
- \'8#*EL9.'/ A.5 VEF5$9A$7$$ <.7 (-'6*/.%<8*-'$' *5 'U 5*8 (-'7$p$'A$' &$% I-%/$7EF*EF8$ 6N% $*' PYT2I$%7</$':

Y<%<.7 .'& <.7 &$' K$78*55$'&$' OF_7*L<9*7EF$' U%-A$77$' %$7.98*$%$' 7O$A*6*7EF$ T$8-'.'/$' *' &$']-&$99$' .'&*F%$% (-OO9.'/C

- ^KFB'/*/L$*8$' &$% <e*<9$' .'& %<&*<9$' I$%9</$%.'/7O%-A$77$ *5 ($%' 0-' (NF9$*'69N77$'J 7O$A*6*7EF$' *'K<.8$' .'& \66$L8$' &$%]-&$99*$%.'/ &$7 VEF5$9A$'7 .'& \%78<%%$'7 SA:T: 8F$%5*7EF$7 D*EF8/9$*EF/$#*EF8J VEF5$9A$2 OF<7$'X 7-#*$ &$7 VEF5$9A$69.77$7 SP$*K.'/ *' O-%)7$% V8%.L8.% &$7 0$%7</$'&$' ($%'7XJ
- PNELL-OO9.'/ &$% V8%<F96%</5$'8*$%.'/ *5 'U 5*8 '5/$K.'/7K$&*'/.'/$'J *'7K$7-'&$%$ &$5 Y<5O6/$F<98 &$%]*7EF.'/J
- T$&$.8.'/ &$7 P$*K.'/75-&$997 <KFB'/*/ 0-5 V8%)5.'/75.78$% 6N% &*$ L-%%$L8$ \%6<77.'/ &$7 Y<5O6/$F<987 *' &$%]*7EF.'/ .'& &$%$' ^.7#*%L.'/ <.6 &*$ T*9&.'/ LNF9K<%$% VEFN88.'/$' SR%</5$'8<8*-'.'& ^KLNF9.'/XJ
- T$&$.8.'/ &$7 P$*K.'/75-&$997 .'& 0-' 3Y2V8%)5.'/$' &$7 b<77$%7 6N% &*$ (NF9K<%L$*8 0-' VEFN88.'/$' KA#:O-%)7$' V8%.L8.%$'J
- V8.6$' &$% (NF9K<%L$*8 *' &$% \'8#*EL9.'/ A.5 VEF5$9A$7$$ *5 'U SY<5O62 LNF9.'/J T*9&.'/ O<%8*$99 LNF9K<%$% VEF5$9A$7$$'XJ
- ^.6F$*A/$7EF*EF8$ &$7 PYT*' ^'K*'&.'/ <' &*$7$ \'8#*EL9.'/:

\7 #.%&$ &<%/$78$998J &<77 7*EF &*$]-&$99*$%.'/ 6N% ^GcM\G2ZY $'89<'/ &*$7$% T$8-'.'/$' K$#$/8: Y$% V8<'& &$% \'8#*EL9.'/ 9B778 7*EF A.5 $*'$' &.%EF &$' $%6-9/8$' *'K<. &$7]\b^2]-&$997 6N% &$' ($%' *' ^GcM\G2ZY EF<%<L8$%*7*$%$': Y*$7 K$*'F<98$8 &*$ \'8#*EL9.'/ &$7 VEF5$9A$'7 .'& &$% VEF5$9A$7$$K*9&.'/ *' &$%

‘ 5 / $K . ’ / . ’ & K$*5 a . 78%- 5 0- ’ b <77$%J &: F: <. EF &*$]) / 9*EFL$*8 G] W2<%8*/$
VA$’<%*$’ A. K$%$EF’$’: a . 5 <’&$%$’ 9*$/8 5*8 &$’ (\ VV2] -&$99$’ W (\ f \ GkW (\ ] Wx
7-#*$ &$% P$<9*7*$%. ’ / &$7 b ^ T \ 2] -&$997 6N% &*$ VEFN88. ’ / *’ W (\ ] Wx$*’$ $%78$
I \ Z [2 I $%7*-’ 6N% &<7 . ’ 8$%$ U9$’. 5 0-%J 5*8 &$% &*$ V8%<F96%</ 5$’8<8*-’ . ’ &
VEFN88K$882T*9&. ’ / 7-#*$ &*$ (NF9K<%L$*8 &$% VEFN88. ’ / $’ K$%EF’K<% *78:] *8 &$%
’-EF *’ &$% \ ’ 8#*EL9. ’ / K$6*’&9*EF$’ (-OO9. ’ / A.] \ V [Z [9<77$’ 7*EF &*$ a . 78B’&$
K*7 A.% VEF5$9A$7$$2T*9&. ’ / *5 . ’ 8$%$’ U9$’. 5 #$*8$%0$%6-9 / $’: Y*$7 *78 5*8 7$O<%<8$%
^ ’ #$’&. ’ / 0- ’] \ b ^ K$%$*87 5) / 9*EF:

Y*$ ’-8#$’&*/$ b$*8$%$’8#*EL9. ’ / K$8%*668 0-% <99$5 &*$ 0-9978B’&*/$ (-OO9. ’ / &$%
I \ Z [2] -&99 . ’ & &*$ \ *’K*’&. ’ / *’ ^GcM \ G2ZY 7-#*$ HK$%O%N6. ’ / $’ . ’ &
HK$%<%K$*8. ’ / $’ &$%] -&99J *’7K$7-’&$%$ F*’7*EF89*EF &$% / $’<’’8$’ VEF#$%O. ’ L8$:
Y*$7 5 . 77 *’ a . 7<5 5 $’F<’ / 5*8 &$% I<9*&*$%. ’ / 7-#-F9 K$AN / 9*EF 7O$A*6*7EF$%
] -&$99O. ’ L8$ SY<5O6 / $F<98 *’ &$%] *7EF. ’ / J PNELL-OO9. ’ / A.% V8%<F96%</ 5$’8<8*-’ X
<97 <. EF $*’$% *’8$ / %<9$’ I<9*&*$%. ’ / / $7EF$F$’: W5 I-%&$% / %. ’ & 78F’ K$* &$%
’8$ / %<9$’ I<9*&*$%. ’ / ’K’ G] W #$*8$%F’ &*$ UF$K. 72 \ eO$%*5$’8$ kZM \ >@<kJ &*$
.: <: *5 V \ P \ D^2 (-’8$e8 #*$&$% <. 6 / $’-55$’$’ ‘ ’8$%7. EF. ’ / $’ A. R^P [2
\ eO$%*5$’8$’ k] ^ + ddk 7-#*$ &*$ 0-% / 7F$’$’ MW I \ 2 \ eO$%*5$’8$ k \ UU >3k:

Y*$ 0$% / 9$*EF$’&$’ ^%K$*8$’ . ’ & ^K78*55. ’ / $’ A.% V8%<8$ / *$ &$% Z-&$2 \ ’8#*EL9. ’ / J
#$9EF$ *5 P<F5$’ &$7 \ ‘ 2D$8A#$%L$7 V^PD \ G $%6-9 / $’ 7-99$’J K*9&$’ A. &$5 $*’$
#7’89*EF$ T<7*7 A.% (9B%. ’ / . ’ & ^K7*EF$%. ’ / J / 9$*EFA$*8*/ A. 5 \ *’K%*’ / $’ &$%
$*/$’$’ \ ’8#*EL9. ’ / 778%<8$ / *$’ . ’ & T$8-’. ’ / $’ *’ &$’ \ ‘ 2 (-’8$e8: VEF9*$, 9*EF K*9&$’
&*$ ^ ’K*’&. ’ / <’ &*$ PYT2b<’& . ’ & &<5*8 &*$ T$78*55. ’ / 5) / 9*EF$%
I$%7</$’7<%8$’ &$7 PYT $*’$’ VEF#$%O. ’ L8 &$% b$*8$%$’8#*EL9. ’ / S7*$F$ (<O*8$9
!P$<L8-%&%. ELK$FB98$% K$* ($%’7EF5$9A$’;X: Y<%<. 7 $% / *K8 7*EF &*$ R%$*7$8A. ’ / 0-’
VEF5$9A$ *’ &$’ V*EF$%F$*87K$FB98$% . ’ & &<5*8 &*$ VEF’*8878$99$ 6N% VEF5$9A$A. 78B’&$
. ’ & VEF5$9A$0$%F<98$’ *5 V*EF$%F$*87K$FB98$%:

Freisetzung und Transport von Spaltprodukten und Aerosolen

Y*$ VO<98O%-&. L8$ *5 U%*5B%L%$*79<. 6 78$99$’ &$’ O-8$’8*$99$’ O%*5B%$’ %<&*-<L8*0$’
o998%5 6N% &$’ V*EF$%F$*87K$FB98$% ? &$% &. %EF &*$ VO<98O%-&. L82] $’ / $J &$’
R%$*7$8A. ’ / 7A$*8%<. 5J &*$ EF$5*7EF$ VO$A*$7 . ’ & &$%$’ OF_7*L<9*7EF$ R-%5
K$7EF%*$K$’ #*%& ? &<%: Y*$ L-%%$L8$ V*5 . 9<8*-’ &$% R%$*7$8A. ’ / *78 7-5*8 ’-8#$’&*/J
. 5 6N% #$*8$%$ o998%5<’<9_7$’ *5 V*EF$%F$*87K$FB98$% $’87O%$EF$’& <K / $7*EF$%8$

^'6<'/7K$&*'/.'/$' A. /<%<'8*$%$': T$* ''8$%7.EF.'/$' *5 P<F5$' 0-' \'PV^R\ S\.%-O$<' eO%8 '$8#-%L 6-% 8F$ %$&.E8*-' -6 .'E$%8<*'8*$7 *' 7$0$%$ <EE*&$'8 7<6$8_ *77.$7X k]^+>=k #.%&$ &*$ 7*EF$%F$*878$EF'*7EF$ P$9$0<'A &*7% U%-A77 F$%0-%/$F-K$':

Y*$ &$%A$*8 K78F$'&$' 78B%L78$' Y$6*A*8$.'& 7-5*8 <.EF &*$ '-8#$'&*/$' b$*8$%$'8#*EL9.'/$' 6-L.77*$%$' 7*EF <.6 &*$ R%$*7$8A.'/ *' &$% 7OB8$' W'2I$77$92 UF<7$.'& F*$% <.6 &*$ R%$*7$8A.'/ 5*88$969NEF8*/$% .'& *'7K$7-'&$%$ 7EF#$%69NEF8*/$% VO<98O%-&.L8$J <K$% <.EF <.6 7O$A*$99$ R%</$78$99.'/$' #*$ A: T: P.8F$'*.52G%<'7O-%8 .'& 2EF$5*$J 7-#*$ <.6 &*$ R%$*7$8A.'/ 0-' V8%.L8.%5<8$%*<9*$': b$*8$%/F'&$ ''8$%7.EF.'/$' 5*8 T$%NEL7*EF8*/.'/ &$% P<&*-'.L9*&EF$5*$ 0$%&$.89*EF$' &$%$' *'69.77 <.6 &<7 R%$*7$8A.'/70$%F<98$' .'& &*$ D-8#$'&*/L$*8J &*$7$7 *' &$' Z-&$7 <.EF A. 5-&$99*$%$':

V-*78 /$%<&$ <.EF 6N% Z-&$7 #*$ ^GcM\G2ZY &*$ \'8#*EL9.'/ $*'$7]-&$997 A.% T$7EF%$*K.'/ &$% VO<98O%-&.L82R%$*7$8A.'/ <.7 ($%'7EF5$9A$O--97 K<7*$%$'& <.6 G--97 #*$ &$5 Z-&$ P\M[VJ &<7 &*$ L-5O9e GF$%5-EF$5*$ *' &$% VEF5$9A$.'& +<7OF<7$ 6N% *&<9 V_78$5$ K$%NEL7*EF8*/8J A.% ^'<9_7$ &$% 7OB8$' ''6<99OF<7$ '-8#$'&*/: Y<K$* 7-998$' <.7/$F$'& 0-' &$' K*7F$% *: b: K$8%<EF8$8$' *&<9' V_78$5$' A.'$F5$'& <.EF %<9 V_78$5$ 8%-8A &$% $%F$K9*EF <'78$*/$'&$' (-5O9$e*8B8 K$8%<EF8$8 #$%&$':

^.EF &$% G%<'7O-%8 &$% VO<98O%-&.L8$ *5 U%*5B%L%$*79<.6 *78 6N% &*$ T$78*55./ &$7 %<&*-<L8*0$' o$998$%57 6N% &$' V*EF$%F$*87K$FB98$% .'& 6N% &*$ '5/$K.'/J *5 R<99 $*'$7 T_O<77$7 &$7 V*EF$%F$*87K$FB98$%7 &.%EF $*'$' R%$*7$8A.'/7O6<& NK$% &*$ Y<5O6$%A$./$%J 5<,/$K9*EF: Y<K$* *78 '$K$' &$' PNELF<98$O%-A$77$' 0-% ^99$5 &*$ EF$5*7EF$ a.7<55$'7$8A.'/ &$% ^$%-7-9$ 0-' A$'8%<9$% T$&$.8.'/: Y<77 F*$% <.EF *'8$%'<8*-'<9 $*' /%-,$7 W'8$%$77$ K78F8J &*$ K78F$'&$' ''7*EF$%F$*8$' <KA.K<.$'J #*%& &.%EF A<F9%$*EF$ eO%*5$'8$99$ U%-/%<55$.'8$%78%*EF$':

W5 $.%-OB*7EF$' P<F5$' #*%& A.% V*5.9<8*-' &$7 VO<98O%-&.L82 .'& ^$%-7-98%<'7O-%87 *: ^99/: &<7 U%-/%<55 V[Uc^\P[V <'/$#$'&$8 .'& #$*8$%$'8#*EL$98: Y*$ 5*88$96%*78*/$ b$*8$%$'8#*EL9.'/ 0-' V[Uc^\P[V .56<778 6-9/$'&$ ^%K$*87O.'L8$ kf^Z>lkC

- [O8*5*$%.'/ &$7M)7.'/70$%6<F%$'7&.%EF ‘57%.L8.%*$%.'/ &$% f<E-K*2]<8%*eJ
- \%#$*8$%.'/ &$7 ^'#$'&.'/7K$%$*EF7 K$AN/9*EF &$% V8%)5.'/7#$/$ 6N% /$7EF9-77$'$ VEF9$*6$'J U<%<99$9L<'B9$.'& V8%)5.'/7.5L$F%J
- \%#$*8$%.'/ &$% *'7O$*7.'/ 0-' VO<98O%-&.L8$' .'& ^$%-7-9$' 0-' $*'$5 <.6 5$F%$%$ I-9.5$'J
- \%#$*8$%.'/ &$7 ZF$5*$5-&$997 &.%EF T$/%$'A.'/ &$7 EF$5*7EF$' +9$*EF/$#*EF87 K$* '*$&%*/$%$' G$5O$%<8.%$'J
- \%#$*8$%.'/ &$7 ZF$5*$5-&$997 &.%EF P$<L8*-'$' A#*7EF$' &$% +<7OF<7$.'& (-'&$'7<8<.6 7.7O$'&*$%8$' .'& <K/$9</$%8$' ^$%-7-9$':

MB'/$%6%*78*/ #$%&$'J <.EF <.6 &$' I$%7.EF7$%/$K'*77$' A. ^PGWVG k+‘\>Ik <.6K<.$'&J]-&$99$ A.% PNELF<98.'/ <.6 &$% V$L.'&B%7$*8$ &$% Y<5O6$%A$./$% $'8#*EL$98:

Schlussbemerkung

\%/B'A$'& A.% '-8#$'&*/$' b$*8$%$'8#*EL9.'/ &$% Z-&$7 7-998$' .:<: <.EF 5*8 T9*EL <.6 &$' (-5O$8$'A$%F<98 .'& &*$ A.'$F5$'& K%$*8$%$ V8%$..'/ &$% ^'#$'&$%J $%F$K9*EF$ ^'78%$'/.'/$' *' $*'$ I$%K$77$%.'/ &$%]-&$992 .'& Z-&$&-L.5$'8<8*-' .'& $*'$*'8$'7*0$J <.EF $e8$%'$.'& &<5*8 .'<KFB'/*/$ I<9*&*$%.'/ .'& W'8$%O%$8<8*-' &$%]-&99 69*$,$':

6.2.9 Literatur zum Forschungsbereich Stör/Unfallanalyse Kühlkreislauf mit und ohne Kernschäden

k^YP >@k T: ^&%-/.$% $8 <9: V_'8F$7*7 -' O9<'8 E<9E.9<8*-'7 SY@=XJ
R*'<9 Z [M [VV %$O-%8C U<%8 3J WPVDkYPVkV\ ] ^P >@k@>J
V^]2Z [M [VV2U>i>J f.'$ 3>>@

k^G(>Ik (: ^8L$' .'& +: T$%8F-.&C \eO$%*5$'8<9 <'& D.5$%*E<9 W'0$78*/<8*-'7
-' Y$K%*7 T$& Z--9<K*9*8_*' < @Y c-5-/$'$-.7 Z-'6*/.%<8*-': VO$E*<9
W77.$ -' Z-%$] $98 ^EE*&$'87*' M b P7C V8<8$ -6 8F$ ^%8 -6 Z--9<K*9*8_ -6
U-%-.7 Y$K%*7J D.E9$<% \'/*'$$%*'/ <'& Y$7*/'J 8- K$ O.K9*7F$&

k^‘] >3k Y: M: ^.5*99$%J \: G: G-59*'7-'J b: M: b<0%C ^' *'8$/%<8$& P\M^U=2
@Y <'& 5.98*OF<7$ ZRY E-&$ 7_78$5 .8*9*A*'/ <7$5*2*5O9*E*8 E-.O9*'/
8$EF'*p$: D.E9$<% \'/*'$$%*'/ <'& Y$7*/' 31n8>>3Xn 2in

kT\P >3k Y: T$%<F< $8 <9J ^GM^V 3>>>C \%#$*8$%8$ R.'L8*-'<9*8B8 6N%
P$<L8-%7*EF$%F$*87<'<9_7$' 5*8 5-&$%'$% V*5.9<8*-'78$EF'-9-/*$J
^K7EF9.77K$%*EF8J +PV2^2@>i@J 3>>3

kT\P >@k G: 0: T$%9$O7EFJ]:U: (*77<'$J W: (9$*'F*$8O<,J b: U9.5$E-Epp
D: P$*'L$J]:(: (-EF: M<8$2UF<7$ V-.%E$2G$%5 UF$'-5$'<C ^'<9_7*7
-6 \eO$%*5$'87J WPVDJ D-8$ G$EF'*p$ V\ ] ^P >@ k3dJ V^]2MUU2Y@>J
R$K%.<%_ 3>>@

kT\P >@<k G: 0: T$%9$O7EFJ]:U: (*77<'$J W: (9$*'F*$8O<,J b: U9.5$E-Epp
D: P$*'L$J]:(: (-EFJ c: ‘ '/$%J c:2f: b</'$%: M<8$ UF<7$ V-.%E$
G$%5 UF$'-5$'<?]-&$9 Y$0$9-O5$'8 R*'<9 P$O-%8 2J
P.F%2‘ '*0$%7*8B8 T-EF.5J M$F%78.F9 6N% \'$%/*$7_78$5$.'&
\'$%/*$#*%87EF<68 SM\\XJ M\\2@J V^]2MUU2Y3dJ]<%EF 3>>@

kT\V >3k Y: T$78*-' $8 <9J V8<8$2-628F$ ^%8 <'& M*5*8<8*-'7 -6 U%7'8 D.E9$<%
GF$%5<92c_&%<.9*E Z-&$7 <'&]-&$97J \‘ P [R^VGD\GJ 3>>3

kT\V >Ik Y: T$78*-'J U: Z-78$J Y: f<5$8J Z:]-%$9J +: V$%%$J]: I<9$88$J $8 <9:J
D\UG‘D\ UF_7*E<9]-&$99*'/C GF$ PY \66-%8 6%-5 YDV 8- V_78$5
^OO%-<EF$7: Z^Gc^P\2D\UG‘D\ V$5*'<%J]<_ 1>213J 3>>I:
+%$'-K9$J R%<'E$

kT [D d=k f:]: T-''$8C ^' W'8$/%<9]-&$9 6-%8F$ Z<9E.9<8*-' -6 c$<8 R9.e
Y*78%*K.8*-'*' < U--9 #*8F W'8$%'<9 c$<8 +$'$%<8*-': U%-E: D‘P\Gc2n
V<%<8-/<J ‘V^J V$O8$5K$% 1dd=

kTP [dlm ‘ : T%-EL5$*$%: V0%$ E-%$ &<5</$ 5-&$99*’/ *’ 8F$ E-&$7
^GcM\GkZYJWZ^P\3J]\MZ[P <’& VZY^UkP\M^U=J ^ 78<8$2-628F$2
<%8 %$O-%8J \.%-O$<’ Z-5 5*77*-’J \ ‘ P 1dd@nY\k\DJ 1ddm

kT‘\ >1k]:TN%/$%J]:T.ELJ b:VEF5*&8J +:U-F9’$% .’& b: b*&5<’’C ^.7K<.
.’& I$%*6*L<8*-’ &$% VOB8OF<7$’5-&$99$.’& &$7 +$7<585-&$997 A.5
($%’7EF5$9A$’ *’ (\VV .’& ^GcM\G2ZY: ^K7EF9.,K$%*EF8 A.5
I-%F<K$’ T]TR 1=> 1>ddW(\3 21I=J]<*3>>1

kT‘\ >@k]:TN%/$%C G<7L3?Z-5O<%*7-’ -6 I<%*-.7 ^OO%-<EF$7 6-% Z<9E.9<8*’/
f$8 T%$<L2.O <’& U%$5*e*’/: ^%K$*87O<O*$%J V\P\D^

kT‘\ >Ik]:TN%/$% $8 <9:C VEF5$9A0%9</$%.’/ .’& (NF9K<%L$*8*’ 7OB8$’
($%’7EF5$9AOF<7$’*5 PYTC I$%0-9978B’&*/.’/ &$%]-&$99$J
I$%*6*L<8*-’ .’& *’K<.*’ ^GcM\G2ZY: : ^K7EF9.,K$%*EF8 A.5
I-%F<K$’ T]TR 1=> 133hW(\3 21=3J YA5K$% 3>>I

kZc‘ ddk ZF.JG:j:JU*9EFJ]:]:JT$’8AJ f:c:JM.&#*/7$’J f:V:JM.J b:j:J
c.5OF%*$7JM:M:S1dddXC ;M-#$% c$<& R<*9.%$ \eO$%*5$’87 <’&
^’<9_7$7;J P$O-%8J D‘P\+kZP2==i3JV^DYdi23>lhV<’&*< D<8*-’<9
M<K-%<8-%*$7J ^9K.p$%p$JD]J ‘V^

kZM\ >@k T: Z9$5$’8J G: c<78$: Z-5O<%*7-’ P$O-%8 -’ W’8$%’<8*-’<9 V8<’&<%&
U%-K9$5 WVU2lnSUF$K.7 RUG1XJ WPVDJ D-8 GEF’*p$ V\]^P
3>>@k31 &%<68 @JV^]2Gc\DUc\TWVU2Y>>= &%<68 @J f.’$ 3>>@

kZM\ >@<k Z9$5$’8J T: ’: c<’’*$82+*%<.98J +: P$O$88-J Y: f<Ep$5<*’J
^: I: f-’$7J]:U: (*77<’$J U: 0-’ &$% c<%&8J 3>>@J M b P 7$0$%$
<EE*&$’8 7*5.9<8*-’C 7_’8F$7*7 -6 %$7.987 <’& *’8$%O%$8<8*-’ -6 8F$ 6*%78
UF$K.7 RU eO%*5$’8 RUG>J D.E9$<% \’/*’$$%*’/ <’& Y$7*/’ 33m

kY [P >Ik W: Y-%JGF$ Z^Gc^P\ I3:= @Y]-&.9$Q Y$7E%*O8*-’ <’& I<9*&<8*-’:
Z^Gc^P\2D\UG‘D\V$5*’<%J]<_ 1>213J 3>>I: +%$’-K9$J R%<’E$

k\UU >3k T: \OO*’/$%J b: G%-55 .’& G: b$’AC GF$%5*7EF$% ^’/%*66 &.%EF
($%’7EF5$9A$.’& &$%$’ 9<’/6%*78*/$ (NF9.’/ k VOB8$7 W’2 I$77$92
I$%F<98$’: U%-h$L8 D.L9$<%$ V*EF$%F$*876-%7EF.’/J f<F%$7K$%*EF8 3>>3J
Ra(

kRWZ >1k R: R*EF-8J U: ZF<8$9<%&J]:T<%%<EF*’J I: +.*99<%&J V:]$9*7 .’&
]:a<K*$/-C WZ^P\kZ^Gc^P\ ^ Z-5O.8$% Z-&$ R-% ^’<9_7*7 -6
V0%$ ^EE*&$’87*’ M b P7C Y$7E%*O8*-’ -6 UF_7*E<9]-&$97: D-8$
G$EF’*p$ V\]^P >>k>@J WUVDkYPVkV\]^PJ 3>>1

kRWZ >lk R: R*EF-8J R: Y.0<9 J D: G%/-.%7J Z: TEF<.& .'&]:o*'8<%&C
GF$W5O<E8 -6 GF$%5<9 D-'2\p*9*K%*.5 <'& M<%/$ 2VE<9$ 3Yk@Y \66$E87
-' Y$K%*7 T$& P$69--&*'/ <'& Z--9<K*9*8_: VO$E*<9W77.$ -' Z-%$]$98
^EE*&$'87*' M b P7C V8<8$ -6 8F$ ^%8 -6 Z--9<K*9*8_ -6 U-%-.7 Y$K%*7J
D.E9$<% \'/*'$$%*'/ <'& Y$7*/'J 8- K$ O.K9*7F$&

kRWZ >l<k R: R*EF-8 $8 <9J V8<8.7 P$O-%8 -' U%-/%$77 5<&$*' 8F$ M<78 R*68$$'
j$<%7 8F%-./F ^'<9_7$7 -6 8F$ G]W23 ^EE*&$'8 O$%6-%5$&*']$5K$%
Z-.'8%*$7J [\ZYkZVDWk+^]^ Y%<68 I$%7*-' 3>>l

k+\M i3k R: +$9K<%&J]^\P[V '7$%]<'.<9J V^DYi>2>i33J D'P\+kZP21@d1
SYE5K$% 1di3X

k+P^ >1k ':+%<6J U:U<O<&*5*8%*-.J U:P-578$8&8J]:VEF$.$%$%J b$*8$%$'8#*EL9.'/
&$% 3Yk@Y2]-&.9$ 6N% ^GcM\GJ +PV2^23d33J 3>>1

k+P^ >@k ':+%<6J U:P-578$&8J ^VG^P T$'EF5<%L V-9.8*-'7 #*8F 8F$ *FLU*T [x
Z-&$J W'8$%'<8*-'<9 ^VG^P b-%L7F-O -' ^&0<'E$& D.5$%*E<9
]$8F-&76-%].98*&*5$'7*-'<9 V*5.9<8*-' -6 G#-2OF<7$ R9-#J
+PV +<%EF*'/J 3>>@

k+P^ dik ':+%<6J W5O9*E*8 Z-.O9*'/ -6 R9.*&2Y_'<5*E V_78$57C ^OO9*E<8*-' 8-
].98*&*5$'7*-'<9 Z-.'8$%E.%%$'8 G#-2UF<7$ R9-# -6 b<8$%<'& V8$<5J
D.E9$<% VE*$'E$<'& \'/*'$$%*'/J 13dJ @>=2@1>J 1ddi

k+P\ ddk +%K%J]N99$%J V*$0$%7J 1dddJ b$*8$%$'8#*EL9.'/ &$% ^'<9_7$8$EF'*L
.'& /$'$%*7EF$ ^'<9_7$' A.5 (-5O-'$'8$' I$%F<98$'*5 I$%K.'&6N%
<.79$/.'/7NK$%7EF%$*8$'&$ V8)%6B99$J ^K7EF9.77K$%*EF8 +PV2^23m

k+P' d=k ':+%.'&5<''J Y:M.E<7J ':P-F&$J Z-.O9*'/ -6 8F$ GF$%5<92c_&%<.9*E
Z-&$ ^GcM\G #*8F 8F$ D$.8%-' (*'$8*E Z-%$]-&$9 YjD@YJ
W'8$%'<8*-'<9 Z-'6$%$'E$ -']<8F$5<8*E7 <'& Z-5O.8<8*-'7J P$<E8-%
UF_7*E7J <'& \'0*%-'5$'8<9 ^'<9_7$7J U-%89<'&J 'V^J 1dd=J
U%-E$$&*'/7 O: 3=n

k+'\ >lk +N'8<_J V:J Y: V.EL-#J ^: Y$FK*<'& P: (<O.99<J 3>>lJ ^PGWVGC
'8%-&.E8-' <'& 6*%78 %$7.987J D.E9$<% \'/*'$$%*'/ <'& Y$7*/'J
I-9.5$ 3@1JW77.$ 1J f.'$ 3>>lJ U</$7 1>d213>

kc\^ d3k G: f: c$<5$7 $8 <9J IWZG [PW^C ^]$EF<'*78*E]-&$9 -6 P<&*-'.E9*&$
T$F<0*-.%*' 8F$ P$<E8-% Z--9<'8 V_78$5 .'&$% V$0$%$ ^EE*&$'8
Z-'&*8*-'7J D'P\+kZP2==l=J P$0:1J 1dd3

kc \ P >3k c$%*' / J b :Q c - 5 <' ' J ZF:Q M<5 _J f:V:J] *<77 - $& - 0J ^Q VEF<' A + :Q
V$O - 9& M:Q V8$*' K%NEL] :Q Z - 5 O<%*7 - ' <' & W' 8$%O%$8<8*- ' P$O - %8 - 6 8F$
[\ ZY W' 8$%' <8*- ' <9 V8<' &<%& U%- K9$ 5 D - : l = \ e$%E*7$ - ' &$9<_$&
E - %$ %$69 - - & Só \ DZ c 2>kh b *77$ ' 7EF<689*EF$ T$%*EF8$J Ra (^ 2h8
S3>>3X

kc \ P >lk c$%*' / b :J c - 5 <' ' ZF:J Z%*8$%*< 6 - % 7 . EE$776 . 9 E - %$ %$69 - - & . '&$%
7$0$%$ <EE*&$' 8 E - '&*8*- ' 7J U<O$% l 3d lJ U%- E$$&*' / - 6 8F$ WZ ^ UU2>lJ
U*887K . %/FJ U^J ' V^J f . '$ 1@21h1>>lJ] <&*7 - 'J b *7:C [5 '*O%$77J
3>>lJ V: 1>d>2d=J ZY2P [ ] WVTDC >2 i d l l i 2h1> 23

kc \ P >l<k c$%*' / b :J 3>>lJ V . 5 5 <%_ - 6 O%$28$78 E<9E . 9<8*- ' 7 O$%6 - % 5 $& 6 - %
8$78 3'& M^ Z [ ] \ P^ ó \ DZ c 8$78 o 2M3 Só \ DZ c 211X
V^] 2M^ Z [ ] \ P^2Y>=

kc \ P d@k c$%*' / b :J] *' <8 - (:J D</<7$ R:C T$F<0*- . % - 6 8F$ a*%E<9 - _ Z9<&&*' / *'
U b P2VO$E*6*E Z [P^ \ eO$%*5 $ ' 87J D . E9$<% G$EF' - 9 - / _J l - 9: 1>3J
V: 1>>211=J ^O%*9 1dd@

kc \ P dlk c$%*' / J b : c - 6 5 <' ' J U:C] <8$%*<9 W' 8$%<E8*- ' 7 &. %*' / V0%$ M b P
^EE*&$' 87Q V . 5 5 <%_ - 6 V$O<%<8$2$66$E87 P$7 . 987J (6 (=13=J
R$K%. <% 1ddl

kc [Z d=k (:Y: c - EL$J T: ^&% - / . $%J W: VF$OF$%&J ^: VEF<8A: R*77*- ' O% - &. E8
%9<7$J V8<8$2 - 628F$2<%8 %$0*$#J \ . % - O$<' Z - 5 5*77*- 'J
\ ' P 1hdd \ DJ 1dd=

kc [R i1k \: c - 6$%J ^ ' ^S a X2V8<K9$ l <%*<K9$ [%&$% [Y \ 2V - 90$% <'& *87
^OO9*E<8*- ' <7 ^&0<' E5 ' 8 U%- E$&. %$ 6 - % V*5 . 9<8*- ' 7 *' GF$% 5 - 2
<'& R9. *&&_ ' < 5 *E7: W' 8: G - O:] $$8*' / - ' ^&0<' E$7 *'] <8F$5 <8*E<9
] $8F - &7 6 - % 8F$ V - 9 . 8*- ' - 6 D . E9$<% \ ' /*' $$%*' / U%- K9$ 5 7J l - 9:1J
] N' EF$' J 1di1

kc [ ] >lk c - 5 <' ' ZF:Q c$%*' / b :J] *<77 - $& - 0 ^:J V$O - 9& M:J W' 0$78*/<8*- ' - 6 8F$
P$69 - - & UF<7$ *' o$' EF \ eO$%*5 $ ' 87J U%- E$$&*' / 7 - 6 WZ [D \ 13J
13 8F W' 8$%' <8*- ' <9 Z - ' 6$%$ ' E$ - ' D . E9$<% \ ' /*' $$%*' / J ^O%*9 3=?3dJ
3>>lJ ^%9*' / 8 - 'J l *% / *' *< ' V^

kWZ^ >@k 11 8F WZ ^P \ kZ ^Gc ^P \ U$%*- &*E D$#7J] <* 3>>@

kf ^Z >lk R: f<EpV [Uc ^ \ P [V Y$0$9 - 05 $ ' 8 [%*$' 8<8*- ' 7J D - 8$ G$EF' *p$
YU^] 3>>l2>hWPVDk + PV

kf [D >@k (: f - ' $7J ZF: +*' / %*EFJ V_ 5 K - 9*E D . E9$<% ^ ' <9_7*7 U<EL</$ SVD^UX:
R<99 3>>@ Z^] U] $$8*' / : T<98*5 - %$J] YJ ' V^: [E8 - K$% 3@23 lJ 3>>@

kf [P i=k c: f-%&<' <'&] : P: (.F95<'J GP^U2] \MG3 ' 7$%7] <' .<9J
T] W2313lJ D ' P \ +kZP2l3>= S] <_ 1di=X:

k(\P dik \: ($%78*' /J c: M)669$%J V*EF$%F$*87<' <9_8*7EF$ ' '8$%7 .EF. ' /$' A.
7EF#$%$' V8)%6B99$' *' V b PJ ^K7EF9.77K$%*EF8J +PV2^23=1dJ 1ddi

k(M\ >3k b : (9$*'2c$,9*' /J b : \%&5<' 'J WVU l@UF$K.7 RUG1J Z<9E.9<8*-' #*8F
E-.O9$& Z [Z [V j V 2 ^GcM\G2ZY 0$%7*-'J G$EF'*E<9 D-8$ GD2(Mc
3k3>>3J +PVJ 3>>3

k(M\ >@k W: (9$*'F*$8O<,J D: P$*'L$J c: ' ' /$%J] : (: (-EF: Z<9E.9<8*-' -6 8F$
\eO$%*5$'8 UF$K.7 RUG21*' 8F$ E-'8$e8 -6 8F$ WVU lm#*8F ^GcM\G 2
ZY1:3Yk1:1WJ U%-E: D ' P \Gc21>J V$-.9J (-%$<J ZY2l$%7*-'J
[E8-K$% 3>>@:

k([Z >@k] : (: (-EFJ] : V8$*'K%NEL: V8<8.7 '<8*-'<9$% .'&*'8$%'<8*-'<9$%
R-%7EF.'/70-%F<K$' .'&<K/$9$*8$8$ \%L$'8'*77$A.5 ' '6<99<K9<.6
*5 U%*5B%7_78$5 S*'20$77$9XJ b*77$'7EF<689*EF$ T$%*EF8$ &$7
R-%7EF.'/7A$'8%.57 (<%97%.F$*' &$% c$95F-98A2+$7$997EF<68J
Ra(^ d@=J V: =nV: 3dn 2@1l S<.EF <97 ZY2l$%7*-' $%FB989*EFXJ
WVVD >dln2i8>

k([P dn ZF: (-%8AJ] : (: (-EFJ c: ' ' /$%: R*77*-' U%-&.E8 P$9<7 6%-5] -98$'
U--97C ^ V8<8$2-628F$2^%8 P$0*$#J P.F%2 ' '*0$%7*8B8 T-EF.5J
Y$O<%85$'8 6-% D.E9$<% <'& D$# \'$%/_ V_78$57J P ' T \21i1J
VGC] USdXn 2U>1@J ^./.78 1ddn

k([P ddk ZF:R: b : (-%8A: ' '8$%7.EF.' / &$% P<&*-'.L9*&6%$*7$8A.' / <.7
] $F%L-5O-'$'8$'2k] $F%OF<7$'2($%'7EF5$9A$'J Y*77$%8<8*-'J P.F%2
' '*0$%7*8B8 T-EF.5J R<L.98B8 6N%] <7EF*'$'K<.J 1ddd

kM^D ddk V: M<' /$'K.EFJ (:2Y: VEF5*&8J (: I$%L-0J GF$ Z-.O9$& Z-&$ V_78$5
^GcM\G2ó ^T [kZ ' TT [&] -&$9 R$<8.%$7 <'& P$7.987 6-%8F$ Z-%$
G%<'7*$'87 -68F$ [\ZY U b P] VMT T$'EF5<%L: W'8: Z-'6: -'
] <8F$5<8*E7 <'& Z-5O.8<8*-'J P$<E8-% UF_7*E7 <'& \'0*%-'5$'8<9
^'<9_7$7*' D.E9$<% ^OO9*E<8*-'7J I-9: 1J OO@=12@=i V$O:3n2@>J 1dddJ
V$'&< \&*8-%*<9J] <&%*&

kM^V >1k (: M<775<' 'J !GF$ GP^DV ' P^D ' V Z-&$? U<78J U%7'8 <'& R.8.%$J
P$0*$# ^%8*E9$q3>>1J O: 1m233J WG ' ^E8*0*8_ P$O-%8 3>>1 ? \ ' P
3>3=3J WVTD d32idl2@@d 2=

kM\ \ n T:0<' M$$%J G-#<%&7 8F$ ' 98*5<8$ Z-'7$%0<8*0$ Y*66$%$'E$ VEF5J
f-.%'<9 -6 Z-5O.8<8*-'<9 UF_7*E7J 3@J 3m 23ddJ 1dn

k] ^ + >=k] </<99- ' $8 <9J 3>>=J \ . %- O$<' eO%8 '$8# - %L 6- % 8F$ %$&. E8*- ' -6
. 'E$%8<*'8*$7 *' 7$0$%$ <EE*&$'8 7<6$8_ *77. $7 S\ ' PV^R \XJ D. E9$<%
\ ' /*' $$%*' / <'& Y$7*/ 'J I -9: 3@=J OO: @>d2@ l m

k] ^ + ddk Y:] </<99- 'J W: c. F8*'*$5* . '& c: c - F5<' 'C M$77- '7 9$<%'8 6% - 5
R^P [kG \P] [V Z -%*. 5] $98 o$'EF*' / \eO$%*5$ '87: D. E9$<%
\ ' /*' $$%*' / <'& Y$7*/ 'J I -9: 1 i dJ OO: 33@23@ i S1dddX

k] WM ddk P:] :] *99$%J $8 <9: J Z - 5O9$8*- ' P$O - %8 6 - % 8F$ Z - . O9$& GP ^ Z2
] kU^PZV Z -&$J U ' kD \2dd23> U. %&. $ ' '*0$%7*8_ 1ddd

k] WV >>k] :] *77*%9<'J +: ^9O_J] : U: (*77<'$J V [Uc ^ \P [V Z -&$ I $%7*- ' 3:>C
GF$ - %$8*E<9 5<' . <9J D - 8$ G$EF'*p$ V \ ] ^P >>k@dJ WPVDJ 3>>>

k] [P > l k (:] - %*_<5<J c: D<L<5 . %< . '& j:] <%. _<5<C f ^V] WD \ ^ '<9_8*E<9
G - - 9 Y$0$9 - O5$'8 6 - % Z - <%7$ T%$<L2. O -6 <] - 98$' f$8 *' < Y$$O
b <8$% U - - 9: VO$E*<9 W77. $ - ' Z - %$] $98 ^EE*&$'87 *' M b P7C V8<8$ -6
8F$ ^%8 -6 Z - - 9<K*9*8_ -6 U - % - . 7 Y$K%*7J D. E9$<% \ ' /*' $$%*' / <'&
Y$7*/ 'J 8 - K$ O. K9*7F$&

k] ' \ >1k Z:] N99$% . '& (: VEF<<6C Y$% V*5 . 9<8*- '75 -&. 9 ^WY^: + PV2^23d l lJ
] <* 3>>1

k] ' \ >@k b: Z:] N99$%C T$%*EF8 NK$% [\ ZY P^VUM^ I . '& [\ ZY] ^VZ^
U% - h$L8$. '& 0$%6N / K<%$ ' '8$%9</$'J ^%K$*878%$66$' + PV + <%EF*' / J
3d: i :3>>@

k] ' P >@k ZF: f:] . %%<_J PE'8 Y$0$9 - O5$'8 ^E8*0*8_ - ' 8F$ DPZ Z - '7 - 9*&<8$&
Z -&$: R<99 3>>@ Z ^] U] $$8*' /: T<98*5 - %$J] YJ ' V^:
[E8 - K$% 3@23 l J 3>>@

k [Y^ >@k R: [&<%J ZJ] . %%<_J P: VF. 5 #<_J] : T - 9<'&$%J Y: T<%K$%J f:] <F<66_C
GP ^ ZkP \M^U= ^&0<'E$& Z - 5O. 8<8*- '<9 \ ' /*'$ SGP ^ Z \X: GP ^ Z \
I l :> ' 7$%] <' . <9: ' V DPZJ] <_ 3>>@

kU^W >@k c: U<*99{$ $8 <9:J ^&0<'E$& GF%$$ Y*5$'7*- '<9 G# - 2UF<7$ R9 - #
V*5 . 9<8*- '7 G - - 97 6 - % ^OO9*E<8*- ' 8 - P$<E8 - % V<6$8_ S^VG^PXJ RWV^ k
\ ' P7<%EF *' P$<E8 - % V<6$8_J M. e$5K - . % / J 3>>@

kUM ' > l k b: U9. 5$E - Ep + : + . *99<%&: \MV^ 3:1C R*77*- ' O% - &. E8 <'& 78%. E8. %<9
$9$5$'8 %$9<7 6% - 5 *'8<E8 <'& &$/%<&$& E - %$7J P$0: >J WPVDJ D - 8$
G$EF'*p$ YU^] kV \ ] WZ 3>> l k3@J ^VG \ Z 2 l 1kY [Zk> l 2>3J f. '$ 3>> l

kUP^ >@k c:2] : U%<77$%J] : T$_$%J ^: T-88/$%J c: Z<%9J Y: M.E<7J ^: VEF<66%<8FJ
U: VEF.8AJ R:2U: b$*77J f: a7EF<.J 3>>@J W'69.$'E$ -6 8F$ U*O$
Y*<5$8$% -' 8F$ V8%.E8.%$ -6 8F$ +<72M*p*& W'8$%6<E$*' < I$%8*E<9 G#- 2
UF<7$ U*O$ R9-#J U%-E$$&*'/7 -6 GF$ G$'8F W'8$%'<8*-'<9 G-O*E<9
]$$8*'/ -' D.E9$<% P$<E8-% GF$%5<9 c_&%<.9*E7 SD‘P\Gc21>X
[E8-K$%=21>J V$-.9J (-%$<

kP^] i lk P<5-'<G$<5J Y$7E%*O8*-'<'& ^77$775$'8 -6 P<5-'<2@T] [Y:>
Z_E9$I^ E-5O.8$% Z-&$ #*8F GF%$$2Y*5$'7*-'<9 D$.8%-' (*'$8*E7 6-%
T b P V_78$5 G%<'7*$'87J TDM P$O-%8: TDM2D‘P\+2=1mjm‘VDPZJ
D‘P\+kZP2@mn1di l

kP\W>lk D: P$*'L$J G: Y%<8FJ G: 0: T$%9$O7EFJ]: (-EF<'& c: ‘'/$%C R-%5<8*-'J
ZF<%<E8$%*7<8*-'<'& Z--9*'/ -6 Y$K%*7 ? VE$'<%*- Y*7E.77*-' #*8F
\5OF<7*7 -' G]W23: VO$E*<9 W77.$ -' Z-%$]$98 ^EE*&$'87*' M b P7C
V8<8$ -6 8F$ ^%8 -6 Z--9<K*9*8_ -6 U-%-.7 Y$K%*7J D.E9$<% \'/*'$$%*'/
<'& Y$7*/'J 8- K$ O.K9*7F$&

kP\M ddk P\M^U GF$%5<9 c_&%<.9*E7 +%-.O: P\M^U= Z-&$]<'.<9J I-9.5$ 12
nD‘P\+kZP 2==@=: f.'$ 1ddd: WVMkVE*$'8$EF: W&<F- R<997J W&<F-J
‘V^

kP[+d>k f:G: P-/$%7J \&*8-%: R*77*-' U%-&.E8 G%<'7O-%8 U%-E$77$7*' P$<E8-%
^EE*&$'87J c$5*7OF$%$ U.K9*7F*'/ Z-%O-%<8*-'J D$# j-%LJ M-'&-'J
1dd>J WVTD >2id11m2im 21

kP[ ] d>k U:P-578$&&J ^ VO9*82]<8%*e]$8F-& 6-% 8F$ D.5$%*E<9 V-9.8*-' -6
G#-2UF<7$ R9-# \p<8*-'7J D.E9$<% VE*$'E$ <'& \'/*'$$%*'/J 1>lJ
12dJ 1dd>

kVZc >lk VEF<'A +:$8 <9:J ^&0<'E$& 8%$<8 5$'8 -6 A*%E<9-_ E9<&&*'/ F*/F2
8$5O$%<8.%$ -e*&<8*-'*' 7$0$%$ <EE*&$'8 E-&$ E<9E.9<8*-'7J U<%8 W2WWWJ
D\YJ 3@3S3>>lXm 21>d

kVZc d3k D:]: VEF'.%%J GP^Z2UR1k] [Y3 GF$-%_]<'.<9: M^DM P$O-%8
M^213>@12]J ‘VDPPZ P$O-%8 D‘P\+kZP2=@n 1dd3

kV\c dn T: P: V$F/<9J ^: I: T.*J G: D: Y*'F .'& P: P: D-.%/<9*$0C c$<8 G%<'76$%
U%-E$77$7*' P$<E8-% I$77$9 M-#$% U9$'.5 &.%*'/ M<8$ UF<7$ -6 W'2
I$77$9 Z-%$]$98 U%-/%$77*-': f-.%'<9 !^&0<'E$7*' D.E9$<% VE*$'E$
<'& G$EF'-9-/_;J U9$'.5 U.K9*7F*'/ Z-%O:J I-9: 3mS1ddkn

kV\W>>k f:]: V$*9$% .'& (: R%-5$'8C]<8$%*<9 \66$E87-'].98*OF<7$
UF$'-5$'<*' M<8$ UF<7$ -6 V0%$ ^EE*&$'87*' D.E9$<% P$<E8-%7:
].98*OF<7$ VE*$'E$ <'& G$EF'-9-/_J o<%8$%9_ I-9: 13 W77.$ 3J 3>>>

kV\D >3k V$'/O*$9J b:Q c$%*'/J b:WVU2lmUF$K.7 RUG1: UF<7$ 1C T.'&9$ 2
E<9E.9<8*-'7 .7*'/WZ^P\3<'& VZY^UkP\M^U=:WVU2lmd%-/%$77
]$$8*'/J ^*e2$'2U%-0$'E$J RJ [E8-K$% 3123@J 3>>3 $l=@>33X

kV[D >3k c:+:V-''$'K.%/J \:c-6$%J ^:(9--7:]$8F-&$'$'8#*EL9.'/A.%
^'<9_7$ &$7 T%$''78<K0$%F<98$'7 K$* $%F)F8$5 ^KK%<'&J
^K7EF9.77K$%*EF8J +PV2^2@>dJ D-0$5K$% 3>>3

kVG^ >1k c:V8B&8L$J +:R%<'EF$99-J T:b-%8FJ D.5$%*E<9V*5.9<8*-' -6 +<72M*p*&
R9-#7 '7*'/R9.e l$E8-%VO9*88*'/J Z-5O.8<8*-'<9R9.*& Y_'<5*E7
f-.%'<9J dJ D-:1J =@ 2=i1J 3>>1

kVG^ >=k c:V8<$&8L$ $8<9:J ^&0<'E$& 8F%$$2&*5$'7*-'<9 8#-2OF<7$ 69-#
7*5.9<8*-'78--97 6-%<OO9*E<8*-'78- %$<E8-%7<6$8_S^VG^PXJ D.E9$<%
\'/*'$$%*'/<'& Y$7*/'3@=J @m 2l>>J 3>>=

kGc\dlk G:+:GF$-6<'-.7C Y$<9*'/ #*8F UF$'-5$'-9-/*E<9 ''E$%8<*'8_*' P*7L
^'<9_7*7J b-%L7F-O W*' ^&0<'E$& G-O*E7*' P$9*<K*9*8_<'& P*7L
^'<9_7*7: ^''<O-9*7J]YJ [E8-K$% 3>233J 1dd@:D‘P\+kZU2>1@iJ
[E8-K$% 1ddl

kGc\dln G:+:GF$-6<'-.7 $8<9:C W'2l$77$9 Z--9<K*9*8_<'& P$8$'8*-' -6 Z-%$
]$98:‘:V:Y$O<%85$'8-6 \'$%/_P$O-%8J Y[\kWY21>lmJ l-97:1<'&3
S1ddkm7$$<97-D.E9$<% \'/*'$$%*'/<'& Y$7*/'J l-9:1ddJ OO:1 2lm
S1ddkn

kG[‘dlm W:G-.5*J ^:(.5K<%-J ^' ^OO%-e*5<8$M*'$<%*A$& P*$5<'' V-90$%6-%<
G#-2R9.*&]-&$9J f-.%'<9-6 Z-5O.8<8*-'<9 UF_7*E7J 13lJ 3im2@>>J
1ddm

kGP^ >lk (:G%<5K<.$% $8<9J b$*8$%$'8#*EL9.'/&$7 P$EF$'O%-/%<5 57_78$57
^GcM\Gk^GcM\G2ZYJ ^K7EF9.77K$%*EF8J +PV2^2@31=J 3>>l

kGP^ d3k GP^Z2T G$<5J GP^Z2TR1k][Y1C^' ^&0<'E$& T$782\78*5<8$
Z-5O.8$% U%-/%<5 6-% T b P ^EE*&$'8^'<9_7*7J l [97:12@J
D‘P\+kZP2l@=im1dd3

kGP^ dln (:G%<5K<.$%:]-&$99.56<'/^GcM\G2ZYJ ^.68%</7K$%*EF8J
+PV2^23=>iJ [L8-K$% 1ddn

klWG >@k Z:l*8<'A<J 3>>@J V.55<%_P$E-%&J \eO$%8 5$$8*'/-'8F$ O%-O-7$&
[\ZY 2WPVD VGM[Z U%-h$E8J]<&%*&J 1i 2 1d D-0$5K$%

kbWM >1k c:2+: b*997EFN8AJ \:^9878<&8J T:P:V$F/<9.'&R:2U b$*77C Z-.O9$&
GF$%5<9V8%.E8.%<9^'<9_7*7 -6 M b P l$77$9 Z%$$O R<*9.%$ \eO$%*5$'87J
D.E9:\'/:Y$7:J 0-9 3>iJ OO 3=m 23i3J 3>>1

ka b \ >1k b : a#$%5<’’J V: M<’/$’K.EFJ (%*8*L<9*8B87K$%$EF’.’/$’ 6N% 7EF#$%$ V8)%6B99$ 5*8 ($%’A$%78)%.’/ .’& o<9*6*L<8*-’ &$% P$EF$’5$8F-&*LJ ^K7EF9.77K$%*EF8J +PV2^23id1J 3>>1:

6.3 Kühlkreislauf CFD-Codes

V8%)5.’/72 .’& bB%5NK%8%</.’/70-%/B’/$J #*$ 7*$ *5 (NF9L%$*79<.6 0-’ M$*EF8#<77$%%$<L8-%$’ <K9<.6$’J 7*’& *5 ^99/5*’$’ &%$*&*5$’7*-’<9 .’& A$*8<KFB’/*/:W’ &$’ $*’A$9’$’ ^K7EF’*88$’ &$7 (NF9L%$*79<.67 #$%&$’ 7*$ 5<,/$K9*EF 0-’ &$% h$#$*9*/$’ +$-5$8%*$ &$% ^’9</$’K<.8$*9$J &$’ F$%%7EF$’&$’ Y%.EL2 .’& G$5O$%<8.%0$%FB98’*77$’J &$’ V8-66$*/$’7EF<688$’ &$7 (NF95*88$97J 78%)5.’/75$EF<2 ’*7EF$’ W’78<K*9*8B8$’ .’& I$%A#$*/.’/$’J &$% 78%)5.’/75$EF<’*7EF$’ G.%K.9$’A 7-#*$J K$* a#$*OF<7$’78%)5.’/$’J &.%EF &*$ L-5O9e’ b$EF7$9#*%L.’/75$EF<’*72 5$’ A#*7EF$’ &$’ UF<7$’ K$78*55 8:]*8 c*%6$ &$% ’.5$%*7EF$’ V8%)5.’/77*5.9<8*-’ SZ-5O.8<8*-’<9 R9.*& Y_’<5*E7 u ZRYX *78 $7 6N% $*’*/$ V8%)5.’/7O%-K9$55 F$.8$ 5)/9*EFJ &*7 I-%/B’/$ OF_7*L<9*7EF %*EF8*/ ’<EFA.K*9&$’J p<’8*8<8*0 0-%F$%A.7</$’ 7-#*$ &$’ *’69.77 0-’ T$8%*$K7O<%<5$8$%’ A. .’8$%7.EF$’: Y*$ 78$8*/$ b$*8$%2 $’8#*EL9.’/ 0-’ 5<8F$5<8*7EF2OF_7*L<9*7EF$’]-&$99$’J $66*A*$’8$’ ’.5$%*7EF$’]$8F-&$’ 7-#*$ 9$*78.’/76BF*/$’ P$EF’$%’ 6NF%$’ *’ &*$7$% Y*7A*O9*’ A. $*’$% 78$8*/$’ V8$*/$%.’/ &$% ^’O<77.’/76BF*/L$*8 <’ L-5O9e +$-5$8%*$’ .’& &$% ’.5$%*7EF$’ ^.69)7.’/J 0$%K.’&$’ 5*8 &$%])/9*EFL$*8J *55$% L-5O9$e$%$ OF_7*L<9*7EF$ V8%)5.’/75$EF<’*75$’ &$8<*9/$8%$. .’& A.0$%9B77*/A. 7*5.9*$%$’:

W’ ZRY2I$%6<F%$’ #$%&$’ %B.59*EF A#$*2 KA#: &%$*&*5$’7*-’<9$ \%F<98.’/72 /9$*EF.’/$’ 6N%]<77$J W5O.97 .’& \’$%/*$J $%/B’A8 .5 $5O*%*7EF$]-&99 6N% G.%K.9$’A .’& UF<7$’#$EF7$9#*%L.’/J ’.5$%*7EF *’8$/%*$%8: Y<&.%EF .’8$%7EF$*&$’ 7*EF ZRY2I$%6<F%$’ 0-’ &$’ *’ &$% P$<L8-%7*EF$%F$*8 0$%#$’&$8$’ V_78$5E-&$7J #*$ A.5 T$*7O*$9 ^GcM\G .’& Z^Gc^P\J *’ &$’$’ 6N% &*$ 5$*78$’ (-5O-’$’8$’ $*’&*5$’7*-’<9$ +9$*EF.’/$’ 0$%#$’&$8 #$%&$’:

’ #$*8$%$% ‘’8$%7EF$& *’ &$%]-&$99*$%.’/778%<8$/*$ A#*7EF$’ V_78$5E-&$7 .’& ZRY2I$%6<F%$’ 9*$/8 &<%*’J &<77*’ ZRY2I$%6<F%$’ &$% *’69.77 &$% +$-5$8%*$ NK$% &<7 L)%O$%<’/$O<778$ PEF’’$8A .’& &*$ P<’&K$&*’/.’/$’ *’ $*’$% <99/5*’$’ b$*7$ $*’/$K%<EF8 #*%&: UF_7*L<9*7EF$ \66$L8$ #$%&$’ *’ &$’ +9$*EF.’/$’ /$-5$8%*$2 .’<KFB’/*/ .’& 9-L<9 <K/$K*9&$8J #-&.%EF &*$ VL<9*$%K<%L$*8 &$%]-&$99$ 7*/’*6*L<’8 0$%K$77$%8 #*%&: Y*$ I<9*&*$%.’/ L<’’ &<F$% A.5 /%-,$’ G$*9 5*8 c*%6$ 0-’

\eO$%*5$'8$' *' $*'$5 0$%L9$*'$%8$']<,78<K $%6-9/$': T$* V_78$5E-&$7 9B778 7*EF &</$/$' &*$ /$-5$8%*7EF$.'& OF_7*L<9*7EF$]-&$99*$%.'/ '*EF8 78%*L8 8%$''$': V*$ K*9&$' P$<L8-%7_78$5$ 5*8 $*'$5 V<8A 0-' +%.'&$9$5$'8$' 6N% K$78*55 8$ T<.8$*9$.'& R.'L8*-'$' <KQ &<&.%EF $%/$K$' 7*EF T$7EF%B'L.'/$' *' &$'])/9*EFL$*8$' A.% /$-5$8%*7EF$' ^.69)7.'/:

Y$% 5<8F$5<8*7EF$ ZF<%<L8$% &$% *' ZRY2I$%6<F%$' 0$%#$'&8' +9$*EF.'/77_78$5$ *78 O<%<K-9*7EF K$* A$*8<KFB'/*/$' V8%)5.'/$' .'& $99*O8*7EF K$* 78<8*-'B%$' V8%)5.'/$': Y*$ *' V_78$5E-&$7 0$%#$'&8'J 0$%$*'6<EF8$' +9$*EF.'/77_78$5$ K$%.F$' <.6 &$' $*'&*5$'7*-'<9$' O<%<K-9*7EF$' -&$% F_O$%K-9*7EF$' \.9$%2 +9$*EF.'/$' -&$% &$' a#$*69.*&/9$*EF.'/$'J *' &$'$' &*$ 0*7L-7$' G$%5$.'& &*$ G.%K.9$'A8$%5$ 0$%'<EF9B77*/8 #$%&$': W%%$0$%7*K9$ V8%)5.'/7&%.EL0$%9.78$ #$%&$' K$* V_78$5E-&$7 &.%EF $5O*%*7EF$ (-%%$9<8*-'$' $*'/$K%<EF8J K$* ZRY2Z-&$7 7*'& 7*$ G$*9 &$% M)7.'/ &$7 +9$*EF.'/77_78$57:

ZRY2Z-&$7 A$*EF'$' 7*EF *'7K$7-'&$%$ &.%EF *F%$ '.5$%*7EF$' (-'0$%/$'A2 $*/$'7EF<68$' <.7: Y*$7 K$&$.8$8J &<77 &<7 '.5$%*7EF$ +*88$% S$'87O%*EF8 &$% D-&<9*7*$%.'/ K$* V_78$5E-&$7X .'& &*$ +%),$ &$% (-'8%-990-9.5*'< K$* <.7%$*EF$'& 6$*'$% ^.69)7.'/ '.% '-EF $*'$' 0$%'<EF9B77*/K<% L9$*'$' *'69.77 <.6 &<7 \%/$K'*7 K$7*8A$': Y*$ 5<8F$5<8*7EF2OF_7*L<9*7EF$]-&$99*$%.'/ .'& &*$ '.5$%*7EF$' M)7.'/75$8F-&$' L)''$' &<F$% /$8%$''8 0-'$*'<'&$% /$8$78$8 .'& #$*8$%$'8#*EL$98 #$%&$':

ZRY2Z-&$7 7*'& <99$%&*'/7 K*7F$% #$/$' *F%$7 K$7-'&$%7 F-F$' P$EF$'<.6#<'&$7 <.6 <.7/$#BF98$ ^'#$'&.'/$' K$7EF%B'L8J #BF%$'& &*$ V_78$5E-&$7 5*8 *F%$% /%)K$%$' ^.69)7.'/ V8)%6<99<K9B.6$ *' /<'A$' (NF97_78$5$' *' <LA$O8<K9$% a$*8 K$%$EF'$' L)''$':

I-% E<: 3> f<F%$' #.%&$' <97 O%*'A*O*99 ^98$%'<8*0$ A. R*'*8$2\9$5$'82 .'& R*'*8$2 I-9.5$'2I$%6<F%$' &*$ 7- /$'<''8$' M<88*E$2T-98A5<''2I$%6<F%$' $'8#*EL$98: Y*7 K<7*$%$' <.6 &$% T$%$EF'.'/ $*'$% 78<%L 0$%$*'6<EF8$' G$*9EF$'2]*L%-&_'<5*L: Y<7 F$*,8J $7 #*%& $*'$ V*5.9<8*-' <.6 &$% G$*9EF$'$K$'$ &.%EF/$6NF%8: Y<7 M<88*E$2 T-98A5<''2I$%6<F%$' F<8 7$*'$ 8F$-%$8*7EF$ T<7*7 *' &$% 78<8*78*7EF$' UF_7*L: ^.7 5*L%-7L-O*7EF$% V*EF8 7$8A8 7*EF $*' R9.*& <.7 $*'A$9'$' G$*9EF$' A.7<55$'J &*$ 7*EF $'87O%$EF$'& &$' +$7$8A$' &$%]$EF<'*L &.%EF &$' P<.5 K$#$/$' .'& 5*8$*'<'&$% #$EF7$9#*%L$': Y*$ b$EF7$9#*%L.'/ &$% 5*L%-7L-O*7EF$' G$*9EF$' #*%& &.%EF &*$ T-98A5<''2+9$*EF.'/ K$7EF%*K': ''8$% /$$*/'8' I-%<.77$8A.'/$' L<'' 5<' <.7

&$5 5*L%-7L-O*7EF$' Z-5O.8$%69.*& 5<L%-7L-O*7EF$ +%),$' $%5*88$9'J &*$ &$' D<0*$%2V8-L$72+9$*EF.'/$' /$F-%EF$': T$* &$% M<88*E$2T-98A5<''2]$8F-&$ #$%&$' *5 +$/$'7<8A A. &$' M<88*E$2+<72I$%6<F%$' L$*'$ K*'B%$' G$*9EF$' 7-'&$%' L-'8*'.*$%9*EF$ G$*9EF$'&*EF8$' 0$%#$'&$8: Y*$ '50$%8$*9.'/ *' R-9/$ 0-' G$*9EF$'#$EF7$9#*%L.'/$' #*%& &.%EF $*'$9*'$<%*7*$%8$ R-%5 &$% T-98A5<''2+9$*EF.'/ $%5*88$98: Y*$ ^'#$'&.'/ 0-' M<88*E$2T-98A5<''2I$%6<F%$' *78 &$%A$*8 <.6 *'L-5O%$77*K9$ V8%)5.'/$' K$7EF%B'L8: b$*8$%$' \'8#*EL9.'/7K$&<%6 /*K8 $7 K$* &$% G.%K.9$'A2 .'& a#$*OF<7$'5-&$99*$%.'/ 7-#*$ K$*5 7L<9<%$' G%<'7O-%8 0-' \'$%/*$.'& (-'A$'8%<8*-'$': ^.7 &*7' +%N'&$' #$%&$' M<88*E$2T-98A5<''2I$%6<F%$' *' &$% P$<L8-%7*EF$%F$*8 '-EF '*EF8 $*'/$7$8A8:

6.3.1 Anforderungen aus der Thermohydraulik

W' &$' 9$8A8$' f<F%$' #.%&$' ZRY2I$%6<F%$' *' A.'$F5$'&$5]<77$ A.% V*5.9<8*-' 0-' 78<8*-'B%$' .'& 8%<'7*$'8$' V8%)5.'/$' *' M$*EF8#<77$%%$<L8-%$' $*'/$7$8A8: Y$% +%.'& &<6N% *78J &<77 0*9 6N% &$' T$8%*$K L%*8*7EF$J &%$*&*5$'7*-'<9$J 8F$%5-F_&%<.9*7EF$ V8%)5.'/7OFB'-5$'$ 5*8 $*'&*5$'7*-'<9$' V_78$5E-&$7 '*EF8 <.7%$*EF$'& /$'<. K$%$EF'$8 #$%&$' L)''$': b*EF8*/$ T$*7O*$9$ &<6N% 7*'& &*$ T-%0$%5*7EF./' *5 U%*5B%L%$*7 0-' Y%.EL#<77$%%$<L8-%$' .'& &<7 ^.68%$8$' 0-' G$5O$%<8.%7EF-EL7 SU%$77.%*A$& GF$%5<9 VF-EL7J UGVXJ &*$ &.%EF *'7O$*7.'/ 0-' D-8LNF9#<77$% K$* F-F$' Y%NEL$' #BF%$'& $*'$7 (NF95*88$9O$%9.782V8)%6<997 <.68%8' L)''$': Y*$7$ K$*&$' U%-K9$5L%$*7$ #$%&$' *' &$' 6-9/$'&$' ^K7EF'*88$' 'BF$% K$7EF%*K':

Borvermischung: T-%7B.%$ #*%& <97 9)7K<%$% D$.8%-'$'<K7-%K$% *5 U%*5B%L%$*7 0-' Y%.EL#<77$%%$<L8-%$' $*'/$7$8A8: ''8$% '-%5<9$' T$8%*$K7K$&*'/.'/$' #*%& 5*8 c*96$ &$% T-%7B.%$ &*$ P$<L8*0*8B8 L-'8%-99*$%8 .'& ^KK%<'& .'& $'- '0$%/*68.'/ *''$%F<9K &$% 0-%/$/$K$'$' P$<L8*0*8B875<%/$' L-5O$'7*$%8: T$* P$0*7*-' $*'$% ^'9</$.'& D$.K9<&.'/ &$7 ($%'7 #*%& 5*8 c*96$ &$% T-%7B.%$ &*$ /$6-%&$%8$ ''8$%L%*8*L<9*8B8 $*'/$78$998: Y*$ T-%L-'A$'8%<8*-' #*%& &.%EF &<7 I-9.5$'%$/$97_78$5 $*'/$78$998 .'& K$* V8)%6B99$' &.%EF A.7B8A9*EF$ V_78$5$ /$#BF%9$*78$8: ^K#$*EF.'/$' 0-5 V-99#$%8 &$% T-%L-'A$'8%<8*-' L)''$' &.%EF R$F9$% *5 *'7O$*7$7_78$5 $'878$F$': ^.,$%&$5 K$78$F8 &*$])/9*EFL$*8J &<77 '*EF8 K-%*$%8$7 b<77$% *5 U%*5B%L%$*7 &.%EF I$%&<5O6$' .'& (-'&$'7<8*-' *5 Y<5O6$%A$./$% K$* L9$*'$' M$EL78)%6B99$' $'878$F8: M-L<9 .'8$%7EF*$&9*EF$ I$%8$*9.'/$' &$% T-%L-'A$'8%<8*-' L)''$'J #$'' 7*$ *' &$' ($%' 8%<'7O-%8*$%8 #$%&$'JA. P$<L8*0*8B8778)%.'/$'*5 ($%' 6NF%$':

Y*$ Y.%EF5*7EF.'/7O%-A77 .'& &<5*8 &*$ %B.59*EF$.'& A$*89*EF$ I$%8$*9.'/ &$% T-%L-'A$'8%<8*-' .'& &$% V8%)5.'/7/$7EF#*'&*/L$*8$' <5 ($%'$*'8%*88 7*'& $'87EF$*&$'&$ P<'&K$&*'/.'/$' 6N% &<7 ($%'0$%F<98$': Y*$ 0-' V_78$5E-&$7 K$%$EF'8' 8F$%5-F_&%<.9*7EF$' V8%)5.'/70$%FB98'*77$ *5 P$<L8-%LNF97_78$5 5N77$' &$7F<9K &.%EF A.7B8A9*EF$ W'6-%5<8*-'$' NK$% &*$ 8%<'7*$'8$']*7EF.'/70-%/B'/$ *5 P$<L8-%&%.ELK$FB98$% $%/B'A8 #$%&$': Y*$ $%6-%&$%9*EF$ Y$8<*9*'6-%5<8*-' L<'' &.%EF &%$*&*5$'7*-'<9$ V*5.9<8*-' &$% V8%)5.'/ 5*8 ZRY2 I$%6<F%$' /$#-''$' #$%&$':

Pressurized Thermal Shocks: Y*$ *'7O$*7.'/ 0-' D-8LNF9#<77$%*' &$' U%*5B%L%$*7 0-' Y%.EL#<77$%%$<L8-%$' L<'' A. 8F$%5*7EF$' T$9<78.'/$' <' VEF#$*,'BF8$' .'& P*77$' 6NF%$'J #-&.%EF &*$ W'8$/%*8B8 &$7 Y%.ELK$FB98$%7 K$&%-F8 #$%&$' L<'': W' $*'$5 8_O*7EF$' UGV2VA$'<%*- #*%& L<98$7 b<77$% *' &$' L<98$' V8%<'/ $*'$7 Y%.EL#<77$%%$<L8-%7 #BF%$'& $*'$7 (NF95*88$90$%9.7878)%6<997 $*'/$7O$*78: Y<7 D-8LNF9#<77$% 0$%5*7EF8 7*EF 5*8 &$5 F$*,$' R9.*& *5 L<98$' V8%<'/: ^KFB'/*/ 0-' &$% T%.EF/%),$J L)''$' $*'2 .'& A#$*OF<7*/$ V8%)5.'/7K$&*'/.'/$' A#*7EF$' &$% *'7O$*7$78$99$.'& &$5 P*'/%<.5 <.68%$8$': \7 L<'' 7*EF $*'$ 78%<8*6*A*$%8$ V8%)5.'/ K*9&$'J 5*8 L<98$5 b<77$% *5 .'8$%$' T$%$*EF &$% F-%*A-'8<9$' P-F%9$*8.'/ .'& $*'$% +$/$'78%)5.'/ 0-' F$*,$5 b<77$% -&$% b<77$%&<5O6 *' $*'$% &<%NK$% 9*$/$'&$' VEF*EF8:W' &*$7$5 R<99 8%*88 (-'&$'7<8*-' <' &$% 6%$*$' [K$%69BEF$ &$7 *'7O$*7$78%<F97 .'& <' &$% /$7EF*EF8$8$' V8%)5.'/ <.6: ^97 R-9/$ &$% *'7O$*7.'/ &$7 D-8LNF9#<77$%7 &%*'/8 L<98$7 b<77$% *' &$' P*'/%<.5 $*': Y$% V8%)5.'/7#$/ &$7 (<98#<77$%78%<F97 *78 78<%L 0-' &$' V8%)5.'/7K$&*'/.'/$' .'& &$% Y$8<*9/$-5$8%*$ &$7 L<98$' V8%<'/$7 .'& &$7 P*'/%<.57 <KFB'/*/: G$5O$%<8.%7EF-EL7L)''$' <' &$% b<'& &$7 P$<L8-%&%.ELK$FB98$%7 <.6 +%.'& &$% 8F$%5*7EF$' .'& 5$EF<'*7EF$' T$9<78.'/ <.68%8'J &*$ &.%EF &*$ 7EF'99' G$5O$%<8.%2 .'& Y%.ELB'&$%.'/$' <5 P<'& &$7 (<98#<77$%78%<F97 0$%.%7<EF8 #$%&$': Y*$7 #*$&$%.5 L<'' 5$EF<'*7EF$7 I$%7</$' &$% Y%.ELK$FB98$%#<'&A.%R-9/$F<K$':

G$5O$%<8.%7EF-EL7L)''$' <.EF*' <'&$%$' (-5O-'$'8$'J #*$A.5 T$*7O*$9 I$'8*9$'J G2V8NEL$' .'& (%N55$%'*5 U%*5B%L%$*7 <.68%$8$': a.% I$%9B'/$%.'/ &$% MK'7&<.$% &$% P$<L8-%$' 5N77$' &$7F<9K V8.&*$' /$5<EF8 #$%&$'J .5 &*$ W'8$/%*8B8 &*$7$% (-5O-'$'8$' A. /$#BF%9$*78$': Y<A. *78 &*$ &$8<*99*$%8$ V*5.9<8*-' &$% &%$*&*5$'7*-'<9$'J 8%<'7*$'8$' Y%.EL2 .'& G$5O$%<8.%9<78$' 5*8 ZRY2I$%6<F%$' '-8#$'&*/J.5 %$<9*78*7EF$ T$&*'/.'/$' 6N% &*$ 5$EF<'*7EF$ ^'<9_7$ 0-%A./K':

6.3.2 Stand der internationalen Arbeiten und Validierung

W5 P<F5$' &$7 [\ZYk‘VDPZ *'8$%'<8*-'<9$' V8<'&<%&O%-K9$57 WVUl@ #.%&$' $%7855<97 ZRY2U%-/%<555$ A.% I-%<.7%$EF'./ 0-' 7EF'$99$' T-%0$%5*7EF./728%<'7*$'8$' 0-' G$*9'$F5$%' <.7 Y$.87EF9<'&J \'/9<'&J R*''9<'&J R%<'L%$*EFJ VEF#$&$' .'& &$' ‘V^ $*'/$7$8A8: Y*$ ZRY2P$EF'./$' A$*/8$' /.8$ HK$%$*'78*55./ 5*8 &$']$77&<8$'J &*$ *' &$% ‘]ZU 3 ´ I M--O R<E*9*8_ &$% ‘''*0$%7*8B8 0-']<%_9<'&S‘V^X $%5*88$98 #.%&$':

W' &$' U%-h$L8$' \Z[P^ .'& RM[]Wx2PJ &*$ *5 =: \‘P^G[] P<F5$'O%-/%<55 78<886<'&$'J #.%&$' ZRY2U%-/%<555$ A.% V*5.9<8*-' 0-' I$%5*7EF./70-%/B'/$' *5 U%*5B%L%$*7 .'&*5 Z-'8<*'5$'8 0-' MbP $%6-9/%$*EF 0<9*&*$%8: W' \Z[P^ #.%&$' T$78 U%<E8*E$ +.*&$9*'$7 STU+X A.% ^'#$'&./ 0-' ZRY2U%-/%<555$' <.6 &$5 +$K*$8 &$% ($%'8$EF'*L $'8#*EL$98: Y*7 P*EF89*'*$' #.%&$' &<'' A.% T$%$EF'./ UGV2%$9$0<'8$% $*'2 .'& A#$*OF<7*/$% V8%)5./$' .'& A.% I-%<.7%$EF'./ <.7/$#BF98$% V\Gc2 U^DY^2\eO$%*5$'8$ $*'/$7$8A8: W5 RM[]Wx2P U%-h$L8 #.%&$' \eO$%*5$'8$ A.% T-%0$%5*7EF./ *' &$% &$.87EF$' P[Z[]2^'9</$.'& *' VEF#$&$' <.7/$6NF%8: ^'7EF9*$,$'& #.%&$' .'8$% ^'#$'&./ &$% \Z[P^2TU+7 I<9*&*$%.'/7%$EF'./$' /$5<EF8:

W5 m\‘P^G[] U%-/%<55 #$%&$' *5 U%-h$L8 D‘P\VW] ZRY 2I$%6<F%$' A.% V*5.9<8*-' 0-' UGV2V8)%6B99$' .'8$%7.EF8: Y$% VEF#$%O.'L8 0-' D‘P\VW] *78 h$&-EF &*$ W'8$/%<8*-' .'& (-OO9./ 0-' PEF'O%-/%<55$' 6N% <99$ ^'#$'&./7K$%$*EF$ &$% ($%'8$EF'*L <.6 $*'$% /5*'7<5$' U9<886-%5:

6.3.3 Potenzial von CFD-Codes

Y<7 /%-,$ U-8$'A*<9 &$% ZRY2U%-/%<555$ *78 &*$ &$8<*99*$%8$J 9-L<9$ &%$*&*5$'7*-'<9$ V*5.9<8*-' 0-' V8%)5./728 .'& bB%5NK%/<'/7OFB'-5$'$' *' L-5O9e' +$-5$8%*$': ^.6 &$% T<7*7 &*7% \%/$K'*77$ L)''$' 7-#-F9 p<9*8<8*0$ <97 <.EF p<'8*8<8*0$ ^.77</$' NK$% &*$ I$%8$*9./ 0-' Y%.ELJ G$5O$%<8.%J +$7EF#*'&*/L$*8 .'& (-'A$'8%<8*-' #$*8$%$% VO$A*$7 #*$ A: T: T-%7B.%$ *5 /$7<585$' V8%)5.'/7/$K*$8 *' ^KFB'/*/L$*8 0-' &$% a$*8 /$5<EF8 #$%&$': *'$ &_'<5*7EF$ Y<%78$99./ &$% V8%)5./ $%5)/9*EF8 &<'' $*'$' *'K9*EL .'& $*' 0$%K77%8$7J OF_7*L<9*7EF$7 I$%78B'&'*7 &$% V8%)5./728 .'& G%<'7O-%80-%/B'/$: Y*$7$7 OF_7*L<9*7EF$ I$%78B'&'*7 L<'' A./$A*98' ^'9</$'0$%K77%./$' 0$%#$'&$8 #$%&$'C

- *'$ &$8<*99*$%8$ &%$*&*5$'7*-'<9$ T$%$EF'.'/ &$% +$7EF#*'&*/L$*872J Y%.EL2 .'& G$5O$%<8.%O$%8$*9.'/ *5 (NF9L%$*79<.6 9*6%8 A.5 T$*7O*$9 #*EF8*/$J %$<9*8B87'<F$ P<'&K$&*'/.'/$' 6N% &*$ V*5.9<8*-' &$% T$<'7O%.EF.'/ 0-' T<.8$*9$':

- RN% &*$ @Y2T$%$EF'.'/ &$7 ($%'0$%F<98$'7 5N77$' &*$ P<'&K$&*'/.'/$' 6N% U%*5B%&%.ELJ T-%L-'A$'8%<8*-' *5 YbP .'&]<77$'78%-52 .'& G$5O$%<8.%2 0$%8$*9.'/ <5 ($%'$*'8%*88 0-%/$/$K$' #$%&$':

- Y<%NK$% F*'<.7 #$%&$' ZRY2U%-/%<55$ A.% &%$*&*5$'7*-'<9$' V*5.9<8*-' 0-' V8%)5.'/7OFB'-5$'$' *5 Z-'8<*'5$'8J #*$ A.5 T$*7O*$9 VEF*EF8.'/70-%/B'/$J 9-L<9$ (-'A$'8%<8*-'$'J (-'&$'7<82 .'& VO<98O%-&.L80$%8$*9.'/ .'& b<77$%78-662 0$%K%$''.'/ $*'/$7$8A8:

Y.%EF &$' *'7<8A 0-' 5$EF<'*78*7EF$' .'& /$-5$8%*$.'<KFB'/*/$']-&$99$' 7*'& ZRY2V*5.9<8*-'$' .'<KFB'/*/ 0-' &$% VL<9*$%.'/ &$7 V8%)5.'/7O%-K9$57: ZRY2 U%-/%<55$ L)''$' &$7F<9K 5*8 7$F% /$%*'/$5 A.7B8A9*EF$5 ^.6#<'& 7-#-F9 6N% 7L<9*$%8$ I$%7.EF7<'9</$' <97 <.EF 6N% %<9 P$<L8-%/$-5$8%*$' $*'/$7$8A8 #$%&$':

Y$% *'7<8A 0-' ZRY2I$%6<F%$' *78 &$%A$*8 '-EF &.%EF &$' F-F$' P$EF$'A$*82 .'& VO$*EF$%O9<8AK$&<%6 K$7EF%B'L8: b$/$' &$% Y_'<5*L &$% \'8#*EL9.'/$' <.6 &$5 c<%&2 .'& V-68#<%7L8-% #$%&$' &*7 T$7EF%B'L.'/$' h$&-EF *55$% /$%*'/$%J #$7F<9K $7 '-8#$'&*/ *78J h$8A8 *' &*$7$ <99/5*'$%$' I$%6<F%$' A.*'0$78*$%$'J .5 '<8*-'<9 .'&*'8$%'<8*-'<9L-'L.%%$'A6BF*/A.K9$*K$':

6.3.4 Modellhierarchien für einphasige Strömungen

^.6/%.'& &$% F-F$' P$_'-9&7A<F9$' .'& &$% /$-5$8%*7EF$' (-5O9$e*8B8 7*'& &*$ V8%)5.'/$' *' P$<L8-%<'9</$' NK$%#*$/$'& 8.%K.9$'8: G.%K.9$'8$ V8%)5.'/$' 7*'& 78$87 &%$*&*5$'7*-'<9 .'& *'78<8*-'B% .'& A$*EF'$' 7*EF &.%EF $*' VO$L8%.5 0-' b*%K$9/%),$' <.7J &<7 K$* <'9</$'8_O*7EF$' P$_'-9&7A<F9$' &%$* K*7 0*$% +%),$'-%&'.'/$' .56<778: ‘5 &*$7$7 VO$L8%.5 <' MB'/$'5<77$' *' $*'$% ZRY2 P$EF'.'/ '.5$%*7EF 0-9978B'&*/ <.69)7$' A. L)''$'J 7*'& <.EF K$* $*'6<EF$' +$-5$8%*$' *' h$&$% &$% &%$* P<.5%*EF8.'/$' 5$F% <97 1:>>> +*88$%O.'L8$ '-8#$'&*/J #<7 A. $*'$5 .'%$<9*78*7EF F-F$' VO$*EF$%O9<8A2 .'& PEF'A$*8K$&<%6 6NF%8: a.% T$%$EF'.'/ 8$EF'*7EF %$9$0<'8$% 8.%K.9$'8$% V8%)5.'/$' #.%&$' &$7F<9K 0$%$*'6<EF8$ ^'7B8A$ $*'/$6NF%8: Y*7 .'8$%7EF$*&$' 7*EF *' &$5 ^'8$*9 &$7 b*%K$9/%),$'2 KA#:

\'$%/*$6%p'A7O$L 8%.57J &$% *' $*'$% P$EF'./ <.6/$9)78 #*%&: *'$ /%.'&9$/$'&$ *'8$*9./ &$% 0$%7EF*$&$'$' ^'7B8A$*78 #*$6-9/8C

Direct Numerical Simulations (DNS): T$* YDV2I$%6<F%$' #$%&$'J #*$ -K$' K$7EF%*K'J <99$ *' $*'$% 8.%K.9$'8$' V8%)5./ <.68%8'&$' b*%K$9/%),$' 5*8 c*96$ &$% &%$*&*5$'7*-'<9$' \%F<98./77B8A$ 6N%]<77$J W5O.97 .'& \'$%/*$ K$7EF%*$K$' .'& &.%EF $*' $'87O%$EF$'& 6$*'$7 P$EF$''$8A <.6/$9)78: \7 *78 L$*' G.%K.9$'A5-&$99 '-8#$'&*/: ^97 \%/$K'*7 9*$/$' 7EF#<'L$'&$J &%$*&*5$'7*-'<9$.'& A$*8<KFB'/*/$ R$9&$% &$7 Y%.EL7J &$% +$7EF#*'&*/L$*8$' .'& &$% G$5O$%<8.% 0-%J &*$ K$* T$&<%6 '<EF8%B/9*EF /$5*88$98 #$%&$' L)''$': YDV L)''$' K*7F$% '.% 6N% %$9<8*0 L9$*'$ P$_'-9&7A<F9$' $*'/$7$8A8 #$%&$'C f$ L9$*'$% &*$ P$_'-9&7A<F9J .5 7- #$'*/$% .'8$%7EF$*&$' 7*EF 'B59*EF &*$ ^K5$77.'/$' &$% /%),8$' 0-' &$' L9$*'78$' b*%K$9' .'& .5 7- 5$F% 0-' &$% G.%K.9$'A78%.L8.% L<'' 5*8 $*'$5 /$/$K$'$' PEF''$8A <.6/$9)78 #$%&$':]*8 &$' 78B%L78$'J #$98#$*8 0$%6N/K<%$' PEF'<'9</$' L)''$' &$%A$*8 P$_'-9&7A<F9$' 0-' 5$F%$%$' 1>:>>> %$<9*7*$%8 #$%&$': Y*$ PEF'A$*8$' 9*$/$' *5 T$%$*EF 0-']-'<8$': Y$% PEF'<.6#<'& 0-' YDV 78$*/8 h$&-EF 5*8 &$% &%*88$' U-8$'A &$% P$_'-9&7A<F9J 7-&<77 %$<L8-%8_O*7EF$ ^'#$'&.'/$' *5 P$_'-9&7A<F9K$%$*EF 0-' 1´1>= SP-F%9$*8.'/$'X K*7 A.1´1>i SZ-'8<*'5$'87X '-EF *' #$*8$% R$%'$9*$/$':

Large Eddy Simulations (LES): T$* &$' M\V2]$8F-&$' #*%& '.% $*' G$*9 &$7 b*%K$97O$L8%.57 7*5.9*$%8 .'& &$% <'&$%$ G$*9 5*8 c*96$ 78<8*78*7EF$%]$8F-&$' 5-&$99*$%8: Y*$ K$*&$' ^'8$*9$ #$%&$' &.%EF $*'$ R*98$%6.'L8*-' 0-'$*'<'&$% /$8%$''8: ^97 R*98$%6.'L8*-' #*%& FB.6*/ $*' 0$%<99/5*'$%8$% +*88$%<K78<'& 0$%#$'&$8C b*%K$9J &*$ /%),$% <97 &$% +*88$%<K78<'& 7*'&J L)''$' 0-5 /$/$K$'$' '.5$%*7EF$' D$8A <.6/$9)78 #$%&$' .'& K$')8*/$' L$*' G.%K.9$'A5-&$99: b*%K$9J &*$ L9$*'$% <97 &$% +*88$%<K78<'& 7*'&J #$%&$' ''*EF8 5$F% <.6/$9)78 .'& 5N77$' 5*8 $*'$5 ;R$*'78%.L8.%<'7<8Aq 5-&$99*$%8 #$%&$': Y*$ T<7*7 &$% R$*'78%.L8.%5-&99 7*'& 78<8*78*7EF$]$8F-&$'J &*$ 5*8 $*'$%]*88$9./ &$% G.%K.9$'A *''$%F<9K &$% +*88$%A99' <%K$*8$': Y.%EF &*7]*88$9./ $'878$F$' A.7B8A9*EF$ ‘'K$L<''8$ *' &$']-&$99/9$*EF.'/$'J &*$ 5*8 c*96$ $*'$7 $5O*%*7EF$' G.%K.9$'A5-&$997 5*8 K$L<''8$' +%),$' 0$%L'NO68 #$%&$' 5N77$': Y$% $*'6<EF78$ R$*'78%.L8.%<'7<8A *78 &<7 V5</-%*'7L_2]-&$99J *' &$5 &$% *'69.77 &$% L9$*'27L<9*/$' <.6 &*$ /%-,27L<9*/$ T$#$/.'/ &.%EF $*'$ $%F)F8$ I*7L-7*8B8J &*$ 7-/: b*%K$90*7L-7*8B8J K$7EF%*K' #*%&: Y*$ b*%K$90*7L-7*8B8 *78 O%-O-%8*-'<9 A.% +*88$%#$*8$.'& &$' +$7EF#*'&*/L$*87/%<&*$'8$' &$% /%-,27L<9*/$' T$#$/.'/: M\V2V*5.9<8*-'$' 6NF%$' '.% &<'' A./.8$' \%/$K'*77$'J #$'' $*' <.7%$*EF$'& /%-,$% ^'8$*9 &$7 b*%K$97O$L8%.57 7*5.9*$%8J 78<88 5*8 &$5 %$9<8*0 $*'6<EF$' V5</-%*'7L_2^'7<8A

5-&$99*$%8J #*%&: Y*$7 6NF%8 A.% D-8#$'&*/L$*8J K$* F-F$' P$_'-9&7A<F9$' $'87O%$EF$'& 6$*'$ D$8A$ A. 0$%#$'&$'J #<7 #*$&$%.5 F-F$ PEF'A$*8$' *5O9*A*$%8: *'$ K$7-'&$%$ VEF#*$%*/L$*8 K$* M\V2]$8F-&$' 7*'& bB'&$ *5 V8%)5.'/7/$K*$8: Y*7 5N77$' %$9<8*0 6$*' <.6/$9)78 #$%&$'J .5 /$'<.$ \%/$K'*77$ K$AN/9*EF F_&%<.9*7EF$% I$%9.78$ -&$% 8F$%5*7EF$% ($''A<F9$' A. $%F<98$': Y$% P$EF$'<.6#<'& 0-' M\V2 I$%6<F%$' 78$*/8 'BF$%.'/7#$*7$ 5*8 &$5 o<&%<8 &$% P$_'-9&7A<F9: Y$7F<9K #$%&$' &*7 I$%6<F%$' K*7F$% '.% %$9<8*0 7$98$' <.6 *'&.78%*99 V8%)5.'/$' <'/$#$'&$8: W' P<F5$' &$% P$<L8-%7*EF$%F$*8 #$%&$' M\V2]-&$99$ F<.O87BEF9*EF 0-' 6%<'A)7*7EF$' [%/<'*7<8*-'$' #*$ Z\^ -&$% \&R #$*8$%$'8#*EL$98:

Statistische Turbulenzmodelle (Reynolds-Averaged Navier-Stokes = RANS und Unsteady Reynolds-Averaged Navier-Stokes = URANS): T$* &$' P^DV2]$8F-&$' #*%& '*EF8 '.% $*' G$*9J 7-'&$%' &<7 /$7<58$ VO$L8%.5 0-' &$' /%),8$' K*7 A. &$' L9$*'78$' b*%K$9' 5-&$99*$%8: Y*$7$% 78<8*78*7EF$ ^'7<8A K$*'F<98$8 &*$ ^.68$*9.'/ &$7 V8%)5.'/76$9&7 *' 5*889$%$.'& 7EF#<'L$'&$ +%),$': Y*$7$ ^.68$*9.'/ #*%& *' &*$ 78%)5.'/7K$7EF%$*K$'&$' +9$*EF.'/$' $*'/$7$8A8: Y*$7$ #$%&$' &<'' /$5*88$98: Y<7 \%/$K'*7 7*'& +9$*EF.'/$' 6N% &*$]*88$9#$%8$ &$7 Y%.EL7J &$% +$7EF#*'&*/L$*8$'J &$% G$5O$%<8.% .'& <'&$%$% %$9$0<'8$% +%),$': Y*$]*88$9#$%8$ F<K$' $*'$ /$%*'/$%$ I<%*<8*-' *' P<.5 .'& a$*8 <97 &*$ VEF#<'L.'/7#$%8$.'& L)''$' &$7F<9K <.6 /%)K$%$' D$8A$' .'& *''$%F<9K <LA$O8<K9$% P$EF$'A$*8$' '.5$%*7EF K$7EF%*$K$' #$%&$': W5 +$/$'7<8A A. YDV2 .'& M\V2]-&99' *78 $7 <.EF 5)/9*EFJ 78<8*78*7EF 78<8*-'B%$.'& 78<8*78*7EF A#$*&*5$'7*-'<9$ V8%)5.'/$' A. K$%EF'': Y.%EF &*7 I$%$*'6<EF.'/$' L<'' 7$F% 0*$9 P$EF$'A$*8 /$7O<%8 #$%&$': Y*$]*88$9.'/ F<8 h$&-EF $*'$' /%<0*$%$'&$' D<EF8$*9C Y.%EF &*$ ^'#$'&.'/ &$%]*88$9.'/70-%7EF%*68$' $'878$F$' A.7B8A9*EF$ ‘'K$L<''8$ *' &$' 78%)5.'/7K$7EF%$*K$'&$' +9$*EF.'/$' S;VEF9*$,.'/7O%-K9$5q&$% G.%K.9$'AX: Y*$7$.'K$L<''8$' (-%%$9<8*-'$' 5N77$' 5*8 c*96$ 0-' $5O*%*7EF$' G.%K.9$'A5-&$99$' 5*8 K$L<''8$' +%),$' *' I$%K*'&.'/ /$K%<EF8 #$%&$'J K$0-% $*'$ '.5$%*7EF$ M)7.'/ 5)/9*EF *78: G%-8A &*7% U%-K9$5<8*L #$%&$' &$%A$*8 5$F% <97 /$7EFB8A8$ d=v&$% ZRY 2P$EF'.'/$' *' &$% P$<L8-%2 7*EF$%F$*8 .'& *' 0$%#<'&8$' W'&.78%*$K$%$*EF$' 5*8 c*96$ 0-' 78<8*78*7EF$' G.%K.9$'A5-&99' K$%$EF'$8: Y$% +%.'& 9*$/8 *' &$5 #7'89*EF /$%*'/$%$' P$EF$'<.6#<'& /$/$'NK$% &$' M\V2 .'& YDV2^'7B8A$': b$/$' &$% /%-,$' *'&.78%*99' T$&$.8.'/ &$% P^DV2G.%K.9$'A5-&99 #*%& <.6 &*7 .'8$' '-EF 'BF$% $*'/$/<'/$':

Hybride Ansätze (DES und SAS): W' &$' 9$8A8$' f<F%$' #.%&$']$8F-&$' $'8#*EL$98J #$9EF$ &*$ I-%8$*9$ 0-' M\V2 .'& P^DV2]-&99' 0$%K*'&$': a. &*7' ^'7B8A$'

/$F)%$' &*$ Y$8<EF$& \&&_ V*5.9<8*-'7 SY\VX .'& &*$ VE<9$2^&<O8*0$ V*5.9<8*-'7 SV^VX: M\V2]-&99 F<K$' I-%8$*9$ K$* &$% T$%$EF'.'/ /%-,27L<9*/$% ^K9)7.'/$' .'& 6%$*$%J 8.%K.9$'8$% VEF$%7EF*EF8$': U%-K9$5K$%$*EF$ 0-' M\V 7*'& #<'&'<F$ V8%)5.'/$': T$* &$' P^DV2]-&$99$' *78 &*$ M</$ .5/LF%8C V*$ 7*'& /.8 6N% #<'&'<F$ V8%)5.'/$' L<9*K%*$%8J F<K$' <K$% VEF#BEF$' K$* &$% T$%$EF'./ /%-,7L<9*/$%J *'78<8*-'B%$% ^K9)7.'/$': Y*$ Y\V2 .'& V^V2]-&99 /F' &$7F<9K &$' b$/J &*$7$ K$*&$']-&99 A. L-5K*'*$%$': W' b<'&'BF$.'& #$'' &<7 0-5 P^DV2]-&$99 K$%$EF'8J 8.%K.9$'8$ MB'/$'5<77 L9$*'$% <97 &$% +*88$%<K78<'& *78J #*%& $*' P^DV2]-&$99 0$%#$'&$8: b$*8$% #$/ 0-' &$' bB'&$' .'&*' T$%$*EF$' #-&<7 8.%K.9$'8$ MB'/$'5<77 /%),$% <97 &$% +*88$%<K78<'& *78J #*%& <.6 &<7 M\V2]-&$99 .5/$7EF<98$8: Y*$7$]-&$99L9<77$ *78 %$9<8*0 '$.J K*$8$8 <K$% /.8$ U$%7O$L8*0$' A.%/$'<.$%$' T$%$EF'./ 0-' V8%)5.'/$' *' Y-#'E-5$%' ST-%O$%5*7EF.'/X .'& *' Z-'8<*'5$'87: Y$% PEF'<.6#<'& *78 #7'89*EF /$%*'/$% <97 K$* $*'$% %$*'$' M\V2 P$EF'.'/J <K$% F)F$% <97 K$* $*'$% &%$*2&*5$'7*-'<9$' 'P^DV2T$%$EF'./:

b*$ -K$' $%#BF'8J #$%&$' &*$ 5$*78$' *'&.78%*99' T$%$EF'./$' &$%A$*8 5*8 P^DV2]-&$99$' <.7/$6NF%8: Y*$7 8%*668 7-#-F9 <.6 &*$ P$<L8-%7*EF$%F$*8 <97 <.EF <.6 <'&$%$ W'&.78%*K%$*EF$ A.: Y$7F<9K #*%& &$% V8<'& &$% G$EF'*L K$AN/9*EF &*$7$%]-&$99$ '<EF6-9/$'& 'BF$% K$7EF%*$K$':

Y.%EF &$']*88$9.'/7O%-A$77 $'878$F$' *' &$' &%$* W5O.97/9$*EF./$' 7$EF7 A.7B8A9*EF$ ''K$L<''8$J &*$ 7- /$'<''8$' ;P$_'-9&77O<''./$'q]<8F$5 <8*7EF 9<77$' 7*EF &*$ P$_'-9&77O<''./$' <97 ^.8-2 -&$% (%$.AL-%%$9<8*-'$' 0-' h$#$*97 A#$* (-5O-'$'8$' &$% VEF#<'L.'/7/$7EF#*'&*/L$*8$' &<%78$99$': W' &$% \'$%/*$/9$*EF./ 8%$8$' &%$* A.7B8A9*EF$ ''K$L<''8$ <.6J &*$;8.%K.9$'8$' \'$%/*$2 KA#: bB%5$69N77$q Y*7 9<77$' 7*EF <97 (-%%$9<8*-'$' 7EF#<'L$'&$% +$7EF#*'&*/L$*87L-5O-'$'8$' .'& 7EF#<'L$'&$% G$5O$%<8.% S-&$% \'8F<9O*$X <'7EF%$*K$': Y<7 a*$9 &$% G.%K.9$'A5-&$99*$%.'/ *78J &*7 ''K$L<''8$' 5*8 K$L<''8$' +%),$'J #*$ A.5 T$*7O*$9 &$' 5*888$%$' +$7EF#*'&*/L$*8$' -&$% G$5O$%<8.%$'*' I$%K*'&.'/A.K%*'/$': Y<A./*K8$7A#$*/%.'&9$/$'&$ ^'7B8A$C

T$*5 $%78$' ^'7<8A #$%&$' <.7 &$' D<0*$%2V8-L$72+9$*EF.'/$' $e<L8$ G%<'7O-%8/9$*EF.'/$' 6N% &*$ 7$EF7 P$_'-9&77O<''./$' .'& &*$ &%$* 8.%K.9$'8$' bB%5$69N77$ <K/9*8$8: Y*$7$ +9$*EF.'/$' $'8F<98$' $e<L8$ G$%5$ 7-#*$ (-%%$9<8*-'$' F)F$%$% [%&.'/: Y*$ (-%%$9<8*-'$' F)F$%$% [%&.'/ #$%&$' &<'' G$%5 6N% G$%5 5-&$99*$%8: ^97 \'&$%/$K'*7 9*$/$' ;F<9K$5O*%*7EF$q G%<'7O-%8 2 &*66$%$'8*<9/9$*EF.'/$' 6N% &*$.'K$L<''8$' +%),$' 0-%J &*$ *' I$%K*'&.'/ 5*8 &$'

+%.'&/9$*EF.'/$' $*' /$7EF9-77$'$7 V_78$5 K*9&$': Y*7]-&$99L9<77$ #*%& <97 P$_'-9&77O<''.'/75-&$99$ -&$% ;V$E-'&]-5$'8 Z9-7.%$7qKA*EF'$8: W5 P<F5$' 0-' 78<8*78*7EF$' G.%K.9$'A5-&99' K$7*8A$' &*7 &*$ /%),8$ SO%*'A*O*99X ^99/5*'/N98*/L$*8 .'& K$')8*/$' <5 #$'*/78$' \5O*%*$: WF% D<EF8$*9 *78 $*'$%7$*87 &$% %$9<8*0 F-F$ '.5$%*7EF$ ^.6#<'&C a. &$' 6N'6 +%.'&/9$*EF.'/$' S1]<77$'$%F<92 8.'/7/9$*EF.'/J @ W5O.97/9$*EF.'/$'J 1 \'$%/*$/9$*EF.'/X /$7$99$' 7*EF #$*8$%$ '$.' G%<'7O-%8&*66$%$'8*<9/9$*EF.'/$' 6N% &*$ P$_'-9&77O<''.'/$' .'& &*$ 8.%K.9$'8$' bB%5$69N77$ 7-#*$J <.7]-&$99*$%.'/7/%N'&$'J $*'$ G%<'7O-%8&*66$%$'8*<9/9$*EF.'/ 6N% $*' 8.%K.9$'8$7 MB'/$'5<77: Y<7 %$7.98*$%$'&$ +9$*EF.'/77_78$5 *78 78<%L /$L-OO$98 .'& '*EF89*'$<%J #<7 &*$ '.5$%*7EF$ M)7.'/ 7EF#*$%*/ /$78<98$8: Y$% A#$*8$ D<EF8$*9 0-' P$_'-9&77O<''.'/75-&99' 7*'& &*$ VEF#*$%*/L$*8$' K$* &$%]-&$99*$%.'/ &$% 7-/$'<''8$' Y%.EL2VEF$%2(-%%$9<8*-'$' *' &$' $e<L8$' P$_'-9&77O<''.'/7/9$*EF.'/$': Y*$ &$%A$*8 0-%F<'&$'$']-&99 7*'& $'8#$&$% '*EF8 <.7%$*EF$'& /$'<. .'& <99/5*'/N98*/ -&$% A. L-5O9*A*$%8 .'& <.6#B'&*/ 6N% &$' *'&.78%*$99$' *'7<8A S-&$% K$*&$7X: ^.7 &*7' +%N'&$' #$%&$' P$_'-9&77O<''.'/75-&99 &$%A$*8 '.% %$9<8*0 7$98$' .'& 6N% <.7/$#BF98$ ^'#$'&.'/$'J *' &$'$' 7*$ L9<%$ I-%8$*9$ K*8'J $*'/$7$8A8: Y<A. /$F)%$' A.5 T$*7O*$9 Y%<9978%)5.'/$' .'& 8F$%5*7EF /$7EF*EF8$8$ V8%)5.'/$': T$* DPV2^'#$'&.'/$' L-''8$' &*$ P$_'-9&77O<''.'/75-&$99$ &$' F)F$%$' '.5$%*7EF$' ^.6#<'& &.%EF $%F)F8$ +$'<.*/L$*8 /$/$'NK$% &$' '<EF6-9/$'&$' K$7EF%*$K$'$' b*%K$9O*7L-7*8B875-&$99$' %$EF86$%8*/$'J 7*F A.5 T$*7O*$9 &*$ \%/$K'*77$*''$%F<9K &$7$.%-OB*7EF$' U%-h$L87 RM[ ]Wx2P:

T$*5 A#$*8$' ^'7<8A #*%& &*$ G.%K.9$'A &.%EF Y$6*'*8*-' $*'$7 +$7EF#*'&*/L$*872 .'& MB'/$'5<77$7 &$% $'$%/*$8%</$'&$'J /%-,$' b*%K$9 O<%<5$8%*7*$%8: Y<7 U%-&.L8 &$7 +$7EF#*'&*/L$*872 .'& MB'/$'5<77$7 *78 &*$ b*%K$9O*7L-7*8B8J &*$ <' h$&$% V8$99$ *5 M)7.'/7/$K*$8 .'& A. h$&$5 a$*8O.'L8 &$' *'69.77 &$% 8.%K.9$'8$' VEF#<'2 L.'/7K$#$/.'/ <.6 &<7 5*889$%$ R$9& K$7EF%$*K8: Y<7 B98$78$ b*%K$9O*7L-7*8B875-&$99 *78 &<7]*7EF.'/7#$/5-&$99 0-' U%<'&89J *' &$5 &<7 +$7EF#*'&*/L$*872 .'& MB'/$'5<77 <9/$K%<*7EF 0-%/$/K' #$%&$': Y*$ <9/$K%<*7EF$' b*%K$9O*7L-7*2 8B875-&$99$ F<K$' <K$% '.% $*'$' K$/%$'A8$' *'7<8AK$%$*EF *' A#$*&*5$'7*-'<9$' VEF$%7EF*EF8$': T$* DPV2^'#$'&.'/$' #$%&$' &$7F<9K 6<78 <.77EF9*$,9*EF]-&$99$ 0$%#$'&$8J K$* &$'$' &*$ G.%K.9$'AO<%<5$8$% 5*8 c*96$ 0-' G%<'7O-%82 &*66$%$'8*<9/9$*EF.'/$' K$7EF%*$K$' #$%&$': Y*$ K$L<''8$78$' I$%8%8% 7-9EF$%]-&$99$ 7*'& &<7 L2e2 .'& &<7 L2w2G.%K.9$'A5-&$99: T$* K$*&$']-&$99$' #*%& &<7 +$7EF#*'&*/L$*875<, &.%EF &*$ o< &%<8#.%A$9 &$% 8.%K.9$'8$' L*'$8*7EF$' \'$%/*$J LJ K$78*5 58: a.% T$78*5 5.'/ &$7 MB'/$'5<77$7 #$%&$' $'8#$&$% &*$ Y*77*O<8*-'7%<8$ &$% 8.%K.9$'8$' L*'$8*7EF$' \'$%/*$J eJ -&$% &*$ R%p'A &$% $'$%/*$8%</$'&$' b*%K$9 J

wJ 0$%#$'&$8: T$*&$] -&99 K$7*8A$' *F%$ I-%2 .'& D<EF8$*9$: Y<7 #$*8 0$%K%$*8$8$ L2e2] -&$99 F<8 VEF#BEF$' K$* &$% T$%$EF'.'/ <K9)7$'&$% V8%)5.'/$' .'& $7 *78 7EF#*$%*/J &<7] -&$99 A.% T$%$EF'.'/ &$% V8%)5.'/ *' &$% 0*7L-7$' ''8$%7EF*EF8 *' .'5*88$9K<%$% b<'&'BF$ A. $%#$*8$%': Y<7 F<.O87BEF9*EF *' &$% ^$%-&_'<5*L $*'/$7$8A8$ L2w2] -&$99 F<8 &*$7$ D<EF8$*9$ '*EF8J F<8 <K$% <' VEF$%7EF*EF8%B'&$%' 5<8F$5<8*7EF$ U%-K9$5$: ' 5 &*7 '$/<8*0$' */$'7EF<68$' A. .5/F'J #.%&$' *' &$' 9$8A8$' f<F%$' (-5K*'<8*-'$' &$% K$*&$'] -&$99$ $'8#*EL$98 .'& $*'/$7$8A8: Y<7 5*8 ^K78<'& $%6-9/%$*EF78$J L-5K*'*$%8$] -&$99 *78 &<7 VVG2] -&$99J K$* &$5 &<7 L2w2] -&$99 *' b<'&'BF$.'& &<7 L2e2] -&$99 *5 ^.,$'K$%$*EF $*'/$7$8A8 #*%&: a.7B8A9*EF #*%& *5 VVG2] -&$99 $*' 5-&*6*A*$%8$% ^'7<8A A.% T$/%$'A.'/ &$% b*%K$9O*7L-7*8B8 $*'/$7$8A8: Y<&.%EF $%/$K$' 7*EF K$77$%$ \%/$K'*77$ K$* <K/$9)78$' .'& #*$&$% <'9$/$'&$' V8%)5.'/$': Y<7 VVG2] -&$99 78$998 &$%A$*8 &$' K78' (-5O%-5*77 <.7 +$'<.*/L$*8 .'& PEF'<.6#<'& &<%: \7 #.%&$ *' &$' $.%-OB*7EF$' U%-h$L8$' \Z[P^ .'& RM[ ]Wx2P $%6-9/%$*EF <.6 U%-K9$578$99.'/$' &$% P$<L8-%7*EF$%F$*8 <'/$#$'&$8:

Y*$ 8.%K.9$'8$' bB%5$69N77$ #$%&$' K$* P^DV2] -&$99$' 5*8 c*%6$ &$7 b*%K$9&*66.7*O*8B87O%*'A*O7 K$%$EF'$8: Y*$ b*%K$9&*66.7*O*8B8 #*%& K$%EF'8J *'&$5 &*$ b*%K$9O*7L-7*8B8 &.%EF $*'$] -&$99L-'78<'8$J &*$!8.%K.9$'8$ U%<'&89A<F9; /8*98 #*%&: Y*$ 8.%K.9$'8$ U%<'&89A<F9 *78 0-5 K$8%<EF8$8$' R9.*& .'<KFB'/*/:

*' #*EF8*/$% .'& L%*8*7EF$% U.'L8 K$* &$% ^'#$'&.'/ &$% K$7O%-EF$'$' G.%K.9$'A5-&99 *78 &*$ R-%5.9*$%.'/ &$% b<'&%<'&K$&*'/.'/$': b$/$' &$% F-F$' +%<&*$'8$' &$% I<%*<K9$' *' b<'&'BF$ *78 $7 -68 '*EF8 5)/9*EFJ &*$ #<'&'<F$ V8%)5.'/ 0-9978B'&*/ <.6A.9)7$': ^97 ^KF*96$ #$%&$' &$7F<9K FB.6*/ ;b<'&6.'L8*-'$'q 0$%#$'&$8: T$* &*$7$' #*%& &$% #<'&'BEF78$ +*88$%O.'L8 *' &*$ 0-9928.%K.9$'8$J #<'&'<F$ a-'$ /9/8: Y*$ b<'&7EF.K7O<''.'/$' .'& bB%5$78%)5$ #$%&$' &<'' <.7 &$% ^''<F5$9-/<%*8F5*7EF$% +$7EF#*'&*/L$*872 .'& G$5O$%<8.%O%-6*9$ K$%$EF'$8: Y*$7$% ^'7<8A L<'' 7-#-F9 K$* A. 6$*'$' <97 <.EF K$* A. /%-K$' PEF''$8A$' A. %$9<8*0 F-F$' ''/$'<.*/L$*8$' 6NF%$'J #$7F<9K *' &$' 9$8A8$' f<F%$' 7- /$'<''8$;<.8-5<8*7EF$ b<'&6.'L8*-'$'q$'8#*EL$98 #.%&$': Y*7 7EF<98$'J h$ '<EF U-7*8*-' &$7 #<'&'BEF78$' +*88$%O.'L87 A#*7EF$' 9*'$<%$' .'& 9-/<%*8F5*7EF$' U%-6*9$': Y<&.%EF L<'' 7*EF$%/$78$998 #$%&$'J &<77 7*EF &*$ M)7.'/ K$* I$%6$*'$%.'/ &$7 P$EF$''$8A$7 '*EF8 0$%7EF9$EF8$%8:

6.3.5 Modellhierarchien für mehrphasige Strömungen

W' &*$7$5 (<O*8$9 #*%& &$% V8<'& &$% G$EF'*L K$* &$% OF_7*L<9*7EF25<8F$5<8*7EF$']-&$99*$%.'/ &%$*&*5$'7*-'<9$%J A#$*2 .'& 5$F%OF<7*/$% V8%)5.'/$' K$7EF%*K':
^.7/<'/7O.'L8 6N% &*$ 5$F%&*5$'7*-'<9$]-&$99*$%.'/ 0-' a#$*OF<7$'78%)5.'/$' *'
ZRY2]$8F-&$' *78J #*$*5 (<O*8$9 !]-&$99F*$%<%EF*$' 6N% $*'OF<7*/$ V8%)5.'/$';J &*$
L-'8*'..575$EF<'*7EF$ T$7EF%$*K.'/ 78%)5$'&$%]$&*$'J &*$ 7-#-F9 6N% Y<5O6 <97
<.EF 6N% R9N77*/L$*8$' /N98*/ *78: Y*$ %$7.98*$%$'&$' +9$*EF.'/$' K$7EF%$*K$' &*$
\%F<98.'/ 0-']<77$J W5O.97 .'& \'$%/*$ *''$%F<9K $*'$7 *'6*''8$7*5<9 L9$*'$'
I-9.5$'$9$5$'87 *5 V8%)5.'/7/$K*$8: Y*$ Y*66$%$'8*<9/9$*EF.'/$' #$%&$' &.%EF
P<'&K$&*'/.'/$' .'&J K$* *'78<8*-'B%$' V8%)5.'/$'J A.7B8A9*EF &.%EF ^'6<'/72
K$&*'/.'/$' $%/B'A8:

Y*$ '.5$%*7EF$ W'8$/%<8*-' &*$7$% +9$*EF.'/$' .'8$% ^.69)7.'/ <99$% %$9$0<'8$' a$*82
.'& +%),$'7L<9$' #*%& <97 YDV -&$% K$*]$F%OF<7$'78%)5.'/$' <.EF <97 M-E<9
W'78<'8 R-%5.9<8*-' SMWRX KA*EF'$8: W5 P<F5$' &*7% <99/5*'78$'
T$F<'&9.'/7#$*7$ 9*$/$' &*$ UF<7$'J #*$*' &$% P$<9*8BJ %B.59*EF 'K'$*'<'&$% 0-%
SA: T: +<7K9<7$' *' $*'$% R9N77*/L$*8X: Y*$ UF<7$' #$%&$' 0-' $*'$% UF<7$'2
/%$'A69BEF$ /$8%$''8J <' &$% 5*L%-7L-O*7EF$ +%$'A69BEF$'K$A*$F.'/$' /$98$'J A: T:
W5O.97K*9<'A$' .'8$% T$%NEL7*EF8*/.'/ &$% [K$%69BEF$'7O<''.'/ -&$% $'87O%$EF$'&$
T$A*$F.'/$' 6N% &$' bB%5$2 .'& V8-66NK$%/<'/:]*8 &*7%]$8F-&$ L)''$'
5*L%-7L-O*7EF$ <K$% <.EF 5<L%-7L-O*7EF$ I-%/B'/$ #*$ K$*7O*$97#$*7$ &*$ Y_'<5*L
0-' VEF*EF8$'78%)5.'/$' -F'$ -&$% 5*8 [K$%69BEF$'#$99$' -&$% &*$ T$#$/.'/ $*'$7
/%-,%B.5*/$' R9.*&0-9.5$'7 SA: T: Y<55K%.EFO%-K9$5$X 7*5.9*$%8 #$%&$': Y<K$* #*%&
&*$ U-7*8*-' &$% UF<7$'/%$'A69BEF$ %B.59*EF .'& A$*89*EF <.6/$9)78:

RN% &*$ *5 (NF9L%$*79<.6 <.68%$8$'&$' &*7O$%7$' a#$*OF<7$'78%)5.'/$'
ST9<7$'78%)5.'/$'J V*$&$0-%/B'/$J G%-O6$'78%)5.'/$'X L<'' &*$7$7 5<8F$5<8*7EF$
+$7<587_78$5 #$/$' &$% /%-,$' ^'A<F9 0-' U<%8*L$9' S!U<%8*L$9; #*%& F*$% <97
[K$%K$/%*66 6N% T9<7$' -&$% G%-O6$' 0$%#$'&$8X <99$%&*'/7 '.% 5*8 $*'$5 $e8%$5 F-F$'
^.6#<'& '.5$%*7EF *'8$/%*$%8 #$%&$': Y*$ YDV *78 &<F$% '.% 7$98$' O%<L8*7EF
<'#$'&K<%: WF% D.8A$' 9*$/8 F% &<%*'J &<77 <.7 &$5 5*L%-7L-O*7EF$' I$%F<98$' &$%
U<%8*L$9 .'& &$% G.%K.9$'A \%L$''8''*77$ 6N% &*$]-&$99*$%.'/ KA#: &*$ b$%8$ &$%
]-&$99L-$66*A*$'8$' 6N% &*$ '<EF6-9/$'& K$7EF%*K'$' 5<L%-7L-O*7EF$']-&99
/$#-''$' #$%&$' L)''$':

T$* &$' O%<e*7-%*$'8*$%8$' a#$*OF<7$'5-&$99$' #$%&$' &*$ L-5O9e' 5*L%-7L-O*7EF$' V8%)5.'/70-%/B'/$ $*'$% a#$*OF<7$'78%)5.'/ #*$ G.%K.9$'A .'& Y.%EF5*7EF.'/ &$% UF<7$' 0-' &$% 5<L%-7L-O*7EF$' Y.%EF78%)5.'/ &$% &%$*&*5$'7*-'<9$' +$-5$8%*$ &$7 (NF9L%$*79<.67 /$8%$''8 K$F<'&$98 KA#: 5-&$99*$%8: *'$ (9<77$ 0-']-&$99<'7B8A$'J &*$ 6N% %$<L8-%7O$A*6*7EF$ a#$*OF<7$'78%)5.'/$' 5*8 bB%5$2 .'& V8-66NK$%/<'/ /$$*/'$8 7*'&J K<7*$%$' <.6 &$% (-'8*'..575$EF<'*L *5 P<F5$' /$5*88$98$% ^'7B8A$: V*$ 9<77$' 7*EF NK$%7*EF89*EF *' R-%5 $*'$% c*$%<%EF*$ &<%78$99$'J 7*F T*9& m21: ^.7/<'/7O.'L8 7*'& #*$&$% &*$ \%F<98.'/7/9$*EF.'/$' 6N%]<77$J W5O.97 .'& \'$%/*$J h$&-EF #$%&$' &*7 '*EF8 &*%$L8 *'8$/%*$%8J 7-'&$%' A.0-% $*'$%]*88$9.'/ .'& ‘56-%5.'/ .'8$%A-/$': Y<%<.7 %$7.98*$%$'J h$ '<EF &$' /$8%-66$'$' I-%<.77$8A.'/$'J .'8$%7EF*$&9*EF$ L-'8*'..575$EF<'*7EF$]-&$92 /9$*EF.'/$':

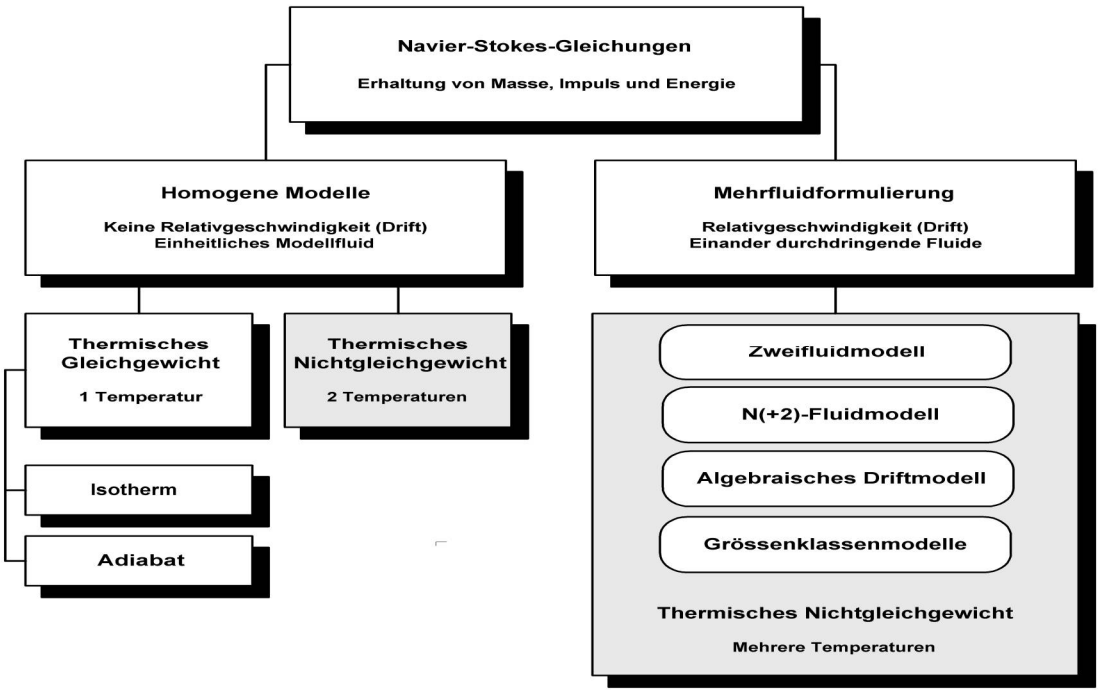


Bild 6-1: c*$%<%EF*$ &$% L-'8*'..575$EF<'*7EF$']-&$99$ 6N% a#$*OF<7$'78%)2 5.'/$' 5*8 bB%5$2 .'& V8-66NK$%/<'/
S'<EF \: M<.%*$'J 3>>@J !].98*&*5$'7*-'<9 G#-2UF<7$ R9-#]-&$99*'/ *'E9.&*'/ c$<8 <'&]<77 G%<'76$%;J *' U%-E: b-%L7F-O -' ^&0<'E$& D.5$%*E<9]$8F-&7 6-%].98*&*5$'7*-'<9]-&$99*'/ -6 G#-2UF<7$ R9-# S^VG^PXJ +<%EF*'/J +$%5<'_X

‘ ’8$% &$% I -%<.77$8A.’/J &<77 &*$ U<%8*L$9 L9$*’ /$/$’NK$% &$’ ^K5$77.’/$’ &$7 V8%)5.’/76$9&$7 7*’&J A: T: K$* &$% (-’&$’7<8*-’ L9$*’$% G%-O6$’ -&$% K$*5 *’7$8A$’ 0-’ Y<5O6K*9&.’/ K$* Y%.EL<K6<99J L<’’ &<7 UF<7$’/$5*7EF 9-L<9 <97 F-5-/$’ &.%EF5*7EF8 K$8%<EF8$8 #$%&$’ SF-5-/$’$7]-&$99J 9*’L$% ^78*’ T*9& m21X: Y*$ UF<7$’ K$7*8A$’ &<’’ 5<L%-7L-O*7EF L$*’$ P$9<8*0/$7EF#*’&*/L$*8$’ SY%*68X A.$*’<’&$%J &< &*$ L9$*’$’ U<%8*L$9 &$% V8%)5.’/ .’5*88$9K<% 6-9/$’: ^97]-&$99 #$%&$’ 9-L<9 /$5*88$98$ a.78<’&7/%),$’ SY*EF8$J +$7EF#*’&*/L$*8J G$5O$%<8.%X $*’$5 $*’F$*89*EF$’ \%7<8A69.*& S]-&$996 9.*&X A./$-%&’$8J &77’ V8-66$*/$’7EF<68$’ &$’h$’*/$’ &$7 9-L<9$’ a#$*OF<7$’/$5*7EF$7 $’87O%$EF$’: *’$ ’.5$%*7EF$ ^.69)7.’/ &$% 5*L%-7L-O*7EF$’ V8%)5.’/70-%/B’/$ *78 ’*EF8 $%6-%&$%9*EFJ &< &*7 5-&$99*$%8 #$%&$’: ^97 A.7B8A9*EF$ a.78<’&7/%),$ $%7EF$*’8 ’-EF &$% UF<7$’/$F<98 S0-9.5$8%*7EF -&$% 5<77$K$A-/$’J A: T: <97 R$.EF8/$F<98X: RN% V8%)5.’/$’ 5*8 bB%5$2 .’& V8-66NK$%/<’/J #*$ 7*$ *5 (NF9L%$*79<.6 0-’ W’8$%77 7*’&J 5.77 A.7B8A9*EF &*$ \’$%/*$K*9<’A $*’K$A-/$’ #$%&$’J #-K$* *5 8F$%5*7EF$’ +9$*EF/$#*EF8 <97 I-%<.77$8A.’/ $’8#$&$% *7-8F$%5$ -&$% <&*<K<8$ a.78<’&7B’&$%.’/ 0-%F$%%7EF8: ^’7EF<.9*EF 7O*$/$98 7*EF &<7 8F$%5-&_’<5*7EF$ I$%F<98$’ &$% a#$*OF<7$’78%)5.’/ *’ &$% &$.89*EF %$&.A*$%8$’ VEF<99/$7EF#*’&*/L$*8 #*$&$%:

^99$%&*’/7 *78 *’ O%<L8*7EF$’ ^’#$’&.’/$’ &*$ T$&*’/.’/ &$7 8F$%5*7EF$’ +9$*EF/$#*EF87 7$98$’ $%6N998J &< &$% UF<7$’NK$%/<’/ 0$%/9*EF$’ 5*8 &$’ V8%)5.’/70-%/B’/$’ FB.6*/ 0$%A)/$%8 <K9B.68: T$* <.7/$O%B/8$5 8F$%5*7EF$’ D*EF8/9$*EF/$#*EF8J #*$ $7 K$* (-’8<L8L-’&$’7<8*-’J .’8$%LNF98$5 V*$&$’ -&$% K$* Y<5O6K*9&.’/ *’ NK$%F*8A$’ R9N77*/L$*8$’ <.68%*88J #$%&$’ &$’ K$*&$’ UF<7$’ &$7F<9K .’8$%7EF*$&9*EF$ G$5O$%<8.%$’ A./$-%&’$8: ^.7/$F$’& 0-’ 0-%F<’&$’$’ (-’&$’7<8*-’72 -&$% V*$&L*5$’ L)’’$’ T9<7$’ -&$% G%-O6$’ <’#<EF7$’J #$’’ 9-L<9 &*$ VB88*/.’/78$5O$%<8.%*’ &$% R9N77*/L$*8 .’8$%2 KA#: NK$%7EF%*88$’ #*%&: W78 &$% Y<5O6&%.EL 7$F% L9$*’J #*$ A: T: K$* (<O*8<8*-’70-%/B’/$’ K$* ‘5/$K.’/78$5O$%<8.%J 7- #*%& &<7 T9<7$’#<EF78.5 &.%EF &*$ I$%&%B’/.’/ &$% &*$ T9<7$ .5/K’&$’ 8%B/$’ R9N77*/L$*8 &-5*’*$%8 SP<_9$*/F2U9$77$82]-&$99X: T$* F)F$%$’ G$5O$%<8.%$’ &$% R9N77*/L$*8 .’& 8F$%5*7EF$% Y<5O6K*9&.’/ *78 &*$]-&$99*$%.’/ &$7 bB%5NK%/<’/7 A#*7EF$’ &$’ UF<7$’ 0-’ $’87EF$*&$’&$% T$&$.8.’/: Y*7% FB’/8*5 b7’89*EF$’ 0-’ &$% T9<7$’/%),$J KA#: K$* D<77&<5O6 0-’ &$% G%-O6$’/%),$ <K: Y*$ I-%8$*9$ &*$7$7 F-5-/$’$’]-&$997 9*$/$’ *’ 7$*’$% *’6<EFF$*8J h$&-EF K$78F’ <.6/%.’& &$% /$8%-66$’$’ I-%<.77$8A.’/$’ SL$*’$ P$9<8*0/$7EF#*’&*/L$*8$’ &$% UF<7$’X *’7EF%B’2 L.’/$’ K$AN/9*EF &$% ^’#$’&K<%L$*8 <.6 <99/$5$*’$ %$<L8-%7O$A*6*7EF$ T$&*’/.’/$’:

]$*78 K$7*8A$' &*$ K$*&$' UF<7$' .'8$%7EF*$&9*EF$ +$7EF#*'&*/L$*8$'J #*$ A: T: K$*5 ^.678*$/ 0-' T9<7$' *' $*'$% R9N77*/L$*8 .'& &<7 F-5-/$'$]-&$99 L<'' '*EF8 5$F% <'/$#$'&$8 #$%&$': ^98$%'<8*0 #*%& *5 P<F5$' &$%]$F%69.*&6-%5.9*$%.'/ h$&$ UF<7$ <97 $*' $*/$'$7 R9.*& <'/$7F' S7*F %$EF8$% ^78 *' T*9& m21X: Y*$.'8$%7EF*$&9*EF$' R9.*&$ &.%EF&%*'/$' $*'<'&$% *5 /$7<58$' V8%)5.'/76$9&J 7-&<77 <' h$&$5 [%8 5$F%$%$ VB8A$0-' a.78<'&7/%),$' 0-%F<'&$' 7$*' 5N77$':W5 <99/$5$*'$' R<99 $*'$% L-5O%$77*K9$']$F%69.*&6-%5.9*$%.'/ 0-' D UF<7$' K$7*8A8 h$&$ UF<7$ $*'$' 0-9978B'&*/$' V<8A 0-' a.78<'&7/%),$' SI-9.5$'/$F<98J Y*EF8$JW5O.97 O%- I-9.5$' .'& 7O$A*6*7EF$ +$7<58$'$%/*$X: W' &*7% <99/5*'$' R-%5 *78 &<7]-&$99 h$&-EF '-EF<.6#B'&*/J7-&<77 I$%$*'6<EF.'/$' /$8%-66$' #$%&$' 5N77$':

RN% <&*<K<8$J &_'<5*7EF &-5*'*$%8$ V8%)5.'/$'J A: T: a#$*OF<7$'78%)5.'/$' SM.68J b<77$%XJ L<'' FB.6*/ &*$ *'L-5O%$77*K9$ a#$*69.*&6-%5.9*$%.'/ <'/$#$'&$8 #$%&$': V$8A8 5<' <97]-&$99 0-%<.7J &<77 $'8#$&$% &*$ T9<7$'/%),$ -&$% &$%$' ^'A<F9&*EF8$ L-'78<'8 *78J 7- $%/$K$' 7*EF /.8 $%O%-K8$ I<%*<'8$' &$7]$F%69.*&5-&$997: Y*$ P$9<8*0/$7EF#*'&*/L$*8 6-9/8 <97 P$7.98<8 &$% V*5.9<8*-' <.7 &$5 a.7<55$'7O*$9 .'8$%7EF*$&9*EF$% <' $*'$5 U<%8*L$9 <'/%$*6$'&$% (%B68$J #*$ A: T: &*$ b*&$%78<'&7L%<68J &*$ F_&%-78<8*7EF$ ^.68%*$K7L%<68J &*$ 0*%8.99]<77$'L%<68J &*$ 8.%K.9$'8$ Y*66.7*-'7L%<68J &*$ b<'&L%<68 7-#*$ &*$ F_&%-&_'<5*7EF$ o$%L%<68: Y*$7$ (%B68$ K$$*'69.77$' <.EF 5<,/$K9*EF &*$ UF<7$'0$%8$*9.'/ SV8%)5.'/76-%5X .'& 7*'& h$ '<EF ^'#$'&.'/76<99 0-' .'8$%7EF*$&9*EF$% b*EF8*/L$*8: V-5*8 $%/*K8 7*EF O%*'A*O*$99 &*$ V8%)5.'/76-%5 *' $*'$% P-F%78%)5.'/ <97 \%/$K'*7 &$% V*5.9<8*-'Q 7*$ #*%& '*EF8 0-%/$/$K$': ^99$%&*'/7 *78 $7 F$.8$ '-EF '*EF8 5)/9*EFJ <99$ HK$%/B'/$ A#*7EF$' eO%*5$'8$99 K$-K<EF8$8$' V8%)5.'/76-%5$' 5*8 c*96$ 0-' ZRY2]-&99' 0-%F$%A.7</$'J &< <99/5*' /N98*/$ &_'<5*7EF$]-&99 6N% &*$ +<72b<77$%2 b$EF7$9#*%L.'/ '-EF '*EF8 0-9978B'&*/ $'8#*EL$98 7*'&:

UF_7*L<9*7EF$]$EF<'*75$'J &*$ '*EF8 *5 V8%)5.'/76$9& 7-'&$%' <' &77' T$%<'&.'/ <K9<.6$'J #$%&$' 5*8 c*96$ 0-']-&$99%<'&K$&*'/.'/$' $%6<778J #*$ A: T: K$* $*'$5 b<'&7*$&$5-&$99:]<' .'8$%7EF$*&$8 F*$%J <K$% <.EF <99/5*' K$* UF<7$'#$EF7$9#*%L.'/75-&99'J A#*7EF$' %$*' OFB'-5$'-9-/*7EF$' I<%*<'8$'J #$9EF$ <.77EF9*$,9*EF <.6 L-%%$9*$%8$']77%/$K'*77$' K$%.F$' .'& 5$EF<'*78*7EF$']-&99'J #$9EF$ &$' V*$&$0-%/<'/ *' $*'$ R-9/$ OF_7*L<9*7EF$% I-%/B'/$.'& $'87O%$EF$'&$% G$*95-&$99$ <.68$*9$' ST9<7$'#<EF78.5J T9<7$'<K9)7.'/ 5*8 ^K7EF%EL' .'& b<%8A*8X:

Y<7 a#$*69.*&5-&$99 $'8FB98 &*$ +%.'&/9$*EF.'/$' &$% YDV <97 V-'&$%6<99 .'&*78 7-5*8 <.EF 6N% &*$ Y_'<5*L 0-' VEF*EF8$'78%)5.'/$' /$$*/'$8J <.EF *' (-5K*'<8*-' 5*8 V*$&$' -&$% (-'&$'7<8*-': Y*$]$EF<'*75$' &$% UF<7$'#$EF7$9#*%L.'/ S]<77$'2J W5O.972 .'& \'$%/*$<.78<.7EF A#*7EF$' &$' UF<7$'X 7*'& K$* *'L-5O-'$'2 8$'78%)5.'/$' *5 ^99/5*'$' 7$F% L-5O9$e .'& A.&$5 &<0-' <KFB'/*/J -K <97 U<%8*L$9 G%-O6$' *' .5/K'&$5 +<7 -&$% T9<7$' *' .5/$K$'&$% R9N77*/L$*8 0-%F<'&$' 7*'&: RN% &$' bB%5$NK$%/<'/ $*'$7 .578%)58$' U<%8*L$97 #*%& FB.6*/ &*$ P<'A2]<%7F<992(-%%$9<8*-' 0$%#$'&$8 .'& <.6 &*$ 0-9.5$'K$A-/$'$' 5<L%-7L-2 O*7EF$' +9$*EF.'/$' .5/$%EF'8:

W' $*'$% /$7EF*EF8$8$' V8%)5.'/ L)''$' <.EF T9<7$' .'& G%-O6$' /9$*EFA$*8*/ 0-%F<'&$' 7$*'J A:T: K$*5 PNEL69.77 0-' (-'&$'7<8 <.7 &$5 Y<5O6$%A$./$% &.%EF &$' F$*,$' V8%<'/ *' &$' P$<L8-%&%.ELK$FB98$%: Y<F$% #*%& K$*5 I*$%6$9&5-&$99 0-' Y%$# .'& M<F$_ A#*7EF$' T9<7$' *' R9N77*/L$*8 .'& G%-O6$' *' Y<5O6 .'8$%7EF*$&$'J 7-&<77 A#$* &*7O$%7$.'& A#$* L-'8*'.*$%9*EF$ UF<7$' K$8%<EF8$8 #$%&$': +%.'&7B8A9*EF *78 &<7]$F%69.*&5-&$99 '*EF8 <.6 &*7O$%7$ a#$*OF<7$'78%)5.'/$' K$7EF%B'L8J 7-&<77 $*'$ \%#$*8$%.'/ <.6 V8%)5.'/$' 5*8 L-5O9$e$% 9-L<9$% V8%.L8.% &$7 UF<7$'/$5*7EF$7J #*$ A:T: VEF<.578%)5.'/$' -&$% VEF*EF8$'78%)5.'/$' 5*8 F-EF8.%K.9$'8$' [K$%69BEF$'J 5)/9*EF*78:

T$* $*'*/$' V8%)5.'/$' 5*8 P$9<8*0/$7EF#*'&*/L$*8 A#*7EF$' &$' UF<7$' SY%*68X *78 #$/$' &$% ^KFB'/*/L$*8 &$% P$9<8*0/$7EF#*'&*/L$*8 0-' &$% U<%8*L$9/%),$J '*EF8 '.% &*$ [%87<KFB'/*/L$*8 &$% U<%8*L$9/%),$ 7-'&$%' <.EF &<7 U<%8*L$9/%),$'7O$L8%.5 <' h$&$5 [%8 A.K$%NEL7*EF8*/$'J*'7K$7-'&$%$ #$'' (-<9$7A$'A .'& R%</5$'8<8*-' &$% U<%8*L$9 7-#*$ &$% V8-66NK$%/<'/ SI$%&<5O6.'/ -&$% (-'&$'7<8*-'X A.$*'$% I<%*<8*-' &$% U<%8*L$9/%),$ 6NF%$': Y<7 +%),$'7O$L8%.5 L<'' 5*8 c*96$ 0-' D U-O.9<8*-'7L9<77$' &*7L%$8*7*$%8 #$%&$'J #-K$* h$&$ +%),$'L9<77$ #*$ $*'$ /$7-'&$%8$ UF<7$ K$F<'&$98 #*%&: T$*5 D@/ 2R9.*&2]-&$99 0-' G-5*_<5< 9*$/$' D &*7O$%7$ UF<7$' .'8$%7EF*$&9*EF$% U<%8*L$9/%),$.'& A#$* /$7EF*EF8$8$J L-'8*'.*$%9*EF$ UF<7$' 0-%: Y$% '.5$%*7EF$ ^.6#<'& K$*]-&$99$' 5*8 #$7$'89*EF 5$F% <97 &%$* +%),$'L9<77$' *78 h$&-EF K$8%BEF89*EFJ &< h$#$*97 L-5O9$88$ VB8A$ 0-' W5O.97/9$*EF.'/$' '.5$%*7EF *'8$/%*$%8 #$%&$' 5N77$': *'$ <'&$%$])/9*EFL$*8J &<7 +%),$'7O$L8%.5 A.&*7L%$8*7*$%$'J K78F8*' &$% ^''<F5$0-' I$%8$*9.'/76.'L8*-'$':

*'$ O%<L8*L<K9$ I$%$*'6<EF.'/ &$7]$F%69.*&2Y*66$%$'8*<9/9$*EF.'/75-&$997 K*8' <9/$K%<*7EF$]-&99J #$9EF$ <.6 $*'$% I$%'<EF9B77*/.'/ <99$% &_'<5*7EF$' \66$L8$ K$%.F$': c*$% $'86B998 &*$ '.5$%*7EF$ W'8$/%<8*-' 0-' W5O.97/9$*EF.'/$' 6N% &*$

&*7O$%7$' UF<7$'C Y<7 (%B68$/9$*EF/$#*EF8 <' h$&$5 [%8 #*%& &.%EF $*'$ <9/$K%<*7EF$ T$A*$F.'/ K$7EF%*$K$': Y*$ I<9*&*$%.'/ &*$7$%]-&$990<%*<'8$ K$6*'&$8 7*EF <99$%&*'/7 '-EF *5 ^'6<'/778<&*.5: *'$ */'.'/ 6N% <.7/$K*9&$8$ T9<7$'78%)5.'/$' *' P-F%$' -&$% (<'B9$' 7-#*$ <.6 T$FB98$%78%)5.'/$' L<'' $%#<%8$8 #$%&$'J h$&-EF '*EF8 <.6 &_'<5*7EF &-5*'*$%8$ V8%)5.'/$'J A: T:*' $*'$5 P-F%L%N55$%:

b*$&$% <'&$%$ ^'7B8A$ 0$%#$'&$' <' V8$99$ &$7 T9<7$'&.%EF5$77$%7 &*$ 7O$A*6*7EF$ UF<7$'/%$'A69BEF$ <97]-&$99O<%<5$8$%: Y*$7 F<8 &$' I-%8$*9J &<77 &*$]-&$99*$%.'/ &$% UF<7$'#$EF7$9#*%L.'/ '*EF8 5$F% <.6 &*7O$%7$ V8%)5.'/$' K$7EF%B'L8 *78J 7-'&$%' <.EF 9-L<9$ VEF<.5/$K*$8$ .56<778: RN% &$' U<%<5$8$% &$% 7O$A*6*7EF$' UF<7$'/%$'A69BEF$ L)''$'J 6<997 $%6-%&$%9*EFJ '<EF &$5 I-%7EF9</ 0-' W7F** $*'$ -&$% 5$F%$%$ G%<'7O-%8/9$*EF.'/$' S$8#< 6N% D UF<7$'/%$'A69BEF$'2(9<77$'X *'8$/%*$%8 #$%&$':

Y*$ 5$*78$' F*$% <.6/$6NF%8$' 5$F%&*5$'7*-'<9$']-&99 6N% a#$*OF<7$'78%)5.'/$' K$6*'&$' 7*EF '-EF *5 ^'6<'/778<&*.5 *F%$% \'8#*EL9.'/: T$*7O*$97#$*7$ *78 &<7 <&*<K<8$ T9<7$'78%)5.'/75-&$99 '.% 6N% 0$%&N''8$ T9<7$'78%)5.'/$' 5*8 $*'$5 0-9.5$8%*7EF$' +<7/$F<98 0-' #$'*/$% <97 E<: =vK$%$*87 #$*8 $'8#*EL$98J h$&-EF '-EF '*EF8 6N% &*EF8$ T9<7$'78%)5.'/$'J *' &$'$' &*$ b$EF7$9#*%L.'/$' A#*7EF$' K$'<EFK<%8$' T9<7$' K$&$.87<5 7*'&: Y< $*' .'*0$%7$99$7 a#$*OF<7$'2b$EF7$92 #*%L.'/75-&$99 K*7F$% '*EF8 $e*78*$%8J 5N77$' 6N% .'8$%7EF*$&9*EF$ V8%)5.'/$' h$#$*97 &*$ <5 K78' /$$*/'8' I<%*<'8$' <.7/$#BF98 #$%&$':

^99/5*' K78F8 &*$ '.5$%*7EF$ V*5.9<8*-' 0-' a#$*OF<7$'78%)5.'/$' &<5*8 *' $*'$% (-5K*'<8*-' 0-' '.5$%*7EF$% W'8$/%<8*-' .'& \5O*%*$C Y*$ &$5]$F%69.*&5-&$99 A. +%.'&$ 9*$/$'&$' +9$*EF.'/$' 9<77$' 7*EF A#<% &.%EF %B.59*EF$ -&$% A$*89*EF$]*88$9.'/ <.7 &$' D<0*$%2V8-L$72+9$*EF.'/$' <K9$*8$': Y<7 &<&.%EF $'878$F$'&$ +9$*EF.'/77_78$5 6N% h$&$ UF<7$ *78 &$' P^DV2+9$*EF.'/$' 6N% 8.%K.9$'8$ *'OF<7$'78%)5.'/$' BF'9*EF .'& $'8FB98 5$F% ''K$L<''8$ <97 +9$*EF.'/$'J *78 <97-5<8F$5<8*7EF '*EF8 /$7EF9-77$': Y<7 VEF9*$,.'/7O%-K9$5 #*%&J #*$ -K$' K$%$*87 $%#BF'8J <.6 $5O*%*7EF$ b$*7$ 5*8 c*%$ 0-']-&99' /$9)78: Y*$ A.7B8A9*EF$' G$%5$ *' &$' Y*66$%$'8*<9/9$*EF.'/$' 7*'& &*$ 8.%K.9$'8$' P$_'-9&77O<''.'/$' .'& bB%5$69N77$ 6N% h$&$ UF<7$ 7-#*$ &*$ UF<7$'<.78<.7EF8$%55$ A#*7EF$' &$' UF<7$': Y*$ G.%K.9$'A *' &$%k&$' L-'8*'.*$%9*EF$' UF<7$S'X 5.77 #*$ K$* *'OF<7$'2 78%)5.'/$' 5*8 c*%$ 0-' $5O*%*7EF$' G.%K.9$'A5-&$99$' 5-&$99*$%8 #$%&$'J #-K$* &*$ ^'#7'F$*8 &$% A#$*8$' UF<7$.'& &*$ &<5*8 0$%K.'&$'$ ^'6<EF.'/J YB5O6.'/ -&$% *'&.A*$%8$ ^'*7-8%-O*$ &$% G.%K.9$'A K$7-'&$%$]-&*6*L<8*-'$' &$%]-&99 $%6-%&$%'

L<'': Y*$ UF<7$'<.78<.7EF8$%5$ 7*'& K'6<997 .'K$L<''8 .'& 5N77$'J #*$ 7EF-' K$7EF%*$K$'J &.%EF UF<7$'2b$EF7$9#*%L.'/75-&99 6N%]<77$ SV8-66$XJ W5O.97 S(%B68$X .'& \'$%/*$SA: T: bB%5$X 5-&$99*$%8 #$%&$':

G.%K.9$'A5-&$99$ 6N% a#$*OF<7$'78%)5.'/$' K$%.F$' FB.6*/ <.6 &$' 6N% *'OF<7$'78%)5.'/$' K$L<''8$' ^'7B8A$':]<' .'8$%7EF$*&$8 A#*7EF$' <9/$K%<*7EF$']-&$99$'.'& G%<'7O-%85-&$99$'7-#*$A#*7EF$' b*%K$9O*7L-7*8B872.'& P$_'-9&77O<''.'/75-&$99$': ^97 A.7B8A9*EF$ #*EF8*/$ +%),$' 7*'& &*$ 8.%K.9$'8$ Y*66.7*-' &$% UF<7$' 7-#*$ &*$ 8.%K.9$'8$' bB%5$78%)5$A. 5-&$99*$%$': *' FB.6*/ 0$%#$'&$8$7 <9/$K%<*7EF$7 b*%K$9O*7L-7*8B875-&$99 0-' V<8- <OO%-e*5*$%8 &*$ b*%K$9O*7L-7*8B8 6N% K9<7$'*'&.A*$%8$ G.%K.9$'A 5*8 c*96$ &$7 +<7/$F<987J &$7 T9<7$'&.%EF5$77$%7 .'& &$% T9<7$'2^.678$*/$/$7EF#*'&*/L$*8: *'$ \%F)F.'/ &$% -K$' $%#BF'8$' P$_'-9&77O<''.'/$' <97 R-9/$ 0-' T9<7$' #*%& <.EF *' &$5 P$_'-9&77O<''.'/75-&$99 0-' M-O$A && T$%8-&<'-K$%NEL7*EF8*/8J 0-' &$5 $7 <.EF $*'$ L2e2]-&$990<%*<'8$ /*K8: Y</$/$' K$%NEL7*EF8*/$']-&99 6N% 7EF#$%$ U<%8*L$9 .'& G%-O6$' $*'$ P$&.A*$%.'/ &$% G.%K.9$'A KA#: \%F)F.'/ &$% Y*77*O<8*-' /$/$'NK$% *'OF<7$'78%)5.'/$': Y*$ 5$*78$' G.%K.9$'A5-&$99$ 6N% a#$*OF<7$'2 78%)5.'/$' K$6*'&$' 7*EF <99$%&*'/7 '-EF*5 \'8#*EL9.'/778<&*.5 .'& 7*'& K*7F$% '.% .'A.%$*EF$'&0<9*&*$%8:

\7 #$%&$' <.EF M\V 6N% a#$*OF<7$'78%)5.'/$' <./$6NF%8Q F*$% 9*$/8 #*$ K$* *'OF<7$'78%)5.'/$' &$% I-%8$*9 *' &$%])/9*EFL$*8J 6N% &*$ &<'' '.% '-EF $%6-%&$%9*EF$' R$*'78%.L8.%5-&99J 0$%$*'6<EF8$ ^'7B8A$ 0$%#$'&$' A.L)''$': Y*7 I-%/F'7#$*7$ *78 *'7K$7-'&$%$ &<'' 0-%8$*9F<68J #$'' <.6/%.'& /%-,%B.5*/$%J *'78<8*-'B%$% b*%K$978%.L8.%$' &*$ V*5.9<8*-' <97 A$*89*EF /$5*88$98$ V8%)5.'/ '*EF8 5$F% 7*''0-99 *78: Y$% F)F$%$ '.5$%*7EF$ ^.6#<'& *78 #$/$' &$% $%F)F8$' OF_7*L<9*7EF$' +$'<.*/L$*8 /$%$EF86$%8*/8C O%*'A*O*$99 L)''$' *'78<8*-'B%$ \66$L8$ 7*5.9*$%8 #$%&$'J &*$*' $5O*%*7EF$' G.%K.9$'A5-&$99$' '*EF8 $'8F<98$' 7*'&J A: T: &*$ b$EF7$9#*%L.'/0-' T9<7$' 5*8 /%-,%B.5*/$' G.%K.9$'A2-&$% b*%K$978%.L8.%$':

Y*7O$%7$ a#$*OF<7$'78%)5.'/$'J K$* &$'$' $*'$ L-'8*'.*$%9*EF$.'& $*'$ &*7L-'8*'.*$%9*EF$ S&*7O$%7$X UF<7$ *&$'8*6*A*$%K<% 7*'&J #$%&$' FB.6*/ <.EF 5*8 c*96$ &$% \.9$%2M</%<'/$ R-%5.9*$%.'/ 5-&$99*$%8J K$* &$% &*$ L-'8*'.*$%9*EF$ UF<7$ &.%EF &*$ D<0*$%2V8-L$72+9$*EF.'/$' .'& &*$ U<%8*L$9 5*8 &$% M</%<'/$7EF$' T$7EF%$*K.'/7#$*7$ &$% V8%)5.'/75$EF<'*L 8%<h$L8-%*$'K<7*$%8 K$7EF%*K' #$%&$': Y<A. #$%&$' $*'A$9'$ U<%8*L$98%<h$L8-%*$' *5 V8%)5.'/76$9& %B.59*EF .'& A$*89*EF 0$%6-9/8: Y*$ PNEL#*%L.'/ <.6 &<7 V8%)5.'/76$9& #*%& 5*8 c*96$ 0-' A.7B8A9*EF$'

o$%%$%5$' *' &$' (-'8 *'..57/9$*EF.'/$' K$%NEL7*EF8*/8 Sa#$*#$/$L-OO9.'/X: Y*7 I-%/F'7#$*7$ *78 '.% $66*A*$'8 6N% 0$%&N''8$ Y*7O$%7*-'$' .'& O<%8*L$9K$9<&$'$ V8%)5.'/$'J*' &$'$' b$EF7$9#*%L.'/$' A#*7EF$' &$' U<%8*L$9' L$*'$ P-99$ 7O*9': T$* &*EF8$' Y*7O$%7*-'$' 5N77$' '-EF b$EF7$9#*%L.'/$' A#*7EF$' &$' U<%8*L$9' K$%NEL7*EF8*/8 #$%&$'J A.5 T$*7O*$9 (-99*7*-'$'J #<7 '.5$%*7EF 7$F%<.6#B'&*/*78: Y*$ b*%L.'/ &$% G.%K.9$'A L<'' &.%EF *'6NF%.'/ 0-' 78<8*78*7EF$' R9.L8.<8*-'$' Sa.6<997A<F9$'X 'BF$%.'/7#$*7$ 5*8 $*'K$A-/$' #$%&$': Y*$ \.9$%2M</%<'/$ R-%5.9*$%.'/ $*/'$8 7*EF '*EF8 6N% V8%)5.'/$' 5*8 F-F$5 0-9.5$8%*7EF$5 +$F<98 &$% &*7O$%7$' UF<7$ -&$% 6N% /$7EF*EF8$8$ V8%)5.'/$' 5*8 8.%K.9$'8$'J 7EF<.5<%8*/$']*7EF.'/7A-'$'J #*$ 7*$*5 (NF9L%$*79<.6<.68%8' L)''$':

6.3.6 Numerische Verfahren

Y*$ #*EF8*/78$' \9$5$'8$ 0-' '.5$%*7EF$' I$%6<F%$' *' ZRY2Z-&$7 7*'& [%87&*7L%$8*7*$%.'/70$%6<F%$'J a$*8&*7L%$8*7*$%.'/70$%6<F%$' .'&]<8%*e9)7$%:W' &*$7$5 (<O*8$9 #*%& &$% V8<'& &$% G$EF'*L K$AN/9*EF &*7% (-5O-'$'8$' K$7EF%*$K$': ^K7EF9*$,$'& #$%&$' T$5$%L.'/$' K$AN/9*EF &$% P-K.78F$*8 .'& &$% \66*A*$'A &$% $e*78*$%$'&$' I$%6<F%$' /$5<EF8:

Ortsdiskretisierungsverfahren: T$* &$% M)7.'/ &$% O<%8*$99$' Y*66$%$'8*<9/9$*EF.'/$' 0-' *'2 .'&]$F%OF<7$'78%)5.'/ 5*8 ZRY2I$%6<F%$' #*%& &$% /$-5$8%*7EF$ PEF'%<.5 &.%EF $*'$' &*7L%8' U.'L82 -&$% I-9.5$'%<.5 $%7$8A8 SPEF'/*88$%X: Y*$ &%$* #*EF8*/78$']$8F-&$' A.% +*88$%$%A$./.'/*' L-5O9$e$' +$-5$8%*$' 7*'&C

- V8%.L8.%*$%8$ KA#: K9-EL78%.L8.%*$%8$ +*88$%*' L)%O$%<'/$O<778$' (--%&*'<8$'J
- ‘''78%.L8.%*$%8$ +*88$%J A: T: 5*8 Y%$*$EL7$9$5$'8$' .'&
- (<%8$7*7EF$ +*88$%:

Y*$ Y*7L%$8*7*$%.'/ &$% O<%8*$99$' Y*66$%$'8*<9/9$*EF.'/$' <.6 &*$7$' U.'L82 -&$% I-9.5$'%B.5$' 6NF%8 A. &*7L%8' b$%8$'J &*$ K$* 6*'*8$' Y*66$%$'A$'0$%6<F%$' <97 &*$ b$%8$ <' &$' &*7L%$8$' U.'L8$' <.6/$6<778 #$%&$' .'& K$* 6*'*8$' I-9.5$'0$%6<F%$' <97]*88$9#$%8$ <.6 &$' &*7L%$8$' I-9.5*'<:

RN% &*$ Y*7L%$8*7*$%.'/ &$% O<%8*$99$' Y*66$%$'8*<9/9$*EF.'/$' <.6 &$' &*7L%8' +*88$%' /*K8 $7*5 b$7$'89*EF$' A#$* I-%/$F$'7#$*7$': Y*$ F_O$%K-9*7EF$' I$%6<F%$' 5<EF$' *5 I$%9<.6 *F%$7 M)7.'/7O%-A$77$7 $eO9*A*8 0-' &$' %$$99$' */$'#$%8$' .'&

*/$'0$L8-%$' S&*$ OF_7*L<9*7EF$' ^.7K%$*8.'/7%*EF8.'/$'X &$7 L-'0$L8*0$' G%<'7O-%82 8$*97 &$% V8%)5.'/7/9$*EF.'/$' +$K%<.EF: V*$ 9*6%' $*' 78<K*9$7J &*7L%$8$7 V_78$5 &$% /$L-OO$98$' V8%)5.'/7/9$*EF.'/$': W' &$' $99*O8*7EF$' Y*7L%$8*7*$%.'/70$%6<F%$' #$%&$' &*$ $*'A$9'$' V8%)5.'/7/9$*EF.'/$' A.'BEF78 $'8L-OO$98 .'& '<EF$*'<'&$% /$9)78: Y*$ (-OO9.'/ A#*7EF$' &$' V8%)5.'/7/9$*EF.'/$' #*%& &<'' *8$%<8*0 #*$&$%F$%/$78$998:

Zeitdiskretisierungsverfahren: T$* &$% A$*89*EF$' Y*7L%$8*7*$%.'/ L-55$' #$/$' &$% V8$*6F$*8 &$%]-&$99/9$*EF.'/$' 6N%]$F%OF<7$'78%)5.'/$' O%<L8*7EF '.% *5O9*A*8$ I$%6<F%$' A.5 *'7<8A: Y*7 7*'& #$/$' +$'<.*/L$*872 .'& \66*A*$'A<'6-%&$%.'/$' 5*'&$78$'70-'A#$*8$% [%&'.'/:

Matrixlöser: Y.%EF &*$ Y*7L%$8*7*$%.'/ &$% V8%)5.'/7/9$*EF.'/$' $'878$F8 $*' 9*'$<%$7 +9$*EF.'/77_78$5: a. 7$*'$% M)7.'/ /*K8 $7 <.EF F*$% /%.'&7B8A9*EF .'8$%7EF*$&9*EF$ I-%/F'7#$*7$': W']<8%*eA$%9$/.'/70$%6<F%$' #*%& K$* &$% M)7.'/ &$7 9*'$<%$' +9$*EF.'/77_78$57 &*$ V8%.L8.% &$%]<8%*e 5)/9*EF78 /$7EF*EL8 <.7/$'.8A8: T$* &$% a#*7EF$'7EF%*885$8F-&$ SR%<E8*-'<9 V8$O]$8F-&X A.5 T$*7O*$9J #*%& $*' L-5O9$e$7 &%$*&*5$'7*-'<9$7 U%-K9$5 *' $*'$ R-9/$ $*'&*5$'7*-'<9$% G$*9O%-K9$5$ A$%9$/8: W8$%<8*0$ I$%6<F%$' $%A$./$' $*'$ R-9/$ 0-' ^OO%-e*5<8*-'$'J &*$ /$/$' &*$ M)7.'/ L-'0$%/*$%$':]$F%/*88$%O$%6<F%$' 0$%7.EF$' F*$%K$* &.%EF ^OO%-e*5<8*-' <.6 $*'$5 /%)K$%$' +*88$% .'& W'8$%O-9<8*-' $*'$ (-'0$%/$'AK$7EF9$.'*/.'/ A. $%%$*EF$': (-'h./*$%8$ +%<&*$'8$'0$%6<F%$' NK$%6NF%$' &*$ M)7.'/ 9*'$<%$% +9$*EF.'/$' <.6 $*']*'*5*$%.'/7O%-K9$5:

Robustheit: Y*$ M)7.'/70$%6<F%$' *' &$' 6N% &*$ P$<L8-%7*EF$%F$*8 $*'/$7$8A8$' ZRY2 Z-&$7 7*'& '<EF/$#*7'$%5<,$' %-K.78J &: F: /$$*/'$8 6N% &$' *'7<8A A.% M)7./ &$%]$F%OF<7$'78%)5.'/7O%-K9$5$ *' &$% P$<L8-%7*EF$%F$*8J 7*F A.5 T$*7O*$9 &*$ T$'EF5<%L2G$786B99$ &$7 $.%-OB*7EF$' U%-h$L87 ^VG^P:

Effizienz: *' &*%$L8$% p<'8*8<8*0$% I$%/9$*EF &$% -K$' $%#BF'8$' I$%6< F%$' K$AN/9*EF &$% \66*A*$'A *78 '.% 7$F% 7EF#$% 5)/9*EFJ &< &$% I$%/9$*EF 5$*78 O%-K9$5<KFB'/*/ *78J &: F: $*' I$%6<F%$' *78 $66*A*$'8 K$* $*'$5 K$78*558$' U%-K9$5J K$* $*'$5 <'&$%$' U%-K9$5 *78 $*' <'&$%$7 I$%6<F%$' K$77$% /$$*/'$8J .'& .5/$L$F%8: V*''0-99$% *78 $7J p<9 *8<8*0$ ^.77</$' A. 5<EF$': T$* &$% M)7.'/ 9*'$<%$% +9$*EF.'/77_78$5$ FB'/8 &*$ \66*A*$'A &$7 ^9/-%*8F5.7 A.5 T$*7O*$9 78<%L &<0-' <KJ -K &$% P$EF$'<.6#<'& '.% 9*'$<% 5*8 &$% U%-K9$5/%),$ #BEF78: ^.EF &*$ U<%<99$9*7*$%K<%L$*8 $*'$7 ^9/-%*8F5.7 *78 $'/ 5*8 &$% \66*A*$'A 0$%K.'&$' .'& F*$% K$7-'&$%7 *' I$%K*'&.'/ 5*8 &$%

VL<9*$%K<%L$*8 S9*'$<%$% VO$$&.O K$* $*'$% /%),$%$' ^'A<F9 0-' U%-A$77-%$'X: b$*8$% #*EF8*/ 6N% &*$ \66*A*$'A *78 &*$ ^'/<K$ &$% I$%6<F%$'7-%&'.'/: Y*$ I$%6<F%$' 7-998$' *5 [%8 .'& *' &$% a$*8 #$'*/78$'7 0-' A#$*8$% [%&'.'/ 7$*': b$*8$% #*EF8*/ 6N% &*$ \66*A*$'A *78 &*$ *'7$8AK<%L$*8 <&<O8*0$% +*88$%J &: F: &*$ <.8-5<8*7EF$ ^'O<77.'/ &$% &*7L%$8$' +*88$%#$*8$' <' &$' M)7.'/70$%9<.6C R$*'$ +*88$% K$* 78$*9$' M)7.'/7/%<&*$'8$'J /%-K$ +*88$% K$* 69<EF$' +%<&*$'8$':

6.3.7 Umsetzung der Ein- und Mehrphasenmodelle in CFD-Codes

Y*$ A.'BEF78 <.6 &$% +%.'&9</$ O<%8*99% Y*66$%$'8*<9/9$*EF.'/$' .'& <9/$K%<*7EF$% +9$*EF.'/$' 5*8 &$' &<A./$F)%*/$' P<'&K$&*'/.'/$' .'& $5O*%*7EF$' VEF9*$,.'/7K$A*$F.'/$' 6-%5.9*$%8$' *'2 .'&]$F%OF<7$'2]-&99 K$&N%6$' A.*F%$% E-5O.8$%/$%$EF8$' ‘57$8A.'/ $*'$% W5O9$5$'8*$%.'/ *' ZRY2Z-&$7: c*$%A. #$%&$' &*$]-&$99/9$*EF.'/$' .'& *F%$ ^'6<'/72 .'& P<'&K$&*'/.'/$' *' *F%$% &*7L%$8*7*$%8$' R-%5 5*8 /$$*/'8' U%-/%<55*$%7O%<EF$' *' $*'$' 0-' F-EF9$*78.'/76BF*/$' Z-5O.8$%' <K<%K$*8K<%$' Z-&$ NK$%7$8A8J #-K$* <97 <5 FB.6*/78$' 0$%#$'&8 U%-/%<55*$%7O%<EF$' R[PGP^D .'& ZA.5 *'7<8AL-55$':

W' $*'$% /%-K$' V_78$5<8*L L<'' K$* &$% *'8$*9.'/ 0-' ZRY2Z-&$7 A#*7EF$']$F%A#$EL2ZRY2Z-&$7 S+$'$%<9 U.%O-7$ ZRY Z-&$7X .'& <.6 $*'$' K$78*55 8$' $*'/$7EF%B'L8$' ^'#$'&.'/7K$%$*EF 7O$A*<9*7*$%8$' ZRY2Z-&$7 SVO$E*<9 U.%O-7$ ZRY Z-&$7X .'8$%7EF*$&$' #$%&$': *'$ HK$%7*EF8 NK$% 0$%6N/K<%$ L-55$%A*$99$.'& '*EF82L-55$%A*99 ZRY2Z-&$7 *78 A: T: <.6 ZRY2['9*'$ 0$%6N/K<%: ^99*' &*$ M*78$ &$% L-55$%A*99' Z-&$7 .56<778 <''BF$%'& d> *'8%B/$: Y<K$* #$%&$' h$&-EF E<: n v &$7 #$98#$*8$']<%L8<'8$*97 <' 9*A$'A*$%8$% ZRY2V-68#<%$ 0-' &$' V-68#<%$O<L8' RM‘\DGJ ZRx.'& VG^P 2ZY <K/$&$EL8:

Mehrzweck-CFD-Codes

]$F%A#$EL2ZRY2Z-&$7 #*$ A.5 T$*7O*$9 &*$ -K$' /$'<''8$' L-55$%A*99' U%-/%<55O<L8 F<K$' 7*EF *' &$' 9$8A8$' A$F' f<F%$' A. <'$%L<''8$' .'& <.6 0*$%B98*/$ b$*7$ /$'.8A8$' b$%LA$./$' *' R-%7EF.'/ .'& \'8#*EL9.'/J*5 \'8#.%6 .'& &$% ^.79$/.'/ 0-' T<.8$*9$' .'& *' &$% [O8*5*$%.'/ 6N% $*'OF<7*/$ V8%)5.'/7O%-K9$5$ *' V8%)5.'/75<7EF*'$'J b<77$%L%<68<'9</$'J ^$%-&_'<5*L .'& ^.8-5-K*9K<. $'8#*EL$98: V*$ 6*'&$' <.EF ^'#$'&.'/ K$* 5$F%OF<7*/$' V8%)5.'/7O%-K9$5$' &$% \'$%/*$2 .'& I$%6<F%$'78$EF'*L:

]$F%A#$EL2ZRY2Z-&$7 A$*EF'$' 7*EF &<&.%EF <.7J &<77 5*8 &*7' Z-&$7 0$%7.EF8 #*%&J $*' 5)/9*EF78 K%$*8$7 VO$L8%.5 0-' 78%)5.'/75$EF<'*7EF$' ^.6/<K$'78$99.'/$' 6N% $*'2 .'& 5$F%OF<7*/$ ^'#$'&.'/76B99$ 5*8 &$' *' &$' ZRY2Z-&$7 $'8F<98$'$']-&$99$' <KA.&$EL$': Y*$ 5$*78$']$F%A#$EL2ZRY2Z-&$7 $'8F<98$' &<F$% $*'$ I*$9A<F9 <' G.%K.9$'A5-&99'J 0$%7EF*$&$'$]-&99 6N% &*$ \.9$%2\.9$%2 .'& \.9$%2 M</%<'/$2V*5.9<8*-' 0-']$F%OF<7$'78%)5.'/$'J]-&$99$ A.% T$%$EF'.'/ 0-' /$7EF*EF8$8$' V8%)5.'/$' 5*8 6%$*$% [K$%69BEF$J]-&99 A.% V*5.9<8*-' 0-' I$%K%$''.'/ .'& EF$5*7EF$' P$<L8*-'$'J V8%<F9.'/7#B%5$8%<'7O-%8 7-#*$ bB%5$2 .'& V8-66NK$%/<'/ *' $*'OF<7*/$']$F%L-5O-'$'8$'2 .'&]$F%OF<7$'78%)5.'/$': b$*8$%$ #7'89*EF$ */$'7EF<68$' 0-']$F%A#$EL2ZRY2Z-&$7 7*'&C

- R9$e*K9$ +$-5$8%*$&<%78$99.'/ .'& +*88$%/$'$%*$%.'/J
- I$%#$'&.'/ .'78%.L8.%*$%8$% .'& F_K%*&$% P$EF$''$8A$J K$78F'& <.7 c$e<$&$%'J G$8%<$&$%'J U%*75$'J U_%<5*&$'J
- ^'K*'&.'/<' Z^Y2R-%5<8$ &$% 5<%L86NF%$'&$' ^'K*$8$%J
- '.8A$%6%$.'&9*EF$7 U%$2 .'& U-78O%-E$77*'/J .'8$%78N8A8 &.%EF /%<6*7EF$ D.8A$%2 -K$%69BEF$'J &*$ <.EF]$EF<'*75$' A.% P$&.A*$%.'/ 0-' ^'#$'&$%6$F9$%' K$%$*878$99$'J
- 9<'/6%*78*/$ I$%6N/K<%L$*8 &$7 Z-&$7 <.6 $*'$% I*$9A<F9 0-' .'8$%78N8A8$' P$EF'$%O9<886-%5$'J
- T$'.8A$%.'8$%78N8A./ .'& Y-L.5$'8<8*-'J
- V-68#<%$O69$/$.'& 2#$*8$%$'8#*EL9.'/ $'87O%$EF$'& &$% D.8A$%<'6-%&$%.'/$' .'& &$5*'8$%'<8*-'<9$' V8<'& &$% G$EF'*LJ
- T$%$*878$99.'/ 0-' VEF'*8878$99$' A.% W5O9$5$'8*$%.'/ $*/$'$% G$*95-&99 &.%EF ^'#$'&$% SA: T: 'V\P2R[PGP^DXJ
- T$%$*878$99.'/ 0-' 78<'&<%&*7*$%8$' VEF'*8878$99$' A.% (-OO9.'/ 5*8 $e8$%'$' U%-/%<5 57_78$5$' A.% +*88$%/$'$%*$%.'/J I*7.<9*7*$%.'/J R9.*&2V8%.L8.%2(-OO9.'/J V8%)5.'/7<L.78*LJ]</'$8-F_&%-&_'<5*L .'&<'&$%$' ^'#$'&.'/$'J
- I$%6N/K<%L$*8 &$% ZRY2Z-&$7 *' !$*'/$6%-%$'$'; V-68#<%$2I$%7*-'$' <97 $*'$ #7'89*EF$ I-%<.77$8A.'/ 6N% 9<'/6%*78*/ %$O%-&.A*$%K<%$ V*5.9<8*-'7%$EF'.'/$' SL$*'$!/9$*8$'&$; R-%8$'8#*EL9.'/ &$7 Z-&$7X:

Y$%]$F%A#$ELEF<%<L8$% &*7% ZRY2Z-&$7 6NF%8 <.6 &$% $*'$' V$*8$ A. $*'$% /%-,$' ^'A<F9 0-' *' &*$7$' Z-&$7 0$%6N/K<%$']-&99'J L<'' <K$% <.6 &$% <'&$%$' V$*8$ <.EF &<A. 6NF%$'J &<77]-&$99$ 6N% K$78*5 58$ F-EF7O$A*<9*7*$%8$.'& 7$98$' K$')8*/8$ V8%)5.'/7<'#$'&.'/$' *' &*7' ZRY2Z-&$7 NK$% $*'$' 9B'/$%$' a$*8%<.5 '*EF8 0$%6N/K<% 7*'&: Y*$ Z-&$2+$'$%<9*7*$%.'/J &*$ R9$e*K*9*8B8 *' &$% Z-&$2^'#$'&.'/ <.6 .'8$%7EF*$&9*EF78$ V8%)5.'/76-%5$' .'& ^'#$'&.'/$' .'& &*$ /%-,$ ^'A<F9 0-' .'8$%78N8A8$' G$*95-&$99$' 6NF%8 A. $*'$% F-F$' (-5O9$e*8B8 &$7 ZRY2Z-&$7J &*$ 7*EF /$/$'NK$% &$' *5 6-9/$'&$' ^K7EF'*88 K$F<'&$98$' 7O$A*<9*7*$%8$' ZRY2Z-&$7*' $*'$% /$%*'/$%$' \66*A*$'A KA#: PEF'/$7EF#*'&*/L$*8 *' &$%<%8*/$' 7O$A*<9*7*$%8$' ^'#$'&.'/$' S#*$ A: T: YDV' '*$&$%7EF9</$' L<'': W5 *'A$%<99 L<'' &*$ W5O9$5$'8*$%.'/ '$.$% 6-%8/$7EF%*88$'$%]-&99 &.%EF &*$ (-5O9$e*8B8 $*'$7]$F%A#$EL2ZRY2Z-&$7 $%7EF#$%8 -&$% 0$%A)/$%8 #$%&$':

Spezialisierte CFD-Codes

Y*$ *5 0-%*/$' ^K7EF'*88 0-%/$78$998$']$F%A#$EL2ZRY2Z-&$7 A*$9$' &<%<.6 <KJ $*' K%$*8$7 VO$L8%.5 0-' 8$EF'*7EF$' ^'#$'&.'/$' A.0$%9B77*/ K$%EF'' A. L)''$':W5 +$/$'7<8A &<A. 7*'& 7O$A*<9*7*$%8$ ZRY2Z-&$7 <.6 7O$A*6*7EF$ ^'#$'&.'/$' A./$7EF'*88$' .'& 6N% &*7 #$*8$78/F'& -O8*5*$%8: Y*$ [O8*5*$%.'/ L<'' &<K$* 5$F%$%$ ^7O$L8$ K$8%$66$'J #*$ A: T: &*$ +$'<.*/L$*8 &$7 '.5$%*7EF$' I$%6<F%$'7 SR$F9$%-%&'.'/X -&$% &*$ VO$*EF$%O9<8A$66*A*$'A: W' &$' 5$*78$' RB99$' $%6-9/8 &*$ [O8*5*$%.'/ h$&-EF F*'7*EF89*EF &$% P$EF$'/$7EF#*'&*/L$*8:

Y*7 [O8*5*$%.'/ #*%& '-8#$'&*/$%#$*7$ &.%EF *'7EF%B'L.'/$' $%L<.68: Y*$ *'7EF%B'L.'/$' L)''$' &<K$* &*$ <KA.K*9&$'&$ +$-5$8%*$ SA: T: p<&$%6)%5*/ -&$% A_9*'&%*7EFXJ &<7 +*88$%'$8A SFB.6*/ 78%.L8.%*$%8XJ <K$% <.EF &*$ UF_7*L .'& &*$ A.% I$%6N/.'/ 78$F$'&$']-&99 K$8%$66$': T$7O*9 &<6N% 7*'& &*$ T$7EF%B'L.'/ <.6 L-5O%$77*K9$ -&$% *'L-5O%$77*K9$ V8%)5.'/$' .'& &*$ I$%#$'&.'/ &$% D<0*$%2 V8-L$72+9$*EF.'/$' 5*8 L-'78<'8$' V8-66#$%8$' -&$% &*$ I$%#$'&.'/ &$% \.9$%2 +9$*EF.'/$': T$AN/9*EF &$%]-&$99*$%.'/ 0-']$F%OF<7$'78%)5.'/$' K$7EF%B'L$' 7*EF 7O$A*<9*7*$%8$ ZRY2Z-&$7 FB.6*/ $'8#$&$% <.6 &<7 \.9$%2\.9$%2]-&$99 Sa#$*69.*&5-&$99XJ &<7 \.9$%2M</%<'/$2]-&$99 -&$% <.6 &*$ YDV 5*8 I$%6-9/.'/ &$% UF<7$'/%$'A69BEF$:

VO$A*<9*7*$%8$ ZRY2Z-&$7 #$%&$' *5 ^99/$5$*'$' <' ''*0$%7*8B8$' -&$% R-%7EF.'/7$*'%*EF8.'/$' $'8#*EL$98 .'& $*'/$7$8A8: V*$ K*9&$' &*$ T<7*7 6N% &*$

\'8#*EL9.'/ 0-' '$.$' '.5$%*7EF$']$8F-&$' S<L8.$99 A:T: &*$ +*88$%2T-98A5<''2]$8F-&$.'& &*$ M$0$92V$82]$8F-&$X .'& OF_7*L<9*7EF$']-&99'J &*$ &<'' '<EF ^.7%$*6.'/ .'& I$%*6*A*$%.'/ A$*89*EF 0$%A)/$%8 *']$F%A#$EL2ZRY2Z-&$7 *5O9$5$'8*$%8 .'& 7- 6N% 8$EF'*7EF$ V8%)5.'/7O%-K9$5$.'& $*'$' K%$*8$' ^'#$'&$%K$%$*EF 0$%6N/K<% /$5<EF8 #$%&$': ‘5/LF%8 L<'' &*$.'K$6%*$&*/$'&$ HK$%$*'78*55.'/ &$% \%/$K'*77$ 0-']$F%A#$EL2ZRY2Z-&$7 5*8 \eO$%*5$'8$' <.6A$*/$'J #- T$&<%6 <' 0$%K77%8$']-&$99$' K$78$F8: D$K$' /%.'&9$/$'&$' eO%*5$'8$99$' ‘'8$%7.EF.'/$' F<8 7*EF &<K$* *' &$' 9$8A8$' K$*&$' f<F%A$F'8$' *'7K$7-'&$%$ &*$ YDV 0-' $*'OF<7*/$' .'& 5$F%OF<7*/$' V8%)5.'/$' 5*8 7O$A*<9*7*$%8$' ZRY2Z-&$7 <97 $*' #$%80-99$7 b$%LA$./ 6N% &*$ \'8#*EL9.'/ 0$%K$77$%8$% OF_7*L<9*7EF$%]-&$99$ SA:T: 0-' G.%K.9$'A5-&$99$'X $8<K9*$%8: VO$A*<9*7*$%8$ ZRY2Z-&$7 .'&]$F%A#$EL2 ZRY2Z-&$7 78F' &<5*8 *' $*'$% 7*EF $%/B'A$'&$' .'& K$6%.EF8$'&$' b$EF7$9#*%L.'/:

6.3.8 Qualitätskontrolle

Y< ZRY2T$%$EF'.'/$' *' &$% P$<L8-%7*EF$%F$*8 7*EF$%F$*87L%*8*7EF$ ^'<9_7$' K$*'F<98$'J 5.77 5$F% +$#*EF8 <.6 &*$ a.0$%9B77*/L$*8 .'& o<9*8B8 &$% \%/$K'*77$ /9/8 #$%&$' <97 *' <'&$%$' ^'#$'&.'/7/$K*8': ^.7 &*$7$5 +%.'&$ #.%&$' *' &$' 9$8A8$' f<F%$' *' 0$%7EF*$&$'$' W'&.78%*$K$%$*EF$' T$78 U%<E8*E$ +.*&$9*'$7 STU+7X 6N% &*$ ^'#$'&.'/ 0-' ZRY2I$%6<F%$' $'8#*EL$98: Y*7 TU+7 &*$'$' <97 b$%LA$./ A.% o<9*8B877*EF$%.'/ .'& <97 b*77$'77O$*EF$%: V*$ 7-99$' &.%EF 78B'&*/ 0$%K77%8$ ZF$EL9*78$' .'&]-&$99$5O6$F9.'/$' <.EF &<A. K$*8%</$'J &<77 K$* T$<%K$*8.'/ &$%7$9K$' ZRY2^.6/<K$ &.%EF .'8$%7EF*$&9*EF$ T$<%K$*8$% #$*8/F'& *&$'8*7EF$ \%/$K'*77$ $%A*$98 #$%&$': Y*$7*78 5-5$'8<' '*EF8*55$% &$% R<99:

TU+7 6N% <99/5*'$ ZRY2^'#$'&.'/$' #.%&$' *' &$' 9$8A8$' f<F%$' 0-' &$% \.%-O$<' Z-55.'*8_ 6-% R9-#J G.%K.9$'E$ <'& Z-5K.78*-' S\PZ[RG^ZX .'& 0-5 ^5$%*E<' W'78*8.8$ 6-% ^$%-'<.8*E7 .'& ^78%-'<.8*E7 S^W^^X $'8#*EL$98 .'& <'/$#$'&$8: RN% &*$ 7O$A*$99$' T$9<'/$ &$% ZRY *' &$% P$<L8-%7*EF$%F$*8 #.%&$' *5 P<F5$' &$7 $.%-OB*7EF$' U%-h$L87 \Z[P^ TU+7 $'8#*EL$98 .'& <.6 UGV2%$9$0<'8$ V8%)5.'/$' .'& V8%)5.'/$' *5 V*EF$%F$*87K$FB98$% 0-' Y%.EL#<77$%%$<L8-%$' <'/$#$'&$8: Y*7 TU+7 #.%&$' <.EF *' <'&$%$' U%-h$L8$' #*$ RM[]Wx2P .'& &$5 ZRY2I$%K.'& A.%]-&99'8#*EL9.'/ .'& I<9*&*$%.'/ 6N% $*'2 .'& A#$*OF<7*/$ V8%)5.'/$' 0$%#$'&$8: Y<%NK$% F*'<.7 #$%&$' /$/$'#B%8*/ *5 P<F5$' $*'$% [\ZYkD\^ ^%K$*87/%.OO$ 7O$A*6*7EF$ P*EF89*'*$' 6N% &*$ ^'#$'&.'/0-' ZRY *' &$% ($%'8$EF'*L $%<%K$*8$8:

*' #*EF8*/$7 (-'A$O8 *' &$' \Z[P^ TU+7 *78 &<7 U%*'A*O $*'$% R$F9$%F*$%<%EF*$: Y*7 K$7</8J &<77 0-% &$5 I$%/9$*EF 0-' P$EF'.'/$' .'&]$77.'/$' <99$ '.5$%*7EF$' R$F9$% p<'8*6*A*$%8 .'& /$/K'$'6<997 5*'*5*$%8 #$%&$' 7-99$': Y<&.%EF #*%& $7 5)/9*EFJ '.5$%*7EF$ R$F9$% .'&]-&996F9$% /$8%$''8 A. K$8%<EF8$' .'& 78*EFF<98*/$ VEF9.776-9/$%.'/$' NK$% &<7]-&$990$%F<98$' .'& &<7 I$%F<98$' &$7 '.5$%*7EF$' I$%6<F%$'7 A. /$#*''$': Y*$7$7 I-%/$F$' *78 *'7K$7-'&$%$ 6N% &*$ I<9*&*$%.'/ 0-']-&$99$' #*EF8*/J &< 7-'78 &.%EF I$%5*7EF.'/ 0-' D.5$%*L2 .'&]-&996F9$%' 6<97EF$ \5O6$F9.'/$' K$AN/9*EF &$% M$*78.'/76BF*/L$*8 .'& &$5 *'7<8AK$%$*EF 0-']-&$99$' /$5<EF8 #$%&$' L)''$':

^5 ^'6<'/ $*'$% ZRY2P$EF'.'/ 78$F8 &*$ \%A$./.'/ 0-' P$EF$''$8A$' <.6 &$% T<7*7 $*'$7 +$-5$8%*$5-&$997: T$* /$/K'$% +*88$%O.'L8A<F9 F<8 &*$!o<9*8B8q &$% PEF''$8A$ $*'$' F-F$' *'69.77 <.6 &*$ +N8$ &$% \%/$K'*77$: Y*$ o<9*8B8 0-' PEF''$8A$' #*%& <' U<%<5$8$%' +*88$%#*'L$9J MB'/$'0$%FB98'*77$ <'$*'<'&$%2 /%$'A$'&$% a$99$'J VL<9*$%K<%L$*8 7-#*$ <'&$%$% U<%<5$8$% /$5$77$': Y*$ \Z[P^ TU+7 /K' &$8<*99*$%8$ W'6-%5<8*-'$'J #$9EF$ +%$'A#$%8$ 6N% &*7 U<%<5$8$% $*'/$F<98$' #$%&$' 7-99$'J.5 p<9*8 <8*0 F-EF#$%8*/$ \%/$K'*77$A. $%A*$9$':

Y*$ \Z[P^ TU+7 $'8F<98$' &<%NK$% F*'<.7 U%-A$&.%$' A.% o<'8*6*A*$%.'/ 0-' W8$%<8*-'72 .'& Y*7L%$8*7*$%.'/76$F9$%' 7-#*$ P*EF89*'*$' A.% ^.7#<F9 0-']-&$99$' S#*$ G.%K.9$'A2J bB%5$NK$%/<'/72 .'&]$F%OF<7$'5-&$99$'X: a.&$5 #$%&$' P*EF89*'*$' A.% T$#$%8.'/ 0-' eO%*5$'8$99$' Y<8$' /$/K':

6.3.9 Zukünftige Anwendungsbereiche und Defizite von CFD-Verfahren

Zukünftige Anwendungsbereiche

Y.%EF &*$ 78B'&*/ #<EF7$'&$ M$*78.'/76BF*/L$*8 0-' PEF'%' *78 &$% *'7<8A 0-' ZRY2I$%6<F%$' A.% &%$*&*5$'7*-'<9$' V*5.9<8*-' 0-' $*'2 .'& 5$F%OF<7*/$' V8%)5.'/72 .'& bB%5$NK$%/<'/7OFB'-5$'$'J &*$ K$* &$% T$.%8$*9.'/ 0-' %$<L8-%7*EF$%F$*87%$9$0<'8$' ^K9B.6$' $*'$ #*EF8*/$ P-99$ 7O*9'J *' A.'$F5$'&$5]<,$ 5)/9*EF: Y*$ [\ZY2^%K$*87/%.OO$' F<K$' $*'$ M*78$ 0-' U%-K9$5$' $%78$998J #$9EF$ &*$ ^'#$'&.'/ 0-' ZRY *' &$% P$<L8-%7*EF$%F$*8 $%6-%&$%': Y*7 K$*'F<98$' V8%)5.'/7OFB'-5$'$J &*$ *5 P*'/%<.5J *' &$' L<98$' .'& F$*,$' V8%B'/$' &$7 U%*5B%L%$*7$7 .'&*5 P$<L8-%L$%' 0-' ($%'%$<L8-%$' <.68%$8$'J #*$A.5 T$*7O*$9C

- T-%0$%5*7EF.'/ S$*'OF<7*/XJ
- U%$77.%*A$& GF$%5<9 VF-EL7 S$*'2.'& A#$*OF<7*/XJ
-]<8$%*<9$%5N&.'/ &.%EF 8F$%5*7EF$ VO<''.'/$' S$*'OF<7*/XJ
- ($%'*'78<K*9*8B8*5 VbP SA#$*OF<7*/XJ
- P$2R9--&*'/ SA#$*OF<7*/XJ
- 9-L<9$ UFB'-5$'$J &*$ A. cN99%-F%7EFB&$' 6NF%$' S$*'OF<7*/XJ
- Y$K%*7LNF9.'/ .'& VEF5$9A0%8$*9.'/ *5 .'8$%$' U9$'.5 S5$F%OF<7*/X:

Y*$ /$/$'#B%8*/ 0$%6N/K<%$' ZRY2Z-&$7 L)''$' /%.'&7B8A9*EF <.6 &*7 RB99$ <'/$#$'&$8 #$%&$'J K$7*8A$' <K$% '-EF Y$6*A*8$J #$9EF$ &*$ ^'#$'&.'/ $'8#$&$% 7$F% 8$.$% 5<EF$'J -&$% &.%EF #$9EF$ &*$ \%/$K'*7/$'<.*/L$*8 .'& I-%F$%7</$L%<68 '*EF8 &$' \%#<%8.'/$' KA#: ^'6-%&$%.'/$' $'87O%*EF8: Y*$7$ Y$6*A*8$ #$%&$' '<EF6-9/$'& &*7L.8*$%8: V*$ 78$99$' /9$*EFA$*8*/ &*$ T<7*7 6N% &*$ &*7L.8*$%8$' '-8#$'&*/$' b$*8$%$'8#*EL9.'/$' &<%:

Defizite von CFD-Verfahren

RN% $*'OF<7*/$ V8%)5.'/$' K$78F' &*$ F<.O87BEF9*EF$' Y$6*A*8$ *' &$% G.%K.9$'A5-&$99*$%.'/ 6N% &*$ *' &$% P$<L8-%7*EF$%F$*8 8_O*7EF$' *'78<8*-'B%$' V8%)5.'/$' 7-#*$ 6N% V8%)5.'/$' .'8$% &$5 *'69.77 0-' ^.68%*$K7L%B68$': T$* *'78<8*-'B%$' V8%)5.'/$' /*K8 $7 &*$])/9*EFL$*8J &*$ $e*78*$%$'&$' 78<8*78*7EF$']-&$99$ *'78<8*-'B% A. K$8%$*K$' S‘P^DVXJ M\V2P$EF'.'/$' <.7A.6NF%$' -&$% &*$ '$.$%$' F_K%*&$' ^'7B8A$ #*$ Y\V -&$% V^V A. 0$%#$'&$': \%78$ \%6<F%.'/$' A$*/$'J &<77 ‘P^DV2]-&$99$ R9.L8.<8*-'7K$#$/.'/$' *' &$% *'78<8*-'B%$' V8%)5.'/ FB.6*/ A. 78<%L &B5O6$' .'& &$7F<9K A. ‘''/$'<.*/L$*8$' 6NF%$': Y$% *'7<8A 0-' M\V2]-&$99$' *78 <'&$%$%7$*87 #$/$' &$% A. F-F$' VO$*EF$%O9<8A2 .'& PEF'A$*8<'6-%&$%.'/$' -68 .'%$<9*78*7EF: b$%&$' M\V2]-&99<.6A./%-K$' D$8A$' $*'/$7$8A8J L)''$' BF'9*EF$ -&$% 7-/<% /%),$%$ ^K#$*EF.'/$' A.]$77&<8$' $'878$F$' <97 K$* &$% I$%#$'&.'/ 0-' ‘P^DV2]-&$99$': Y*$ '$.$%$']-&$99$ #*$ V^V -&$% Y\V 7*'& O%*'A*O*$99 0*$9 0$%7O%EF'&J #.%&$' <K$% '-EF '*EF8<.6 U%-K9$5$ &$% P$<L8-%7*EF$%F$*8<'/$#$'&$8:

^.68%*$K7L%B68$J &*$ 6N% &*$ D<8.%L-'0$L8*-' #*EF8*/ 7*'&J L)''$' &*$ G.%K.9$'A78%.L8.% .'& &<7 5*889$%$ V8%)5.'/70$%F<98$' 78<%L K$$*'69.77$': Y$% *'69.77 0-'

^.68%*$K7L%B68$' #*%& *' &$' 0-%9*$/$'&$' P^DV2]-&99' NK$%#*$/$'& &.%EF F$.%*78*7EF$ *'/%*66$ *' &*$ MB'/$'5<77/9$*EF.'/ 5-&$99*$%8: Y<K$* 7*'& .'8$%2 7EF*$&9*EF$]-&99 6N% F-%*A-'8<9 .'& 0$%8*L<9 /$7EF*EF8$8$ V8%)5.'/$' '-8#$'&*/: Y*7 V*8.<8*-' *78 .'K$6%*$&*/$'& .'& 6NF%8 A. /%-,$' ^'#$'&.'/7.'7*EF$%F$*8$': \7 *78 '-8#$'&*/J*' &*$7$5 T$%$*EF <99/$5$*'/N98*/$%$ ^'7B8A$ A. $'8#*EL$9'J*' &$'$' &$% HK$%/<'/ &*%$L8 K$F<'&$98 #*%&:

*' #*EF8*/$% U.'L8 K$8%*668 &*$]-&$99*$%.'/ 0-' *'K<.8$' *5 P$<L8-%: Y< &*7 FB.6*/ '*EF8 &.%EF &<7 PEF'/*88$% <.6/$9)78 #$%&$' L)''$'J #$%&$' 7*$ /9-K<9 &.%EF 7-/$'<''8$;O-%)7$]$&*$'q5-&$99*$%8: Y*$ b$EF7$9#*%L.'/ &$% ;6%$*$'qV8%)5.'/ 5*8 &$% V8%)5.'/ *' O-%)7$']$&*$' .'& &*$ T$$*'69.77.'/ &$% G.%K.9$'A .'& &<5*8 &$% Y%.EL2 .'& bB%5$0$%9.78$ &.%EF &*$ O-%)7$']$&*$' K$&<%6 '-EF /$'<.$%$' ''8$%7.EF.'/$'J.5 $*'$&*7 ^'#$'&.'/7.'7*EF$%F$*8 <.7A.7EF<98$':

T$* &$' 5$F%OF<7*/$' V8%)5.'/$' #.%&$' *' &$' 9$8A8$' f<F%$'J.'8$% <'&$%$5 <.EF &.%EF &*$ ^%K$*8$' *' &$5 '<8*-'<9$' ZRY2I$%K.'&J &$.89*EF$ R-%87EF%*88$ K$* &$%]-&$99*$%.'/ 0-' &*7O$%7$' a#$*OF<7$'78%)5.'/$' /$5<EF8: Y<A. /$F)%$' T9<7$'2 .'& G%-O6$'78%)5.'/$': \7 /*K8 <K$% '-EF #$*8$%$J 6N% &*$ P$<L8-%7*EF$%F$*8 #*EF8*/$ a#$*OF<7$'78%)5.'/$'J 6N% &*$ L$*'$ K*7 #$'*/ \%6<F%.'/$' 0-%9*$/$'J #*$ A.5 T$*7O*$9 U6%-O6$'78%)5.'/$'J P*'/7O<9878%)5.'/$'J F-%*A-'8<9$ (<'<92 .'& P-F%78%)5.'/$' 5*8 b$99$'K*&.'/ .'& VEF<.578%)5.'/$':

U%-K9$5$ 8%8' A.5 T$*7O*$9 K$* F)F$%$' +<7/$F<98$' <.6J &< &<'' *' &$% P$/$9 +<7K9<7$' 5*8 .'8$%7EF*$&9*EF$' Y.%EF5$77$%' 0-%9*$/$' .'& (-<9$7A$'A .'& R%</5$'8<8*-' &$% T9<7$' A. 5-&$99*$%$' 7*'&: Y*$ \%/$K'*77$.'8$%7EF*$&9*EF$%]-&$99$ 6N% (-<9$7A$'A .'& R%</5$'8<8*-' 0-' T9<7$' .'8$%7EF$*&$' 7*EF .5 +%),$'-%&'.'/$': Y*$ /N98*/$ I<9*&*$%.'/ <' \eO$%*5$'8$' 78$F8 '-EF <.7: b$*8$%F*' $%F)F8 7*EF &*$ (-5O$e*8B8 &$%]-&$99*$%.'/ &.%EF &*$ ^KFB'/*/L$*8 &$% b$EF7$9#*%L.'/78$%5$ 0-' &$% T9<7$'/%),$: T$7-'&$%7 #*EF8*/ *78 &<K$* &*$ ^.68%*$K7L%<68J &*$ *F% I-%A$*EF$' *' ^KFB'/*/L$*8 0-' &$% T9<7$'/%),$ #$EF7$98J #<7 A.% G%$''.'/ /%-,$% .'& L9$*'$% T9<7$' 6NF%8: Y<7 *78 #*$&$%.5 6N% &*$ ^.7K*9&.'/ &$% V8%)5.'/76-%5 $'87EF$*&$'&: U%*'A*O*99 #B%$ &*$ V*5.9<8*-' #$*8$%$% &*7O$%7$% +<7OF<7$' &.%EF *'6NF%.'/ #$*8$%$% W5O.972 .'& (-'8*'.*8B87/9$*EF.'/$' 5)/9*EFJ*' &$% U%<e*7 7EF$*8$%8 &<7 I$%6<F%$' h$&-EF <' &$% 78<%L$' \%F)F.'/ &$7 P$EF$'<.6#<'&$7 .'& <' &$% a.'<F5$0-' (-'0$%/$'AO%-K9$5$':

Y*$ 0-%F<'&$'$']-&99 F<K$' K$7-'&$%$ VEF#*$%*/L$*8$'J #$'' 5$F%$%$ a#$*OF<7$'5-%OF-9-/*$' *' $*'$% V*5.9<8*-' 0-%F<'&$' 7*'&: *' T$*7O*$9 *78 &<7 *'&%*'/$' $*'$7 R%$*78%<F97 *' $*'$ /$7EF*EF8$8$ V8%)5.'/J #*$ 7*$ K$* &$% *'7O$*7.'/ 0-' D-8LNF9#<77$% 0-%L-558: W' &*$7$5 R<99 5.77 /9$*EFA$*8*/ &<7 I$%F<98$' 0-' V8%)5.'/$' 5*8 6%$*$' [K$%69BEF$' Sb<77$%78%<F9 .'& b<77$%2 -K$%69BEF$X .'& &$% 0-' &$5 b<77$%78%<F9 5*8/$%*77$'$' M.68K9<7$' K$%$EF'$8 #$%&$': \%/$K'*77$ <.7 &$5 $.%-OB*7EF$' U%-h$L8 \Z[P^ A$*/$'J &<77 &*$ /$/$'#B%8*/ 0$%6N/K<%$']-&99 K$* 7-9EF$' Y-OO$9<'6-%&$%.'/$' 7$F% .'/$'<. 7*'&:

*' #$*8$%$% /%-,$% T$%$*EFJ*' &$5]-&$99O$%K$77$%.'/$' '-8#$'&*/ 7*'&J K$8%*668 <99$ I-%/B'/$ 5*8]<77$'NK$%/<'/ <' &$% UF<7$'/%$'A69BEF$: Y<A. /$F)%$' I-%/B'/$ #*$ (-'&$'7<8*-' *5 I-9.5$' .'& <' bB'&$' SZ-'8<*'5$'87XJ V*$&$' *5 I-9.5$' .'& <' bB'&$'J (<0*8<8*-' .'& R9<7F*'/: Y*$ K*7F$% 0-%9*$/$'&$']-&99 7*'& %.&*5$'8B%$J $%78$ ^'7B8A$: b$/$' &$7 F-F$' P$EF$'<.6#<'&7 K$* &$% ^'#$'&.'/ &$% $e*78*$%$'&$']-&99 .'& &$% 5<'/$9'&$' P-K.78F$*8 &$% '.5$%*7EF$' I$%6<F%$' 6N% 7-9EF$ ^'#$'&.'/$'J 9*$/$' K*7F$% <.EF '.% 7$F% #$'*/$ I<9*&*$%.'/7%$EF'.'/$' 0-%: ^.6 &*$7$5 +$K*$8 K$78$F8 $*' /%-,$% \'8#*EL9.'/7K$&<%6:

*' $%78*' hN'/78$% a$*8*' &$% P$<L8-%7*EF$%F$*86-%7EF.'/ K$8%<EF8$8$7 U%-K9$5 K$8%*668 &$' G%<'7O-%8J &*$ V$&*5$'8<8*-' .'& &*$ P$7.7O$'7*-' 0-' R%$5&78-66$' *5 Z-'8<*'5$'8J #*$ A: T: &.%EF $*'$' M$EL78)%6<99 6%$*/$7$8A8$7 W7-9*$%5<8$%*<9J &< &.%EF 7*$ &*$ V*K *5 P$<L8-%7.5O6 0$%78-O68 #$%&$' L)''$': Y*$]-&$99*$%.'/ &$%<%8*/$% I-%/B'/$ *78 5*8 &$5 \.9$%2M</%<'/$2^'7<8A -&$% &$5 \.9$%2\.9$%2^'7<8A 5)/9*EF: Y$% 0-' $*'$5 6$78$' +%),$'7O$L8%.5 &$% U<%8*L$9 <.7/F'&$ \.9$%k\.9$%2^'7<8A K*$8$8 A.&$5 &*$])/9*EFL$*8 &$% V*5.9<8*-' 0-' V$&*5$'8<8*-' .'& P$7.7O$'7*-' 7-#*$ &$% b*%L.'/ 8$*9#$*7$ 0$%78-O68$% V*K:

Y*$]$F%A<F9 &$% K$7O%-EF$'$' ^'#$'&.'/$' *78 &.%EF F-F$ PEF'A$*8$' K$$*'8%BEF8*/8: \7 7*'& &$7F<9K #$7$'89*EF$ I$%K$77$%.'/$' *' &$' M)7.'/72 <9/-%*8F5$' '-8#$'&*/J .5 &*$ PEF'/$7EF#*'&*/L$*8 A. K$7EF9$.'*/$': U-8$'A*<9 9*$/8 F*$% *' &$% U<%<99$9*7*$%.'/J *' %B.59*EF .'& A$*89*EF <&<O8*0$' I$%6<F%$' A.% (-'8%-99$ &$7 Y*7L%$8*7*$%.'/76$F9$%7J *' &$% I$%6<F%$'7-%&'./ .'& *' &$' (-OO2 9.'/7<9/-%*8F5$' 6N% &<7]-&$99/9$*EF.'/77_78$5:

Y*$ -K$' &*7L.8*$%8$' LN'68*/$' ^'#$'&.'/7K$%$*EF$ 0-' ZRY2I$%6<F%$' A$*/$'J &<77 &*$ (-OO9.'/ .'8$%7EF*$&9*EF$% V*5.9<8*-'70$%6<F%$' *' a.L.'68 *55$% #*EF8*/$% #*%&:

Y*$7 K$8%*668 A.5 $*'$' &*$ (-OO9.'/ 0-' V*5.9<8*-'70$%6<F%$' 6N% &*$ V8%)5.'/ .'& &*$ V8%.L8.%5$EF<'*L SR9.*&2V8%.L8.%2 b$EF7$9#*%L.'/XJ -F'$ &*$]<8$%*<9$%5N&.'/72 .'& T%.EF5$EF<'*LO%-K9$5$ '.% .'A.%$*EF$'& /$9)78 #$%&$' L)''$': *'$ A#$*8$ #*EF8*/$ (-OO9.'/ *78 &*$ (-OO9.'/ 0-' ZRY2I$%6<F%$' 5*8 V_78$5E-&$7: Y$% +%.'& &<6N% *78J &<77 5$F%&*5$'7*-'<9$ ZRY2I$%6<F%$' #$/$' &$7 P$EF$'<.6#<'&7 K*7F$% FB.6*/ '.% <.6 Y$8<*9O%-K9$5$ SA: T: V8%)5.'/ *5 Y-#'E-5$% -&$%*' $*'$5 G2V8NELX <'/$#$'&$8 #$%&$' L)''$': Y*$ P<'&2 .'& ^'6<'/7K$&*'/.'/$' 6N% &*7 Y$8<*9O%-K9$5$ 5N77$' 0-' &$' V_78$5E-&$7 K$%$*8/$78$998 #$%&$': ‘5 U%-K9$5$*5 P$<L8-%L$%' /$'<.$% K$%$EF'$' A. L)''$'J *78 A.&$5 $*'$ (-OO9.'/ 0-' ZRY2 I$%6<F%$' 5*8 D$.8%-'$'L*'$8*LO$%6<F%$' $%6-%&$%9*EF:

6.3.10 Notwendige Weiterentwicklungen von CFD-Verfahren

Einphasige Strömungen

Y*$ '-8#$'&*/$' \'8#*EL9.'/$' 6N% $*'OF<7*/$ V8%)5.'/$' K$8%66'C

- \'8#*EL9.'/ .'& I<9*&*$%.'/ 0-' G.%K.9$'A5-&99' 5*8 &$'$' 7*EF 7-#-F9 #<'&'<F$ +%$'A7EF*EF878%)5.'/$' 5*8 bB%5NK%/<'/ <97 <.EF /%-,27L<9*/$ 8.%K.9$'8$ b*%K$9K$#$/.'/$' KA#: ^K9)7.'/$' K$%EF'' 9<77$'J
- \'8#*EL9.'/ .'& I$%K$77$%.'/ 0-' G.%K.9$'A5-&99' 6N% <.68%*$K7K$F<68$8$ V8%)5.'/$'J A.5 T$*7O*$9 <.6 &$% T<7*7 0-' P$_'-9&77O<''.'/75-&$99$' -&$% Y\VJ
- I$%K$77$%.'/ &$%]-&$99*$%.'/ 0-' O-%)7$']$&*$'J #$'' $*'$ &$8<*99*$%8$ T$7EF%$*K.'/ 0-' G$*9K$%$*EF$' *5 V8%)5.'/7/$K*$8 SV8%.L8.%$' *5 ($%'X '*EF8 %$<9*78*7EF *78J &$% *'69.77 <.6 &*$ V8%)5.'/ h$&-EF K$%NEL7*EF8*/8 #$%&$' 5.77:

Zwei- und mehrphasige Strömungen

Y*$ '-8#$'&*/$' \'8#*EL9.'/$' 6N% A#$*2 .'& 5$F%OF<7*/$ V8%)5.'/$' K$8%66'C

- a#$*OF<7$'78%)5.'/$' 5*8 /9$*EFA$*8*/ <.68%$8$'&$' .'8$%7EF*$&9*EF$']-%OF-9-2 /*$' SA: T: V8%<F9 .'& T9<7$'78%)5.'/J T9<7$'2 .'& U%-O6$'78%)5.'/J R%$*78%<F9$' 5*8 G%-O6$'<K9)7.'/XJ
- Y_'<5*7EF$ T$7EF%$*K.'/ &$% G-O-9-/*$ &$% UF<7$'/%$'A69BEF$' .'& HK$%2 O%N6.'/ &$% (-%%$9<8*-'$' 6N% &*$ a#*7EF$'OF<7$'2P$*K.'/7L%B68$J

- a#$*OF<7$'2] -&99%#$*8$%.'/$' 6N% V8%) 5.'/76-%5$'J 6N% &*$ '-EF L$*'$ <.7%$*EF$'& /$'<.$' a#*7EF$'OF<7$'5-&99 0-%9*$/$'J A: T: U%-O6$'78%) 5.'/J P*'/7O<9878%) 5.'/J R*9578%) 5.'/J F-%*A-'8<9$ P-F%2 .'& (<'<9778%) 5.'/$'J
- \'8#*EL9.'/ .'& I<9*&*$%.'/ 0-']-&$99$' 6N% a#$*OF<7$'78%) 5.'/$' 5*8]<77$'NK$%/<'/ <' &$% UF<7$'/%$'A69BEF$ SV*$&$'J (-'&$'7<8*-'J (<0*8<8*-'J R9<7F*'/XJ
- I$%K$77$%.'/ &$% G.%K.9$'A2 .'& bB%5$NK$%/<'/75-&$99$ 6N% &*$ -K$' /$'<''8$' V8%) 5.'/76-%5$':

Numerische Verfahren

T$* &$' '.5$%*7EF$' I$%6<F%$' 78$F8 &*$ I$%K$77$%.'/ &$% \66*A*$'A .'& +$'<.*/L$*8 &$% PEF'0$%6<F%$' 6N% 8%<'7*$'8$ V8%) 5.'/$' &.%EF <&<O8*0$ a$*87EF%*880$%6<F%$' .'& <&<O8*0$ +*88$%0$%6$*'$%.'/*5 I-%&$%/%.'&:W5 c*'K9*EL <.6 &*$ b$*8$%$'8#*EL9.'/ 0-']$F%OF<7$'5-&$99$ 7*'& &*$ 6-9/$'&$' ^'O<77.'/$' &$% '.5$%*7EF$' I$%6<F%$' '-8#$'&*/C

- T$7EF9$.'*/.'/ &$% W8$%<8*-'72 .'& (-OO9.'/7<9/-%*8F5$'J
- \'8#*EL9.'/ A.0$%9B77*/$%J '.5$%*7EF$% P<'&K$&*'/.'/$' 6N% a#$*OF<7$'2 78%) 5.'/$'J
- T$F<'&9.'/ 0-' 78$*6$' +9$*EF.'/77_78$5$' SA.5 T$*7O*$9J #$'' 5*8 $*'$5 D*EF8/9$*EF/$#*EF875-&$99 *' &$% DBF$ $*'$7 5$EF<'*7EF$' -&$% 8F$%5*7EF$' +9$*EF/$#*EF87A.78<'&$7 /$%$EF'$8 #*%&XJ
- $66*A*$'8$ '.5$%*7EF$ T$F<'&9.'/ &$% 0*%8.99']<77$J
- M)7.'/70$%6<F%$' 6N% a#$*OF<7$'78%) 5.'/$' 5*8 L-5O%$77*K9$%J L-'8*'.*$%9*EF$% UF<7$:

Kopplung von CFD-Verfahren

a.% T$#B98*/.'/ &$% LN'68*/$' ^.6/<K$' *78 $7 '-8#$'&*/J ZRY2I$%6<F%$' *' 0$%78B%L8$5]<77$ 5*8<'&$%$' V*5.9<8*-'70$%6<F%$' A.L-OO$9':Y<A./$F)%$'C

- V_78$5E-&$7 S^GcM\GXJ
- V8%.L8.%5$EF<'*L0$%6<F%$'J
- D$.8%-'$'L*'$8*L0$%6<F%$':

Y*$ (-OO9.'/*78 $%6-%&$%9*EFJ.5 6N% &*$ ZRY2Y$8<*95-&$99*$%.'/ &*$ P<'&K$&*'/.'/$' A.K$78*55$':

Qualitätskontrolle und NRS-spezifische Anforderungen

b$*8$%$% \'8#*EL9.'/7K$&<%6 K78F8 K$* &$' 6-9/$'&$' U.'L8$'C

- o<9*8B877*EF$%.'/ .'& b*77$'75<'</5'8 &.%EF Y-L.5$'8<8*-' 0-' !T$78 U%<E8*E$7; SR$F9$%L-'8%-99$J]-&$99$5O6$F9.'/$'J +*88$%$%A$./.'/J :::X *' 9<.6$'& $%#$*8$%8$' .'& NK$% &<7W'8$%'$8 0$%6N/K<%$' TU+7J
- T*K9*-8F$L 0-' ^'#$'&.'/7K$*7O*$9$' 6N% K$78*558$ ^.6/<K$'78$99.'/$' ST-%0$%5*7EF.'/J UGVJ Z-'8<*'5$'878%)5.'/$'X 5*8 \5O6$F9.'/$' 6N% OF_7*L<9*7EF$]-&99 SG.%K.9$'A2J a#$*OF<7$'2 .'& ^.68%*$K75-&99XJ P<'&K$&*'/.'/$' .'& V8-66#$%8$J
- I$%K$77$%.'/ &$% c<'&F<KK<%L$*8 .'& &$% +$7EF#*'&*/L$*8 &$% U-782U%-A$77-%$' 6N% 8%<'7*$'8$ V8%)5.'/$' .'& /%-,$ Y<8$'5$'/$' S^'*5<8*-'$'J a$*85*88$9.'/$'J (-%%$9<8*-'$' .'& <'&$%$ 78<8*78*7EF$ +%),$'X:

Notwendigkeit experimenteller Daten

Y*$ b$*8$%$'8#*EL9.'/ &$% PEF'0$%6<F%$' L<'' '*EF8 -F'$ eO%*5$'8$99$ Y<8$' <.7L-55$'J &<*' 8$EF'*7EF$' V8%)5.'/$' $*'$ P$*F$ 0-' 78%)5.'/7K$78*55$'&$' Y$8<*97 &.%EF &*$)%89*EF$.'& A$*89*EF$ ^.69)7.'/ &$7 ZRY2I$%6<F%$'7 '*EF8 <.6/$9)78 #$%&$' L)''$' .'& 7-5*8 +$/$'78B'&$ $*'$% A#<'/79B.6*/ $5O*%*7EF$']-&$99*$%.'/ 7*'&: Y*$7 K$8%*668 A.5 T$*7O*$9 &*$ G.%K.9$'A5-&$99*$%.'/ .'& &*$]-&$99*$%.'/ &$% UF<7$'#$EF7$9#*%L.'/ *']$F%OF<7$'78%)5.'/$' <.6 +%.'& &$% %B.59*EF '*EF8 <.6/$9)78$' UF<7$'/%$'A69BEF$ KA#:]-%OF-9-/*$: a.% I$%*6*L<8*-' &$%]-&$99*5O9$2 5$'8*$%.'/J A.% I<9*&*$%.'/ .'& (<9*K%*$%.'/ 0-' $5O*%*7EF$']-&99' .'& A.% Y$5-'78%<8*-' &$% M$*78.'/76BF*/L$*8 &$7 ZRY2I$%6<F%$'7 6N% ^'#$'&.'/$' *5 8$EF'*7EF$']<,78<K #$%&$' &$7F<9K eO%*5$'8$99$ Y<8$' K$')8*/8:

^.7 &$% a*$97$8A.'/ &$7 &$8<*99*$%8$' I$%/9$*EF7 A#*7EF$' &$% ZRY2V*5.9<8*-' .'& &$5 eO%*5$'8$99 .'8$%7.EF8$' V8%)5.'/7OFB'-5$' $%/$K$' 7*EF K$7-'&$%$ ^'6-%&$%.'/$' <' &$%<%8*/$ I<9*&*$%.'/7$eO$%*5$'8$: *'$ +%.'&0-%<.77$8A.'/ 6N% &*$ */'.'/ $*'$7 \eO$%*5$'87 <97 I<9*&*$%.'/78$786<99 6N% ZRY2I$%6<F%$' .'& &$%$']-&99 *78 &<7 I-%9*$/$' 5)/9*EF78 0-9978B'&*/$% W'6-%5<8*-'$': Y*$7 K$8%*668 &*$ 78%)5.'/7K$78*55$'&$' Y$8<*97 &$% V8%)5.'/7/$-5$8%*$J 7B589*EF$ P<'&K$2 &*'/.'/$'J 6N% *'78<8*-'B%$ V8%)5.'/$' ^'/<K$' A. &$' ^.7/<'/7K$&*'/.'/$' 6N% &<7 \eO$%*5$'8 .'& W'6-%5<8*-'$' NK$% &*$ 78%)5.'/7K$78*55$'&$' OF_7*L<9*7EF$' \66$L8$: Y*$ 6N% $*'$' I<9*&*$%.'/78$786<99 <.7/$6NF%8$']$77.'/$' 7-998$' '<EF])/9*EFL$*8 Y*%$L8*'6-%5<8*-'$' NK$% 9-L<9$J ZRY2%$9$0<'8$ V8%)5.'/7/%),$' 9*$6$%'J &< &*$7$ /$'<.$%$.'& &$8<*99*$%8$%$ PNEL7EF9N77$ <.6 '%7<EF$' 5)/9*EF$% ^K#$*EF.'/$' A#*7EF$' \eO$%*5$'8 .'& ZRY2V*5.9<8*-' A.9<77$'J <97 &<7 K$* &$%]$77.'/0-'*'8$/%<9$' -&$%*'&*%$L8 <K/9*8$8$' +%),$' &$% R<99*78: Y<K$* 7-998$ $*' I<9*&*$%.'/78$786<99 &$8<*99*$%8$%$ W'6-%5<8*-'$' <97 *7-9*$%8$ U.'L85$77.'/$' $*'A$9'$% OF_7*L<9*7EF$% +%),$' K$%$*878$99$': *'&*5$'7*-'<9$ U%-6*9$.'& I$%8$*9.'/$' 0-' V8%)5.'/7/%),$' <' 5$F%$%$']$77-%8$' -&$% R$9&&<8$' 6N% A#$*&*5$'7*-'<9$]77K$'$' $*'7EF9*$,9*EF V8%)5.'/70*7.<9*7*$%.'/ 7*'& 6N% &*$ I<9*&*$%.'/ 0-' ZRY2]-&$99$' K$0-%A./8 /$$*/'$8: T$%NF%.'/76%$*$']770%6<F%$' *78 /$/$'NK$% *'8%.7*0$'J 7-'&$'K<7*$%8$' I$%6<F%$' &$% I-%A./ A. /$K$'J .5 V8)%.'/$' &$% V8%)5.'/ &.%EF &*$]$77<OO<%<8.% '<EF])/9*EFL$*8 A. 0$%5$*&$': b$%&$' 6N% &<7 \eO$%*5$'8 0$%$*'6<EF$'&$ ^''<F5$' F*'7*EF89*EF &$% V8<8*-'<%*8B8 -&$% V_55$8%*$ &$% .'8$%7.EF8$' V8%)5.'/ /$5<EF8J 7- 7*'& &*7 *' T$A./ <.6 &*$ 0$%#$'&8 eO%*5$'8$99$ ^'-%&'.'/ 5*8 /$$*/'8' 5$778$EF'*7EF$']*88$9' A. NK$%O%N6$' .'& &*$7 *' /$$*/'8% .'& '<EF0-99A*$FK<%$% b$*7$ A. &-L.5$'8*$%$': Y*$ P$O%-&.A*$%K<%L$*8 &$% eO%*5$'8$99$' \%/$K'*77$ 7-998$ &.%EF $*'$ 5$F%6<EF$ b*$&$%F-9.'/ &$7 \eO$%*5$'87 '<EF/$#*7' #$%&$': *'$ <K7EF9*$,$'&$ R$F9$%<'<9_7$ 7-998$ 5)/9*EF$ 7_78$5<8*7EF$ R$F9$%J *'69N77$ &$%]$77<'-%&'.'/ <.6 &<7 A. .'8$%7.EF$'&$ V8%)5.'/7OFB'-5$' .'& &*$]$77/$'<.*/L$*8 &$% $*'/$7$8A8$']770%6<F%$' p<'8*6 *A*$%$':

6.3.11 Zusammenfassung zum Forschungsbereich „Kühlkreislauf CFD-Codes“

W5 P<F5$' &$% P$<L8-%7*EF$%F$*876-%7EF.'/ L)''$' ZRY2I$%6<F%$'

· A.5 I$%78B'&'*7 L-5O9$e$%J &%$*&*5$'7*-'<9$% V8%)5.'/7OFB'-5$'$ K$*8%</$'J

- V8%)5.'/72 .'& bB%5NK%8%</.'/7O<%<5$8$% 6N% 0-%/$/$K$'$ +$-5$8%*$' .'& V8%)5.'/7%<'&K$&*'/.'/$' p<'8*8<8*0 0-%F$%7</$' .'&
- <97 b$%LA$./ A.% VL<9*$%.'/ A#*7EF$' 8F$%5-69.*&&_'<5*7EF$' M<K-%eO%*2 5$'8$' .'& [%*/*'<9<.76NF%.'/$' &*$'$':

W5 ''8$%7EF*$& A. V_78$5E-&$7 #$%&$' K$* ZRY2V*5.9<8*-'$' 0-%#*$/$'& *'A$9L-5O-'$'8$' &$7 U%*5B%L%$*79<.67 K$F<'&$98: Y<7 V8%)5.'/7/$K*$8 #*%& &%$*&*5$'7*-'<9 &*7L%$8*7*$%8:

'OF<7/$ &%$*&*5$'7*-'<9$ V8%)5.'/7OFB'-5$'$ *5 U%*5B%L%$*79<.6 7*'& *' *F%$' /%.'&9$/$'&$' V8%)5.'/75$EF<'*75$' K$%$*87 #$*8/F'& 0$%78<'&$' SA: T: T-%O$%5*7EF.'/XJ h$&-EF *78 $*'$ /$'<.$ p<'8*8<8*0$ I- %F$%7</$ '-EF *5 5$% '*EF8 5)/9*EF: G%-8A &$% A.'$F5$'&$' T$&$.8.'/ 0-' Y\V .'& V^V #$%&$' <.7 +%N'&$' &$7 P$EF$'<.6#<'&$7 <.EF *' a.L.'68 &*$ 5$*78$' V*5.9<8*-'$' 5*8 P^DV2]-&$99$' <.7/$6NF%8: ''8$% &$' 0$%7EF*$&$'$' G%<'7O-%8/9$*EF.'/75-&$99$' SP$_'-9&72 7O<''.'/72 .'& b*%K$9O*7L-7*8B875-&$99$'X *78 $7 &<F$% $%6-%&$%9*EFJ *5 P<F5$' 0-' G<./9*EFL$*87.'8$%7.EF.'/$' 6N% K$78*55 58$ V8%)5.'/7O%-K9$5$ &*$ h$#$*97 <5 K78' /$$*/''8 I<%*<'8$ $*'$7 P^DV2]-&$997 A. K$78*55$' .'& *5 P<F5$' 0-' T$78 U%<E8*E$ +.*&$9*'$7 A. &-L.5$'8*$%$':

ZRY2]$8F-&$' L)''$' $%78 &<'' A.% p<'8*8<8*0$' I-%F$%7</$ 0$%#$'&$8 #$%&$'J #$'' 7*$ <.7%$*EF$'& 0$%*6*A*$%8 .'& 0<9*&*$%8 7*'&: *'$ I$%*6*L<8*-' 6N% *'OF<2 7$'78%)5.'/$' $%6-9/8 *5 b$7$'89*EF$' &.%EF '.5$%*7EF$ ''8$%7.EF.'/$' .'& D$8A0$%6$*'$%.'/778.&*$': Y*$ I<9*&*$%.'/ &$%]-&99 $%6-%&$%8 78$87 I$%/9$*EF$ 5*8 \eO$%*5$'8$'C ^.7/$F$'& 0-' /.8 &-L.5$'8*$%8$']-&$99O%-K9$5$'J &*$ <.EF eO%*5$'8$99 .'8$%7.EF8 #$%&$' 5N77$'J L<'' 7EF%*88#$*7$ $*'$ ^''BF$%.'/ <' &*$ +$-5$8%*$ &$7 U%*5B%L%$*79<.67 .'8$% T$8%*$K72 .'& V8)%6<99K$&*'/.'/$' $%6-9/$': ^.EF YDV -&$% M\V2V*5.9<8*-'$' L)''$' Y<8$'K<7$' 6N% &*$]-&$990<9*&*$%.'/ 9*6%': Y*7 I-%/F'7#$*7$ 6NF%8 A. /$'<.$' .'& %-K.78$' V*5.9<8*-'72 O%-/%<55$'J &*$ p<'8*8<8*0$ I-%F$ %7</$' $%9<.K$' .'& <97]-&.9$*' V_78$5E-&$7 $*'/$K.'&$' #$%&$' L)''$':

Y</$/$' 7*'& A#$*OF<7*/$J &%$*&*5$'7*-'<9$ V8%)5.'/7OFB'-5$'$ *5 U%*5B%2 L%$*79<.6*' *F%$' /%.'&9$/$'&$' V8%)5.'/75$EF<'*75$' F$.8$ #$*8/$F$'& '-EF '*EF8 0$%78<'&$' .'& L)''$' '-EF '*EF8 A.0$%9B77*/ 5-&$99*$%8 #$%&$': T$*7O*9 7*'& &$% HK$%/<'/ A#*7EF$' V8%)5.'/76-%5$'J b<77$%5*8%*77 K$* +$/$'78%)5.'/J V*$&$' *' 0$%8*L<9$' (<'B9$' -&$% Y<5O6K*9&.'/ K$* Y%.EL$'89<78.'/: ZRY2Z-&$7 #$%&$' &<F$%

0-%#*$/$'& &<A. $*'/$7$8A8J &*$7$ UFB'-5$'$ 7-#*$ &*$ A. +%.'&$ 9*$/$'&$' V8%)5.'/72J bB%5$2 .'& V8-66NK$%8%</.'/75$EF<'*75$' A. 0$%78F' .'& *5 I$%/9$*EF 5*8 eO%*5$'8$99$' ''8$%7.EF.'/$' *5 Y$8<*9 '<EFA.K*9&$': Y$% *'7<8A 0-' ZRY 6N% p<'8*8<8*0$ I-%F$%7</$' 5$F%OF<7*/$% V8%)5.'/$' *78 K*7 <.6 $*'*/$ ^.7'<F5$' SA: T: 0$%&N''8$ T9<7$'78%)5.'/J D<77&<5O678%)5.'/X F$.8$ '-EF '*EF8 5)/9*EF: R-%7EF.'/72 .'& b$*8$%$'8#*EL9.'/7K$&<%6 K78F8 &$7F<9K 6N%C

-]$F%OF<7$'5-&99 6N% V8%)5.'/$' 5*8]<77$'NK$%/<'/ <' &$% UF<7$'2 /%$'A69BEF$ SV*$&$'J (-'&$'7<8*-'J I$%&<5O6.'/J R9<7F*'/J $8E:XJ

- \'8#*EL9.'/ 0-']$F%OF<7$'5-&99'J &*$ V8%)5.'/$' 5*8 0$%B'&$%9*EF$%]-%OF-9-/*$ *' $*'$5 #$*8$' VO$L8%.5 <.68%$8$'&$% I-9.5$'/$F<98$ &$% K$8$*9*/8$' UF<7$' K$7EF%$*K$' L)''$': Y*$7$ ^'6-%&$%.'/ 78$F8 <.EF *5 a.7<55$'F<'/ 5*8 &$5 $%78$' U.'L8J &< *' V8%)5.'/$' 5*8 78<%L$5]<77$'NK$%/<'/ <' &$% UF<7$'/%$'A69BEF$ &$% T$%$*EF $*'$% #-F9 &$6*'*$%8$'J $*'A$9'$' V8%)5.'/75-%OF-9-/*$ 5$*78 NK$%7EF%*88$' #*%&J

- b$*8$%$'8#*EL9.'/ &$% G.%K.9$'A5-&$99$ 6N%]$F%OF<7$'78%)5.'/$'J *'7K$7-'2 &$%$*5 c*'K9*EL<.6 &*$ G.%K.9$'A5-&$99*$%.'/ <'6%$*$' [K$%69BEF$':

ZRY2Z-&$7 L)''$' <'&$%$%7$*87 K$*]$F%OF<7$'78%)5.'/$' $*'$' #7'89*EF$' T$*8%</ A.% HK$%8%</.'/ 0-' eO%*5$'8$99$' \%/$K'*77$' *' $*'$5 0$%L9$*'$%8$']<,78<K <.6 &*$ [%*/*'<9<.76NF%.'/ 9$*78$': b$/$' &$% I*$9A<F9 &$% K$78*55$'&$' V8%)5.'/7O<%<5$8$% *78 &*$ *'F<98.'/ &$% 5$*78$' B'9*EFL$*87/$7$8A$ K$* &$% ^.76NF%.'/ 0-']$F%OF<7$'eO%*5$'8$' ''*EF8 5)/9*EF: Y<F$% K$78$F8 78$87 &*$ R%</$J *' #*$#$*8 eO%*5$'8$99$ \%/$K'*77$ -&$% &*$ &<%<.7 <K/8*8$8$' (-%%$9<28*-'$' <.6 %<9 T$&*'/.'/$' NK$%8%</K<% 7*'&: c*$% K*8' ZRY2]$8F-&$' &$' I-%8$*9J &<77 7*$ 7-#-F9 &*$ M<K-%K$&*'/.'/$' <97 <.EF &*$ %<9' T$8%*$K72 -&$% V8)%6<99K$&*'/.'/$' /9$*EF$%5<,$' '<EFK*9&$' L)''$'J &< &*$ 0$%#$'&8' OF_7*L<9*7EF$']-&$99$ /%),$'.'<KFB'/*/ 7*'&: Y*$7 L)''8$ *' a.L.'68 A. $*'$5 0$%%*'/$%8$' T$&<%6 <' L-787O*$9*/$' \eO$%*5$'8$' *5 +%-,5<,78<K 6NF%$':

ZRY2]$8F-&$' K*8' #*$ <99$ <'&$%$' 8F$-%$8*7EF$']$8F-&$' K$* &$% U9<'.'/ 0-' M<K-%$eO$%*5$'8$' A.7B8A9*EF &*$])/9*EFL$*8 $*'$% I-%<K2V*5.9<8*-': Y<K$* #*%& 0-% &$5 ^.6K<. $*'$% I$%7.EF7<'9</$ &*$ V8%)5.'/ 5*8 0-%F<'&$'$']-&99' '<EF &$5 V8<'& &$% G$EF'*L 0-%<.7K$%EF'8J .5 <KA.7EFB8A$'J #$9EF$ '$.$' W'6-%5<8*-'$' NK$% &<7]-&$99 /$9*6%8 #$%&$' L)''$': Y*$7$ I-%/F'7#$*7$ *78 *'7K$7-'&$%$

&<'' 7*''0-99J #$'' &*$ \eO$%*5$'8$ A.5 a#EL &$%]-&$990<9*&*$%.'/ <.7/$6NF%8 #$%&$':

6.3.12 Literatur zum Forschungsbereich Kühlkreislauf CFD-Codes

k^DGdik ^'8<9J V:J (.%.9J D:J U-&-#7L*J]:j:J M<F$_J G: G: f%:J GF$ Y$0$9-O5$'8 -6].98*2Y*5$'7*-'<9]-&$99*'/ Z<O<K*9*8*$7 6-% ^''.9<% R9-#7J @%& W'8: Z-'6:].98*OF<7$ R9-#J WZ]R diJ M_-'J R%<'E$J 1ddi

kT'P>lk T.%'7J ^: Y:J R%<'LJ G:J c<5*99J W:J VF*J f:2]:J GF$ R<O%2^0%</$& Y%</]-&$9 6-% G.%K.9$'E$ Y*7O$%7*-'*' \.9$%*<'].98*2UF<7$ R9-#7J WZ]R 3>>lJ R*68F W'8: Z-'6:].98*OF<7$ R9-#J j-L-F<5<J f<O<'J 3>>l

kZMWmk Z9*68J P:J +%<E$J f: P:J b$K$%J]:\:J *Bubbles, Drops and Particles*J ^E<&$5*E U%$77 W'E:J D$# j-%LJ 'V^J 1dm

kRP^>lk R%<'LJ G:J VF*J f:2]:J T.%'7J ^: Y:J I<9*&<8*-'-6 \.9$%*<'].98*OF<7$ R9-#]-&$97 6-% D.E9$<% V<6$8_ ^OO9*E<8*-'7J @%& W'8$%'<8*-'<9 V_5O-7*.5 -' G#-2UF<7$ R9-#]-&$99*'/ <'& \eO$%*5$'8<8*-'J U*7<J 3>>l

k+^I>1k +<O%*9<7J]:J c)F'$J G:J WVU l@ P<O*& T-%-' Y*9.8*-' G%<'7*$'8 G$787 6-% Z-&$ I$%*6*E<8*-'J G$EF'*E<9 P$O-%8 WVVD 1l@n ?@33k R-%7EF.'/7A$'8%.5 P-77$'&-%6J 3>>1

k+P^>@k +%<K-0<EJ Y:J V*5.9<8*-'0-' &%$*2&*5$'7*-'<9$' V8%)5.'/$'*5 U%*5B%L%$*70-' Y%.EL#<77$%%$<L8-%$'J Y*O9-5<%K$*8J G$EF'*7EF$ ''*0$%7*8B8]N'EF$'J]B%A 3>>@

kc[c>=k c)F'$J G:J VEF$.$%$%J]JD.5$%*E<9]-&$99*'/ -6 <T.-_<'E_ Y%*0$' R9-# *' <P$<E8-% U%$77.%$ I$77$9 '7*'/ ZRx2=J 8-K$ O.K9*7F$& D'P\Gc 211J 3>>=

kM^'mk M<.'&$% T: \:<'& VO<9&*'/J Y: T:J GF$ D.5$%*E<9 Z-5O.8<8*-' -6 G.%K.9$'8 R9-#7J Z-5O:]$8F: ^OO9:]$EF:<'& \'/:J I-9:@J OO: 3dh ?3idJ 1dm

k] \ D>>k] $ ’ 8 $ % J R : J + % - 8 h < ’ 7 J c : J ^ O O 9 * E < 8 * - ’ - 6 ^ & 0 < ’ E $ & G . % K . 9 $ ’ E $] - & $ 9 7 8 - Z - 5 O 9 $ e W ’ & . 7 8 % * < 9 R 9 - # 7 J * ’ GA<K*%<7J +:J $&:J *Advances in Fluid Mechanics: Calculation of Complex Turbulent Flows,* b W G U % $ 7 7 J 3 > > >

k] \ D>3k] $ ’ 8 $ % J R : J ZRY T $ 7 8 U % < E 8 * E $ + . * & $ 9 * ’ $ 7 6 - % ZRY Z - & $ I < 9 * & < 8 * - ’ 6 - % P $ < E 8 - % 2 V < 6 $ 8 _ ^ O O 9 * E < 8 * - ’ 7 J \ I [M 2 \ Z [P ^ ? Y > 1 J 3 > > 3

k] [P>@k] - % < / < J R : f : J 9 < % % $ 8 $ / . _ J ^ : \ : J Y % $ # J Y : ^ : J M < F $ _ J P : G : J ^ 7 7 $ 7 7 5 $ ’ 8 - 6 G . % K . 9 $ ’ 8 Y * 7 O $ % 7 * - ’] - & $ 9 7 6 - % T . K K 9 _ R 9 - # 7 * ’ 8 F $ M - # V 8 - L $ 7 D . 5 K $ % M * 5 * 8 J W ’ 8 : f :] . 9 8 * O F < 7 $ R 9 - # J I - 9 : 3 d J O O : =m= ? 0 J 3 > > @

kP [c>Ik P - F & $ J ‘ : J] * ’ . 8 $ 7 - 6 8 F $ R * ’ < 9] $ $ 8 * ’ / J RM [ ] W x 2 P Y $ 9 * 0 $ % < K 9 $ Y 1 3 J R - % 7 E F . ’ / 7 A $ ’ 8 % . 5 P - 7 7 $ ’ & - % 6 J V $ O 8 $ 5 K $ % 3 > > I

kVZc>1k VEF$. $ % $ % J] : J c $ * 8 7 E F J] : J D . 5 $ % * 7 E F $ V * 5 . 9 < 8 * - ’ 0 - ’ I $ % 5 * 7 E F . ’ / 7 2 O % - A $ 7 7 $ ’ * 5 P $ < L 8 - % & % . E L K $ F B 9 8 $ % J + P V 2 P $ O - % 8 + P V ? ^ ? 3 d d I J 3 > > 1

kVZc>Ik VEF$. $ % $ % J] : J Y $ 5 - ’ 7 8 % < 8 * - ’ G $ 7 8 Z < 7 $ \ Z [P ^ Y \ ] > 3 ‘ U G R G P ^] Z 1 P . ’ 3 1 < 3 J Y $ 9 * 0 $ % < K 9 $ P $ O - % 8 \ I [M 2 \ Z [P ^ 2 Y d : 3 J ^ . / . 7 8 3 > > I

kVW\ddk V * $ 0 $ % 7 J f : J T < E F 5 < ’ ’ J U : J VEF * 5 O 6 L $ J G : J f $ ’ & % * E F J ‘ : J (% A _ L < E A 2 c < . 7 5 < ’ ’ J T : J V - ’ ’ $ ’ K . % / J c : 2 + : J VEF$. $ % $ % J] : J V $ ’ 7 * 8 * 0 * 8 B 8 7 < ’ < 9 _ 7 $ A . % \ % 5 * 8 8 9 . ’ / & $ % ‘ ’ 7 * E F $ % F $ * 8 $ ’ K $ * & $ % T $ 7 E F % $ * K . ’ / & $ 7 P * 7 7 0 $ % F < 9 8 $ ’ 7 * ’ 6 - 9 / $ 8 F $ % 5 - 2 5 $ E F < ’ * 7 E F $ % T $ 9 < 7 8 . ’ / . ’ 8 $ % \ * ’ K $ A * $ F . ’ / $ e O $ % * 5 $ ’ 8 $ 9 9 $ % \ % / $ K ’ * 7 7 $ J + P V 2 P $ O - % 8 + P V ? ^ ? 3 i m 1 d d d

kVW\>>k V * $ 0 $ % 7 J f : J T - _ & J Z : J Y | ^ . % * < J R : J R * 9 - J f : J c B 6 ’ $ % J b : J c $ % 8 9 $ * ’ J P : J VEF$. $ % $ % J] : J GF$ % 5 < 9 2 c _ & % < . 9 * E ^ 7 O $ E 8 7 - 6 8 F $ W ’ 8 $ % ’ < 8 * - ’ < 9 Z - 5 O < % < 8 * 0 $ ^ 7 7 $ 7 7 5 $ ’ 8 V 8 . & _ - ’ P $ < E 8 - % U % $ 7 7 . % $ I $ 7 7 $ 9 7 . ’ & $ % U G V 9 - < & * ’ / S P U I U G V W Z ^ V X J Z V D W b - % L 7 F - O - ’ ^ & 0 < ’ E $ & G F $ % 5 < 9 2 c _ & % < . 9 * E < ’ & D $. 8 % - ’ * E Z - & $ 7 C Z . % % $ ’ 8 < ’ & R . 8 . % $ ^ O O 9 * E < 8 * - ’ 7 J T < % E $ 9 - ’ < J V O < * ’ J ^ O % * 9 1 > 2 1 @ J 3 > > >

kG [ ] >1k G - 5 * _ < 5 < J ^ : J VF * 5 < & < J D : J ^ D . 5 $ % * E < 9] $ 8 F - & 6 - % T . K K 9 $ R 9 - # V * 5 . 9 < 8 * - ’ T < 7 $ & - ’ <] . 9 8 * 2 R 9 . * &] - & $ 9 J f : - 6 U % $ 7 7 . % $ I $ 7 7 $ 9 G $ E F ’ - 9 - / _ J I - 9 : 1 3 @ J O O : =1> ? =1 J m 3 > > 1

k b WM>=k b *99$ 5 7$ ’J] : V<’ &$%J (- 5 $ ’J \&] :f:J ^77$77 5 $ ’8 -6 P ^DV ZRY
] -&$99*’ / 6-% U%$77 . %*7$& GF$% 5 <9 VF-EL ^ ’ <9_7*7J 8- K$ 0 . K9*7F$&
D ‘ P \ G c211J 3>>=

7 Stör-/Unfallanalyse Sicherheitsbehälter

T$*5 ‘ ’6<99 *’ GF%$$]*9$ W79<’& *78 &*$ A$’8%<9$ P-99$ &$7 V*EF$%F$*87$*’7EF9.77$7 6N% &*$ P$<L8-%7*EF$%F$*8 K$7-’&$%7 &$.89*EF /$#-%&$’: Y$% V*EF$%F$*87$*’7EF9.77 .’& &<K$* *5 b$7$’89*EF$’ &$% V*EF$%F$*87K$FB98$% 78$99$’ K$* ($%’7EF5$9A.’6B99$’ &*$ 9$8A8$ T<%%*$%$ /$/$’ &*$ R%$*7$8A.’/ 0-’ P<&*-<L8*O*8B8 *’ &*$ ‘ 5/$K.’/ &<% .’& 7*$ #*%L$’ <97 VEF.8A 0-% B.,$%$’ *’#*%L.’/$’: V*EF$%F$*87<’<9_7$’ 0-’ V8)%6<99<K9B.6$’ *’ ($%’L%<68#$%L$’ $%6-%&$%’ &$7F<9K .’<K&*’/K<%J &*$ I-%/B’/$ *5 V*EF$%F$*87$*’2 7EF9.77 <’/$5$77$’ A. K$%NEL7*EF8*/$’: Y*$ V*5.9<8*-’ &*7% I-%/B’/$ $%6-9/8 5*8 P$EF$’O%-/%<5 5$’J &*$ K$9<78K<%$ ^’<9_7$’ A.% T$F$%%7EF.’/ 7EF#$%$% V8)%6B99$J A.5 o998%5 <.7 &$% ^’9</$ *’ &*$ ‘ 5/$K.’/ .’& A. ^.7#*%L.’/ $’ 0-’]<,’<F5$’ &$7<’9</$’*’8$%’$’ D-86<997EF.8A$7 $%5)/9*EF$’:

Y*$ I-%/B’/$ *5 V*EF$%F$*87$*’7EF9.77 7*’& *5 R<99$ $*’$7 7EF#$%$’ V8)%6<997 B.,$%78 L-5O9$e: WF%$ 5-&$995B,*/$ \%6<77.’/ $%6-%&$%8 ’*EF8 A#<’/79B.6*/ 6N% h$&$7 *’A$9OFB’-5$’ $*’$ 5)/9*EF78 &$8<*99*$%8$ T$7EF%$*K.’/J 7-’&$%’ O*$95$F% *78 $7 ’-8#$’&*/J <99$ #*EF8*/$’ A$’8%<9$’ b$EF7$9#*%L.’/$’ <’/$5$77$’ A. $%6<77$’:]<’ L<’’ &*$ V*5.9<8*-’7<.6/<K$ A.5 ^K9<.6 $*’$7 7EF#$%$’ V8)%6<997 OFB’-5$’-9-/*7EF *’ $8#< #*$ 6-9/8 K$7EF%$*K$’C a.’BEF78 *78 &*$ GF$%5-F_&%<.9*L *5 P$<L8-%2 LNF9L%$*79<.6 0-5 <.79)7$’&$’ \%$*/’*7 <.7/F’& A. $%6<77$’ K*7 F*’$*’ *’ &*$ ($%’A$%78)%.’/J .’& &<’’ &*$ ($%’A$%78)%.’/7OF<7$ 7$9K78J K’7- &*$ R%$*7$8A.’/ 0-’ VO<98O%-&.L8$’ <.7 &$’ T%$’’78BK$’J &<7 G%<’7O-%8O$%F<98$’ &*7% 6%$*/$7$8A8$’ VO<98O%-&.L8$ S<97 +<7$ -&$% ^$%-7-9$X *5 P$<L8-%LNF9L%$*79<.6J &*$ $’87O%$EF$’&$ ^L8*O*8B87K$%$EF’.’/Q &*$ R%$*7$8A.’/ 0-’ b<77$%&<5O6J +<7$’ 7-#*$ /<72 -&$% <$%-7-96)%5*/$’ VO<98O%-&.L8$’ <.7 &$5 P$<L8-%LNF9L%$*79<.6 2 $O89: <.7 &$5 &6L8$’ Y%.ELK$FB98$% 7$9K78 2 *’ &$’ V*EF$%F$*87K$FB98$%J &*$ GF$%5-F_&%<.9*L *5 V*EF$%F$*872 K$FB98$%J &<7 VO<98O%-&.L8O$%F<98$’J *’7K$7-’&$%$ F*$% &<7 ^$%-7-92 .’& f-&O$%F<98$’ *5 V*EF$%F$*87K$FB98$%J K’6<997 &*$ 0$%7EF*$&$’$’]-&* &$7 VEF5$9A$<.78%</7 <.7 &$5 P$<L8-%&%.ELK$FB98$% *’ &$’ V*EF$%F$*87K$FB98$% .’& &*$ &-%8*/$ I$%8$*9.’/ &$% VEF5$9A$J &*$ T$8-’2VEF5$9A$2 b$EF7$9#*%L.’/ .’& <.EF &*$ V*EF$%F$*877_78$5$J A:T:VO%NF2 -&$% MN68.’/77_78$5$:

^.EF F$.8$ #$%&$’ *55$% ’-EF #*EF8*/$J K*7F$% ’*EF8 -&$% ’.% #$’*/ K$<EF8$8$ *’A$9OFB’-5$’$ *&$’8*6*A*$%8J &*$ 6N% $*’$ K$9<78K<%$ V*5.9<8*-’ $*’$7 7EF#$%$’ V8)%6<997 ’-8#$’&*/ 7*’&:a. ’$’’$’ *78 F*$% A:T:&$% *’69.77 &$% G%<’7O-%8O-%/B’/$ <.6 &<7 f-&O$%F<98$’: c*$% #.%&$ *’ &$’ 9$8A8$’ f<F%A$F’8$’ *’8$%’<8*-’<9 #*$ <.EF 9<’/$ a$*8 ’<8*-’<9 6<78 <.77EF9*$,9*EF <.6 &*$ f-&EF$5*$ /$<EF8$8:^97 #$*8$%$7

T$*7O*$9 7*'& &*$ \%78<%%.'/7O%-A77 <.7 $*'$% ($%'7EF5$9A$ A. '$''$'J &*$ 9-L<9 $*'$.'8$%7EF*$&9*EF /%-,$ P-99$ F*'7*EF89*EF &$7 bB%5$8%<'7O-%87 <.7 $*'$% VEF5$9A$ <' &*$ '5/$K.'/ 7O*$9$' L)''$'J <97- $*'$ #*EF8*/$ T$&$.8.'/ K$* &$% T$8-'2 VEF5$9A$2b $EF7$9#*%L.'/F<K$':

W'8$%'<8*-'<9 #*$ '<8*-'<9 #$%&$' &*$ ^L8*O*8B8$' A.5 V*EF$%F$*87$*'7EF9.77 OFB'-5$'-9-/*7EF*' &%$* c<.O8K$%$*EF$ $*'/$8$*98C

- Y*$ GF$%5-F_&%<.9*LJ
- &<7 VO<98O%-&.L82J ^$%-7-92 .'& f-&0$%F<98$'
- .'& &<7 I$%F<98$' &$% ($%'7EF5$9A$ <.,$%F<9K &$7 PYT S$e20$77$9X:

Y*$ 6-9/$'&$ Y<%78$99.'/ &$7]-&$9978<'&$7 .'& &$% '-8#$'&*/$' b$*8$%$'8#*EL9.'/ -%*$'8*$%8 7*EF 0-%#*$/$'& <' &$% *' Z[Z[VjV $'8F<98$'$' KA#: &<6N% 0-%/$7F'$']-&$99*$%.'/: Y$% *'8$%'<8*-'<9$ V8<'& #*%& *' &$% T$.%8$*9.'/ 7-#$*8 #*$ 5)/9*EF K$%NEL7*EF8*/8: Z[Z[VjV 78$998 &*$ &$.87EF$ Z-&$2\'8#*EL9.'/ A.5 V*EF$%2 F$*87K$FB98$% &<%J &*$ $*'$'J %$9<8*0 A.% ^VG\Z2I<%*<'8$ ZU^J #$*8/$F$'&$' Y$8<*99*$%.'/7/%<& <'78%$K8: Z[Z[VjV 7-99 <99$ #7'89*EF$' I-%/B'/$.'& a.78B'&$ *5 V*EF$%F$*87K$FB98$% 0-' M$*EF8#<77$%%$<L8-%$' 7*5.9*$%$' L)''$'J &*$ K$* ^.79$/.'/72 .'& <.79$/.'/7NK$%7EF%$*8$'&$' V8)%6B99$' <.68%8': *' #*EF8*/$7 \'8#*EL9.'/7A*$9 *78 &<K$* &*$ #$*8/$F$'&$ T$%NEL7*EF8*/.'/ &$% b$EF7$9#*%L.'/$' A#*7EF$' &$' 0$%7EF*$&$'$' UFB'-5$'$'J #*$ A:T: GF$%5-F_&%<.9*LJ b<77$%2 78-660$%K%$''.'/J VEF5$9A$2T$8-'2b $EF7$9#*%L.'/J 7-#*$ ^$%-7-92J f-&2 .'& D.L9*&0$%F<98$': ^'F<'& 0$%6N/K<%$% '<8*-'<9$% .'& *'8$%'<8*-'<9$% I$%7.EF$ #.%&$.'& #*%& $*'$ .56<'/%$*EF$ I<9*&*$%.'/ &$7 Z-&$7_78$57 &.%EF/$6NF%8:]*8 &$' /$L-OO$98$' V_78$5E-&$7 ^GcM\Gk^GcM\G2ZY .'& Z[Z[VjV 9<77$' 7*EF V8)%6<997A$'<%*$' 7$F% &$8<*99*$%8 2 /$%<&$ <.EF F*'7*EF89*EF &$7 a$*80$%F<98$'7 2 %EF''J 7-#*$ $7 A:T:*5 a./$ &$% !7.5O E9-//*'/;2U%-K9$5<8*L &$%A$*8 &$% R<99 *78: HK$% Z-&$2I$%/9$*EF$ S!K$'EF5<%L7;X .'& I<9*&*$%.'/ <'F<'& 0-' \eO$%*5$'8$' *78 <.EF A. L9B%$'J *'#*$#$*8 $*'$ 0$%$*'6<EF8$]-&$99*$%.'/ 8%</6BF*/ K9$*K8: Y*$ V*5.9<8*-' &$7 /$7<58$' ^K9<.67 $*'$7 7EF#$%$' ''6<997 *' $*'$5 M$*EF82 #<77$%%$<L8-% 5*8 F-F$% PEF'/$7EF#*'&*/L$*8 .'& P-K.78F$*8 *78 &<7 ^'9*$/$' &$7 Z-&$7 ^VG\ZJ &$% <97 $.%-OB*7EF$% W'8$/%<9E-&$ /5*'7<5 0-' $*'$% &$.87EF$' .'& $*'$% 6%<'A)7*7EF$' R-%7EF.'/7$*'%*EF8.'/ $'8#*EL$98 #*%&: Y*$ $%6-9/%$*EF$' ^%K$*8$' A.% K%$*8$' I<9*&*$%.'/ .'& $%78$' ^'#$'&.'/ 6N% V8)%6<997A$'<%*$' 0-' \IWG^ S=: \'2

P<F5$'O%-/%<55X #$%&$' *5 T$%$*EF !V$0$%$ ^EE*&$'8 P$7$<%EF D$8#-%L; SV^PD\GX*5 m\ ' 2P<F5$'O%-/%<55 6-%8/$7$8A8:

7.1 Stand der Modellierung am Beispiel COCOSYS

Y<7 Z-'8<*'5$'82Z-&$2V_78$5 SZ[Z[VjVX #*%& 6N% &*$ .56<77$'&$ V*5.9<8*-' 0-' 7EF#$%$' V8)%6B99$' *' V*EF$%F$*87K$FB98$%' 0-' M$*EF8#<77$%%$<L8-%$' $'8#*EL$98: a*$97$8A.'/ *78 &*$ V*5.9<8*-' <99$% #$7$'89*EF$' UFB'-5$'$J U%-A77 .'& a.78B'&$ *5 Z-'8<*'5$'8J &*$ #BF%$'& 7-9EF$% V8)%6B99$ <.68%8' L)''$': ^K&$EL$'& 7-99$' <.EF ^.79$/.'/778)%6B99$ 7*5.9*$%8 #$%&$': *' VEF#$%O.'L8 *' Z[Z[VjV *78 'K' &$% I$%#$'&.'/ 5)/9*EF78 5$EF<'*78*7EF$%]-&$99$J $*'$ #$*8/$F$'&$ T$%NEL2 7*EF8*/.'/ 0-' b$EF7$9#*%L.'/$' A#*7EF$' &$' 0$%7EF*$&$'$' UFB'-5$'$'J #*$ A: T: GF$%5-F_&%<.9*LJ b<77$%78-660$%K%$''.'/J ^$%-7-92 .'& D.L9*&0$%F<98$':

W' Z[Z[VjV #$%&$' 7-#$*8 #*$ 5)/9*EF 5$EF<'*78*7EF$]-&99 6N% &*$ ^'<9_7$ &$% OF_7*L<9*7EF$' .'& EF$5*7EF$' U%-A77 *' &$' V*EF$%F$*87K$FB98$%' 0-' M$*EF82 #<77$%%$<L8-%$'J &*$ #BF%$'& 5)/9*EF$% V8)%6<99<K9B.6$ <.68%8' L)''$'J 0$%#$'&$8: Y<7 U%-/%<557_78$5 *78*' 5$F%$%$ 7-/$'<''8$ c<.O85-&.9$ <.6/8*98 ST*9& n21X:

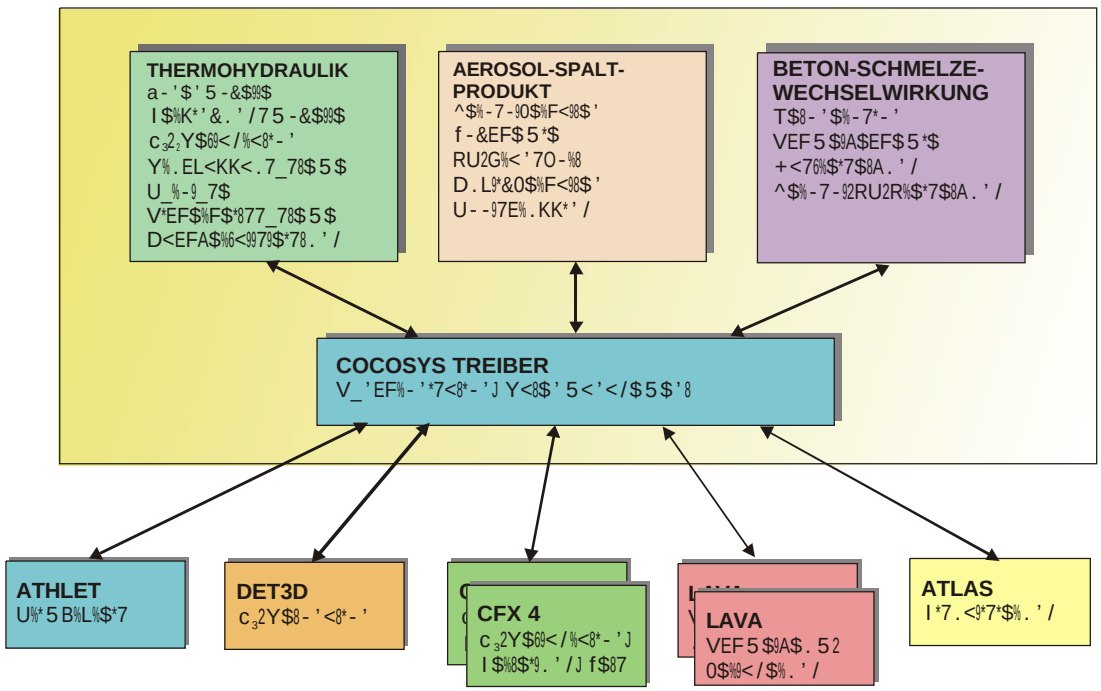


Bild 7-1C V8%.L8.%&$7 Z-'8<*'5$'82Z-&$7 Z[Z[VjV

f$&$% c<.O85-&.9 *78 $*' $*/$'78B'&*/$7 <.76NF%K<%$7 U%-/%<55J A.78B'&*/ 6N% $*'$' K$78*558$' T$%$*EF &$% +$7<58O%-K9$5<8*L: Y*$ (-55.'*L<8*-' A#*7EF$' &*$7$' c<.O85-&.9$' *78 5*88$97 &$7 &$' T$%$EF'.'/7<K9<.6 -%/<'*7*$%$'&$' .'& 78$.$%'&$' U%-/%<557 UI] %$<9*7*$%8: Y*$ T$%$EF'.'/ &$% +$7<58O%-K9$5<8*L &.%EF &*$ $*'A$9'$' c<.O85-&.9$ $%6-9/8 7-J &<77 &*$ (-OO9.'/ &$% c<.O85-&.9$ <.6 a$*87EF%*88$K$'$ $%6-9/$' L<'' .'& &$% '56<'/ &$% <.7A.8<.7EF$'&$' +%),$' %$9<8*0 /$%*'/ *78: '5 &*$ (-5O9$e*B8 &$7 Y<8$'<.78<.7EF7 *' +%$'A$' A. F<98$'J #*%& Y<8$'<.78<.7EF '.% A#*7EF$' &$' c<.O85-&.9$' .'& &$5 Z[Z[VjV2G%$*K$% A./$9<77$': Y<&.%EFJ &<77 &*$ c<.O85-&.9$ $*/$'78B'&*/$ U%-/%<55$ 7*'&J #$%&$' .'$%#N'7EF8$ V$*8$'66L8$ A#*7EF$' &$' c<.O85-&.9$' 0$%5*$&$' .'& 7- &*$ b<%8.'/ &$7 +$7<587_78$57 #$7$'89*EF 0$%$*'6<EF8:

Y*$ I$%#$'&.'/ 0-' UI] *78 $*'$ /.8$ T<7*7 6N% $*'$ U<%<99$9*7*$%.'/ <.6 \K$'$ &$% c<.O85-&.9$: DK' &$' &%$* c<.O85-&.9$' Gcj SGF$%5-F_&%<.9*LXJ ^RU S^$%-7-92 VO<98O%-&.L80$%F<98$'X .'& ZZW SVEF5$9A0%F<98$'XJ #$9EF$ A.5 *''$%$' G$*9 &$7 Z[Z[VjV2V_78$57 /$F)%$'J #.%&$' #$*8$%$ U%-/%<55$ <' Z[Z[VjV <'/$K.'&$': Y*7 7*'& ^GcM\GS2ZYX A.% V*5.9<8*-' &$7 U%*5B%L%$*7$7 .'& Y\G@Y A.% V*5.9<8*-' 0-' c32Y$8-'<8*-'$' S'.% 0$%$*'6<EF8$ ^'L-OO9.'/X: \%78$ VEF%*88$ #.%&$' K$AN/9*EF &$% (-OO9.'/ A.5 ZRY2U%-/%<55 ZRx.'& A.5 U%-/%<55 M^I^ A.% V*5.9<8*-' &$% VEF5$9A$<.7K%$*8.'/ .'& 2O$%9</$%.'/ &.%EF/$6NF%8: T$AN/9*EF &$% (-OO9.'/ #.%&$ &<7 +$7<58L-'A$O8 *' Z[Z[VjV 7- $%#$*8$%8J &<77 '.' O<%<99$9$ P$EF'.'/$' 0$%7EF*$&$'$%]-&.9$ 5)/9*EF 7*'&: b$*8$% L)''$' 0$%7EF*$&$'$ (-OO9.'/70<%*<8*-'$' ST$%$EF'.'/ &$% V_'EF%-'*7<8*-'7A$*87EF%*88#$*8$J ^.78<.7EF &$% Y<8$'X &.%EF &$' Z[Z[VjV2^'#$'&$% 0-%/$/$K$' #$%&$': Y*$ Y<8$' L)''$' -'9*'$.'& -669*'$ 5*8 &$5 ^GM^V U%-/%<55 0*7.<9*7*$%8 #$%&$':

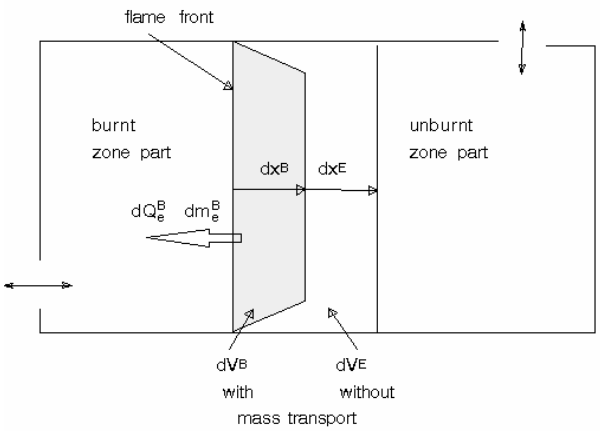
Thermohydraulik (THY)

Y$% GF$%5-F_&%<.9*L2c<.O85-&.9 SGcjX K<7*$%8 <.6 P^M[Z][YIJ RWUM[Z @:1 .'& YP^VjV: Y*$ PB.5$ &$7 (%<68#$%L7 S-&$% <'&$%$ +$KB.&$X #$%&$' *' 7- /$'<''8$ a-'$' .'8$%8$*98 S!9.5O$& O<%<58$%;2(-'A$O8X: Y$% 8F$%5-&_'<5*7EF$ a.78<'& *78 &$6*'*$%8 &.%EF &*$ G$5O$%<8.% .'& &*$]<77$' &$% K$8%<EF8$8$' +<7L-5O-'$'8$' 7-#*$ &$7 b<77$%7: RN% &*$ V*5.9<8*-' L-5O9e% UFB'-5$'$ #$%&$' &*$ a-'$' *' 5$F%$%$ G$*9$.'8$%8$*98: a.%A$*8 7*'& 0*$% 0$%7EF*$&$'$ a-'$'5-&$99$*5O9$55$'8*$%8C

W' &$5 +9$*EF/$#*EF872a-'$'5-&$99 #$%&$' <99$ (-5O-'$'8$' S69N77*/$7 b<77$%J Y<5O6 .'& <'&$%$ +<7L-5O-'$'8$'X <97 F-5-/$' /$5*7EF8 <'/$'-55$'J 7-&<77 *' &$5 (-'8%-990-9.5$' '.% $*'$ G$5O$%<8.% 0-%F<'&$' *78:

Y*$ a-'$ *5 D*EF8/9$*EF/$#*EF872a-'$'5-&$99 *78 *' A#$* a-'$'8$*9$ /8*98C &*$ ^85-7OFB%$ <'<9-/ A.5 +9$*EF/$#*EF872a-'$'5-&$99 .'& &$' V.5O6J &$6*'*$%8 &.%EF G$5O$%<8.% .'& 0-%F<'&$'$ b<77$%5<77$:

RN% &*$ V*5.9<8*-' $*'$% b<77$%78-66O$%K%$''.'/ #*%& &<7 (-'8%-990-9.5$' $*'$% a-'$ #BF%$'& $*'$% I$%K%$''.'/ *' A#$* a-'$'8$*9$ SO-% .'& F*'8$% &$% R9<55$'6%-'8X <.6/$8$*98: Y< &*$ I$%K%$''.'/ 0-' &$% Y_'<5*L &$7 a-'$'A.78<'&$7 <KFB'/8J #.%&$ $*' 7O$A*$99$7 a-'$'5-&$99 Y\Z[P $'8#*EL$98: Y\Z[P *78 $*' $*'&*5$'7*-'<9$7 I$%K%$''.'/75-&$99: Y*$ I$%K%$''.'/ 0$%9B.68 $'87O%$EF$'& &$% aN'&O-7*8*-' KA#: &$% U%-O</<8*-' &.%EF &*$ <'/$L'NO68$' I$%K*'&.'/$' $'89<'/ <' $*'$% 0-' &%$* 5)/9*EF$' I$%K%$''.'/7<EF7$': Y*$ +$7EF#*'&*/L$*8 &$% R9<55$'6%-'8 7$8A8 7*EF A.7<55$' <.7 &$% T%$''/$7EF#*'&*/L$*8 .'& &$% \eO<'7*-' &$7 0$%K%<''8$' a-'$'0-9.5$'7 ST*%& n23X: Y.%EF &*$]-&$99*$%.'/ &$% R9<55$'6%-'8 #*%& *'7K$7-'&$%$ &*$ U%-O</<8*-' $*'$% R9<55$ &.%EF 5$F%$%$ P<.5K$%$*EF$ %$<9*78*7EF$% 7*5.9*$%8:



dVB.....,volume change due to burning
dVE.....,volume change due to expansion
dxB, dxE.....,flame velocity (burning, expansion)
dQ, dm.....,heat and mass transfer due to burning process

Bild 7-2: (-'A$O8 &$7 Y\Z[P2a-'$'5-&$997

RN% &*$ V*5.9<8*-' 0-' Y%.EL<KK<.7_78$5$' #*%& &<7 YP^VjV2a-'$'5-&$99 0$%#$'&$8: W' &*$7$5 a-'$'5-&$99 #$%&$' &%$* a-'$'8$*9$.'8$%7EF*$&$'C &<7 P-F%0-9.5$'J &*$ ^85-7OFB%$ -K$%F<9K &$% b<77$%0-%9</$.'& &*$ b<77$%0-%9</$ 7$9K78: YP^VjV K$%EF'8 &<7 &_'<5*7EF$ I$%F<98$' &$7 b<77$%78<'&$7 *5 P-F%J

&$' +<778%-5 &.%EF &*$ b<77$%0-%9</$ 7-#*$ &*$ (-'&$'7<8*-' &$7 Y<5O6$7 <' &$' T9<7$'-K$%69BEF$' ST*9& n2@X:

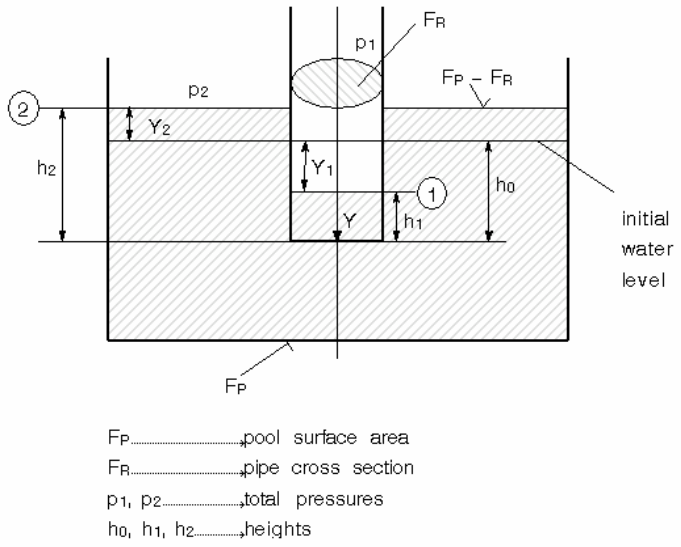


Bild 7-3: (-'A$O8 &$7 YP^VjV a-'$'5-&$997

RN% &*$ I$%L'NO6.'/ &$% a-'$' 78$F$' 0$%7EF*$&$'$ I$%K*'&.'/75-&$99$ A.% I$%6N/.'/: W' Z[Z[VjV #*%& /%.'&7B8A9*EF A#*7EF$' ^85-7OFB%$'2 .'& Y%<*'</0%K*'&.'/$' Sb<77$%8%<'7O-%8X .'8$%7EF*$&$'J #-K$* <.EF &.%EF &*$ ^85-7OFB%$'0$%K*'&.'/$' b<77$% 8%<'7O-%8*$%8 Sb<77$%5*8%*77X .'& &.%EF &*$ Y%<*'</0%K*'&.'/$' /$9)78$7 +<7 8%<'7O-%8*$%8 #$%&$' L<'': a.% V*5.9<8*-' &$% 8$EF'*7EF$' V_78$5$ 78F' 7O$A*$99$]-&99k[O8*-'$' A.% I$%6N/.'/J #*$ A:T: T$%787EF$*K$'J I$'8*9$J 8%B/F$*87K$F<68&8$ (9<OO$'J GN%$'J 7-#*$ <.EF 7O$A*$99$ \eO9-7*-'7L9<OO$'J #$9EF$*' b b\P II>k31@ (%<68#$%L$' 0$%#$'&$8 #$%&$': RN% &*$ Y%<*'</$ 0-' b<77$% 7*'& 0$%7EF*$&$'$]-&99 0-%F<'&$'C b$F%/9$*EF.'/J P-F%78%)5.'/J b<77$%<K9<.6 $'89<'/ b<'&-K$%69BEF$': Y<7]-&$99 6N% U.5O$'7_78$5$ $%9<.K8 &*$ V*5.9<8*-' 0-' D-8LNF97_78$5$'J 0$%7EF*$&$'$% (NF9$%8_O$' .'& VO%NF7_78$5$':

Y*$ bB'&$.'& *''$%$' V8%.L8.%$' #$%&$' &.%EF V8%.L8.%-Kh$L8$ <K/$K*9&$8: \7 #*%& $*' $*'&*5$'7*-'<9$7 bB%5$9$*8.'/75-&$99 0$%#$'&$8: Y*$ O9<88$'2 KA#: A_9*'&$%6)%5*/$' V8%.L8.%$' L)''$' K$9*$K*/ *' VEF*EF8$' S*'L9.7*0$ VO<98$'X $*'/$8$*98 #$%&$': RN% &*$ b$EF7$9#*%L.'/ 5*8 &$% .5/$K$'&$' ^85-7OFB%$ -&$% V.5O6 78$F$' 0$%7EF*$&$'$ bB%5NK%/<'/75-&99 A.% I$%6N/.'/C 6%$*$.'& $%A#.'/$'$ (-'0$L8*-'J (-'&$'7<8*-'J 7-#*$ V8%<F9.'/ 5*8 &$% ^85-7OFB%$.'& A#*7EF$' 0$%7EF*$&$'$' b<'&-K$%69BEF$':

RN% &*$ V*5.9<8*-' 7EF#$%$% V8)%6<997p'A$' 7-#*$ 5)/9*EF$% +$/$'5<,'< F5$'*78 &*$ T$%NEL7*EF8*/.'/ 0-' V*EF$%F$*877_78$5$' '-8#$'&*/: W5]-&.9 Gcj L)''$' 0$%7EF*$&$'$ (NF9$%8_O$' S*'L9.7*0$ a#*7EF$'LNF9L%$*79<.6XJ VO%NF7_78$5$J MN68.'/77_78$5$J *7L-'&$'7<8-%$' .'& L<8<9_8*7EF$ P$L-5K*'<8-%$' 7*5.9*$%8 #$%&$': W'7K$7-'&$%$ 6N% &*$ O<77*0$' L<8<9_8*7EF$' P$L-5K*'<8-%$' SU^PX #.%&$ $*' 7O$A*$99$7 $*'&*5$'7*-'<9$7]-&$99 $'8#*EL$98 ST*9& n2IX: W' &*$7$5]-&$99 #*%& &$% VEF<EF8 *' 5$F%$%$ V$/5$'8$.'8$%8$*98: RN% h$&$7 V$/5$'8 #*%& &$% 8F$%5-&_'<5*7EF$ a.78<'& K$%$EF'$8: T$%NEL7*EF8*/8 #$%&$' <.EF &*$ L<8<9_8*7EF$' R-9*$' .'& &<7 +$FB.7$: Y$% bB%5$NK$%/<'/ 7$8A8 7*EF A.7<55$' <.7 &$% (-'0$L8*-'J (-'&$'7<8*-' .'& &$% V8%<F9./ A#*7EF$' &$' $*'A$9'$' V8%.L8.%-K$%69BEF$': RN% &*$ P$<L8*-' <' &$% L<8<9_8*7EF$' [K$%69BEF$ #*%& $*' ^%%F$'*.72^'7<8A 0$%#$'&$8: Y*$ P$L-5K*'<8*-' 0-' Z[#*%& K'6<997 K$%$EF'$8:

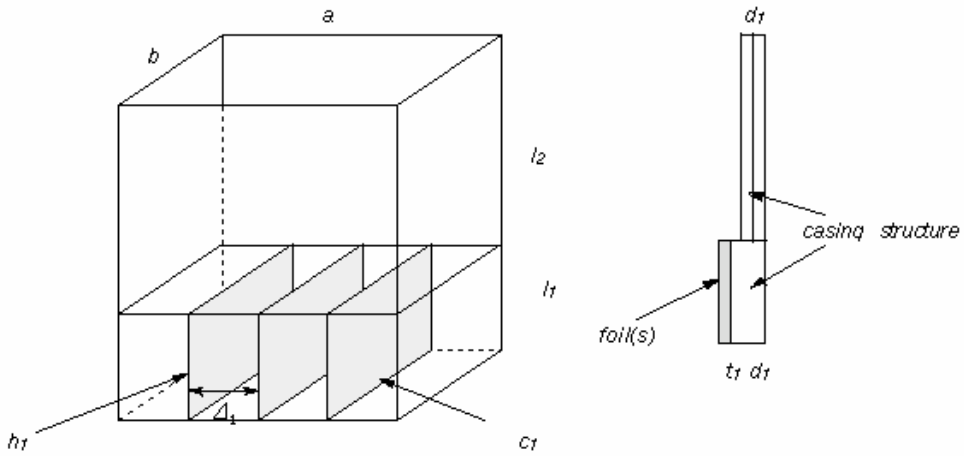


Bild 7-4: U%*'A*O $*'$7 7EF<EF86)%5*/$' P$L-5K*'<8-%7

Y<7 GF$%5-F_&%<.9*L2c<.O85-&.9 #.%&$ 6N% &*$ V*5.9<8*-' 0-' g92 .'& (<K$9K%B'&$' $%#$*8$%8: W5 g9K%<'&5-&$99 #*%& &<7 T%<'&/.8 &.%EF $*'$ V8%.L8.% 5*8 6$78$5 G$5O$%<8.%/*88$% 7*5.9*$%8: RN% &*$ T$%$EF'.'/ &$% U_%-9_7$%<8$ #*%& $*' Y*66.7*-'7<'7<8A 0$%#$'&$8: Y<7]-&$99 #.%&$ <.6 0$%7EF*$&$'$ T%<'&eO%*5$'8$ <'/$#$'&$8 .'& &<5*8 0$%K77%8: b$*8$%$ I$%7.EF$ #$%&$' *5 P<F5$' &$7 WZR]U SW'8$%'<8*-'<9 E-99<K-%<8*0$ 6*%$ 5-&$99*'/ O%-h$E8X '<EF/$%$EF'$8: RN% &*$ V*5.9<8*-' &$7 (<K$9K%<'&$7 78$F8 $*' 9$ %$*'6<EF8$7 (<K$9K%<'&5-&$99; A. I$%6N/.'/: Y*$7$7 #.%&$ <'F<'& &$% cYP \l3 I$%7.EF$ /$8$78$8: a.%A$*8 #$%&$' (<K$9K%<'&0$%7.EF$J #$9EF$ *' Y$.87EF9<'& &.%EF/$6NF%8 #.%&$'J *5 P<F5$' &$7 WZR]U K9*'& '<EF/$%EF'8: Y*$*5 ZPYM[Z U%-/%<55 0$%#$'&$8$' (-%%$9<8*-'$' A.%V*5.9<8*-'

&$7 +%<OF*8K%<'&$7 *' $*'$5 R.7*-'7%$<L8-% #.%&$' *' Z[Z[VjV NK$%'-55$': *'A$9'$ I$%7.EF$.'8$% &$5 *' &*$7$5 P$<L8-%8_O 0-%F<'&$'$' T$&*'/.'/$' S‘'8$%&%.ELJ F-F$ G$5O$%<8.%$'X #.%&$' '<EF/$%$EF'$8 SWZ\2I$%7.EF$Q b<77$%2 $*'K%.EF*' &$' G-%.7X:

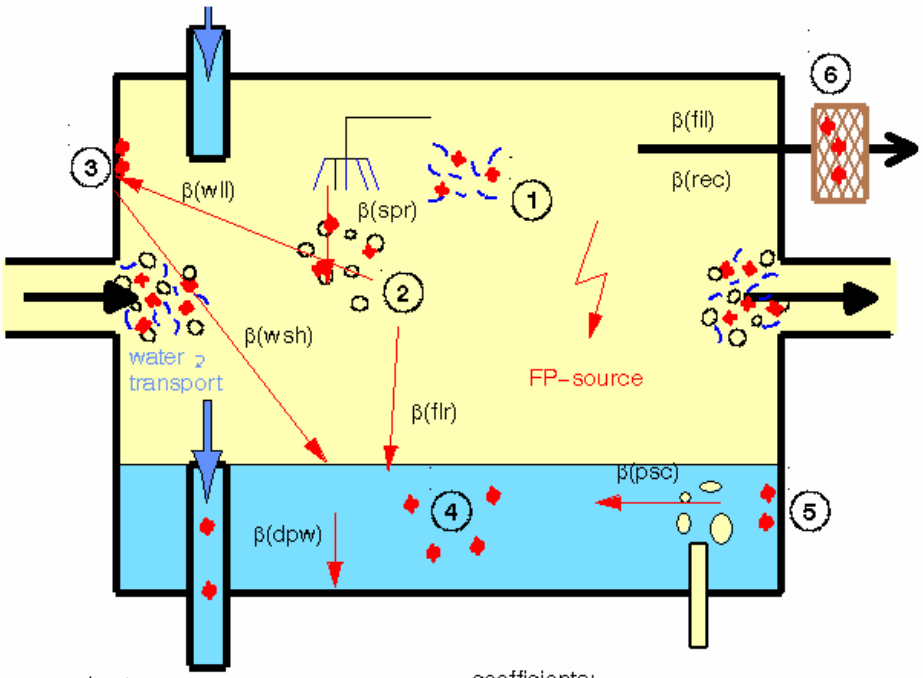
Aerosol- und Spaltproduktverhalten (AFP)

Y<7 ^RU2c<.O85-&.9 *' Z[Z[VjV K<7*$%8 <.6 RWUM[Z @:1: ‘'8$% I$%#$'&.'/ &$% 8F$%5-F_&%<.9*7EF$' P<'&K$&*'/.'/$' #*%& &<7 ^$%-7-90$%F<98$' 0-' K*7 A. <EF8 EF$5*7EF .'8$%7EF*$&9*EF$' ^$%-7-9L-5O-'$'8$' K$%EF'8: ‘'8$%7EF*$&$' #*%& &<K$* A#*7EF$' 9)79*EF$'J '*EF829)79*EF$' 7-#*$ F_/%-7L-O*7EF$' .'& '*EF82F_/%-7L-O*7EF$' ^$%-7-9$': \7 #$%&$' 6-9/$'&$ ^K9</$%.'/7O%-A$77$ K$%NEL7*EF8*/8C V$&*5$'8<8*-'J Y*66.7*-'7<K7EF$*&.'/J GF$%5-OF-%$7$J Y*66.7*-OF-%$7$: a.% T$%$EF'.'/ &$% (-'&$'7<8*-' <' &$' ^$%-7-9$' #*%& &*$ 7- /$'<''8$]+^2]$8F-&$ 0$%#$'&$8J #$9EF$ &*$ '.5$%*7EF$ Y*66.7*-' A#*7EF$' &$' +%),$'L9<77$' $%F$K9*EF 0$%%*'/$%8: T$* F_/%-7L-O*7EF$' ^$%-7-9$' L<'' $*'$ (-'&$'7<8*-' <' &*$7$' 7EF-' .'8$% NK$%F*8A8$' T$&*'/.'/$' <.68%8'J #-K$* 7*EF &*$ R$.EF8$ *' &$% ^85-7OFB%$ B'&$%8: Y*$7$ PNEL#*%L.'/ <.6 &$' VB88*/.'/7A.78<'& #*%& *' &$% GF$%5-F_&%<.9*L2P$EF'.'/ K$%NEL7*EF8*/8J &< &<7 ^$%-7-90$%F<98$' '<F$ &$% VB88*/.'/ $5O6*'&9*EF 0-5 VB88*/.'/7/%<& <KFB'/8:

Y<7]-&.9 RWUc[VG K$%$EF'$8 &$' G%<'7O-%8 &$% VO<98O%-&.L8$ *''$%F<9K &$7 Z-'8<*'5$'87 ST*9& n2=X: ^97 G%B/$% 6N% &*$ VO<98O%-&.L8$ #*%& A#*7EF$' &$% ^85-7OFB%$J &$5 ^$%-7-9 .'& &$5 V.5O6#<77$% .'8$%7EF*$&$': Y*$ VO<98O%-&.L8$ L)''$' <' [K$%69BEF$' *' &$% ^85-7OFB%$.'& *5 V.5O6 <K/$9</$%8 #$%&$': Y$% G%<'7O-%8 $%6-9/8 $'87O%$EF$'& &$% +<72 .'& b<77$%5<77$'78%)5$ &.%EF &*$ I$%K*'&.'/$' A#*7EF$' &$' a-'$': ^99$ %$9$0<'8$' U%-A$77$ &$% VO<98O%-&.L8$ A#*7EF$' &$' 0$%7EF*$&$'$' G%B/$%' #$%&$' K$%NEL7*EF8*/8C ^$%-7-9<K9</$%.'/ &.%EF '<8N%9*EF$ U%-A77 .'& &.%EF 8$EF'*7EF$ V_78$5$ #*$ R*98$% .'& VO%*'L9$%<'9</$'J ^K#<7EF$' 0-' bB'&$' .'& G%B/$%#$EF7$9 &.%EF &$' %<&*-<L8*0$' a$%6<99:

]*8 c*96$ &$7]-&.97 RWUWV[#*%& &<7 D.L9*&0$%F<98$' 7*5.9*$%8: RWUWV[K$%NEL7*EF8*/8 &<7 <'6B'/9*EF$ <L8.99 ($%'*'0$'8<% S0-%<.7K$%$EF'$8 &.%EF <'&$%$ U%-/%<55$X &$7 P$<L8-%7 .'& K$%EF'8 &<%<.7 &$' a$%6<99 &$% VO<98O%-&.L8$ $'87O%$EF$'& &$5 A$*89*EF$' T$/*'' &$% R%$*7$8A.'/ .'8$% I$%#$'&.'/ $8<K9*$%8$% D.L9*&K*K9*-8F$L$' S<'<9-/ A. [PW+WDX: Y$% G%<'7O-%8 &$% D.L9*&$ #*%& 0-' RWUc[VG K$%$EF'$8: RWUWV[L-5O%*5*$%8 &*$ D.L9*&K*K9*-8F$L .'& %$&.A*$%8 &*$ ^'A<F9 &$% D.L9*&$ <.6 &*$ 6N% &$'

K$8%<EF8$8$' R<99 %$9$0<'8$' D.L9*&$: *'$ I-%/<K$ 0-' a$%6<997L$88$' &.%EF &$' D.8A$% *78 &<F$% '*EF8 $%6-%&$%9*EF: HK9*EF$%#$*7$ #$%&$' *' &$' P$EF'.'/$' A#*7EF$' I>> .'& ¤ 0$%7EF*$&$'$ D.L9*&$ K$%NEL7*EF8*/8: Y*$ 0-' RWUWV[K$%$EF'8 D<EFA$%6<9979$*78.'/ *' &$' $*'A$9'$' a-'$' .'& <.6 &$' $*'A$9'$' G%B/$%' #*%& *5 Gcj c<.O85-&.9 K$%NEL7*EF8*/8:



host:
1 – gas
2 – aerosol
3 – gas phase surfaces
4 – water
5 – water phase surfaces
6 – systems (filter, recombiner)

coefficients:
β(flr) – deposition on floor
β(wll) – deposition on wall/ceiling
β(spr) – spraying
β(psc) – pool scrubbing
β(wsh) – washing
β(dpw) – deposition in water
β(fil+rec) – decontamination in systems

Bild 7-5: RWUc[VG2(-'A$O8

Y*$ ZF$5*$ *5 f-&5-&.9 ^W] K<7*$%8 <.6 W] U^WP .'& K$*'F<98$8 ¤ .'8$%7EF*$ &9*EF$ P$<L8*-'$': ^W] .'8$%7EF$*&$8 A#*7EF$' 1nf-&7O$A*$7 *' &$% ^ 85-7OFB%$.'& 1l f-&7O$A*$7 *5 V.5O6: Y$% f-&8%<'7O-%8 A#*7EF$' ^85-7OFB%$.'& V.5O6 7-#*$ &.%EF &*$ I$%K*'&.'/$' #*%& K$%$EF'$8: Y<7 I$%F<98$' &$% <$%-7-%)%5*/$' f-&7O$A*$7 Z7W .'& ^/WJ 7-#*$ ^/ L<'' &*%$L8 0-5 ^$%-7-95-&$99 *' ^RU K$%EF'8 #$%&$': Y<7 f-&5-&.9 ^W] #.%&$ <'F<'& 0$%7EF*$&$'$% GF^W2I$%7.EF$ /$8$78$8: Y<K$* #.%&$' *'7K$7-'&$%$ &*$ b$EF7$9#*%L.'/$' 0-' W3 <' V8<F9-K$%69BEF$' 0$%K77%8:

Y*$ PNELF<98.'/ 0-' ^$%-7-9$' K$*5 +<78%<'7O-%8 &.%EF b<77$%0-%9</$' #*%& &.%EF &<7]-&.9 VU^PZ K$%$EF'$8: Y<5*8 L<'' A:T: &<7 O--9 7E%.KK*'/ *' Y%.EL2 <KK<.7_78$5$'0-' V*$&$#<77$%%$<L8-%$' 7*5.9*$%8 #$%&$':

\7#.%&$' 7O$A*99]-&99 A.% V*5.9<8*-' 0-' R*98$%' Sc\U^2R*98$%J +%<'.9<82R*98$%X*' Z[Z[VjV $*'/$K<.8: T$%NEL7*EF8*/ #*%& &<K$* <.EF &$% A.'$F5$'&$ Y%.EL0$%9.78*' &$' <85-7OFB%*7EF$' I$%K*'&.'/$':

Beton-Schmelze-Wechselwirkung (CCI)

Y<7 K78F$'&$ c<.O85-&.9 ZZW K<7*$%8 K*79<'/ <.6 $*'$% 0$%K$77$%8$' b\ZcVM2 I$%7*-': Y<7 U%-/%<55 K$%EF'8 &<7 8F$%5-&_'<5*7EF$ I$%F<98$' &$% VEF5$9A$ #BF%$'& &$% T$8-'$%-7*-' SbB%5$2 .'& V8-66<.78<.7EF <' &$% VEF5$9A$-K$%69BEF$.'& 5*8 &$' T$8-'78%.L8.%$'J [e*&<8*-'7%$<L8*-'$'*5 VEF5$9A$O--9X:

VEF5$9A$<.7K%$*8.'/7O%-A$77$ L)''$' 5*8 &$5 PEF'O%-/%<55 M^I^ *' &*$ V*5.9<8*-'77p'A $*'K$A -/$' #$%&$': ^.6/%.'& &$% *' R-%7EF.'/70-%F<K$' S\‘2 U%-h$L8 \Z[VG^PX /$#-''$'$' \%L$''8'*77$ A.% VEF5$9A$<.7K%$*8.'/ #*%& $*' L%*8*7EF$%J *'L-5O9$88$% ^.7K%$*8.'/70-%/<'/ S5*8 &$5 \%/$K'*7 $*'$%)%89*EF *'F-5-/$' <.7/$K%$*8$8$' VEF5$9A$ <'78<88 $*'$7 F-5-/$' <.7/$K*9&8' VEF5$9A$O--97X '.% 6N% +%$'AK$&*'/.'/$' S7$F% L9$*'$ +$7<585<77$J 7$F% L9$*'$% I-9.5$'78%-5J 8$*9$%78<%%8$ VEF5$9A$X $%#<%8$8: *'$ 0-99<.8-5<8*7EF$ (-OO9.'/77p'A A#*7EF$' M^I^ .'& b\ZcVM #.%&$ <.7 &*$7$5 +%.'& A.'BEF78 A.%NEL/$78$998:

Y*$ \'8#*EL9.'/ &$%]-&$99$ *' b\ZcVM 6N% &*$ V*5.9<8*-' 0-']ZZW2UFB'-5$'$' -%*$'8*$%8$ 7*EF 7O$A*$99 <' &$% *' &$' T\G^2\eO$%*5$'8$' K$-K<EF8$8$' UFB'-5$'-9-/*$: W' &$' 0$%/<'/$'$' f<F%$' #.%&$ *' Y$.87EF9<'& &$% Z-&$ b\ZcVM S.'8$% &$5 D<5$' b\X*'8$'7*0 NK$%<%K$*8$8 .'& 0<9*&*$%8: ^.6/%.'& &$% \%6<F%.'/$' <.7 &$5 I<9*&*$%.'/7O%-A$77 0$%K9$*K$' *55$% '-EF .'/$9)78$ U%-K9$578$99.'/$' *5 c*'K9*EL <.6 0$%9B779*EF$ P$EF'.'/$' 5*8 b\ZcVM: T$*7O*$97#$*7$ /<K $7 K$* &$% D<EF%$EF'.'/ &$% ‘V2\eO$%*5$'8$ 5*8 &$% .%7O%N'/9*EF$' b\ZcVM2I$%7*-' /%),$%$ Y*7L%$O<'A$' A. &$' eO%*5$'8$99$' \%/$K'*77$' <97 *5 R<99$ &$% T\G^2\eO$%*5$'8$: Y$7F<9K #.%&$ *' &$' bB%5$NK$%/<'/75-&$99$' *' b\ZcVMJ &*$.%7O%N'/9*EF <.6 +%.'&9</$ &$% T\G^2 UFB'-5$'-9-/*$ $'8#*EL$98 #-%&$' 7*'&J$*'$ ^'O<77.'/0-' $5O*%*7EF$' U<%<5$8$%'

0-%/$'-55$'J .5 *5]*88$9 $*'$ K77%$ b*$&$%/<K$ <99$% \eO$%*5$'8$ A. $%F<98$': W' *'A$%B99$' A$*/$' 7*EF h$&-EF .'$%#N'7EF8$ V$*8$'66L8$ <.6 <'&$%$J }$78 0$%&%<F8$8$; G$*95-&$99$ SA: T: &*$ T*9&.'/ 0-' (%.78$' .'& &*$ 0-9978B'&*/$ \%78<%%.'/ $*'$% U--97EF*EF8XJ &*$ A. $*'$5 0-%A$*8*/$' ^KK%.EF &$% b\ZcVM2P$EF'.'/ 6NF%$' L)''$': DK' &*7' ''A.9B'/9*EFL$*8$'J &*$ &*$ PEF'78<K*9*8B8 0-' b\ZcVM K$$*'8%BEF8*/$'J A$*/$' &*$ $%6-9/%$*EF &.%EF/$6NF%8$' I<9*&*$%.'/7%$EF'.'/$' K$* &$' 0-%%<'/*/ *'8$%$77*$%$'&$' +%),$' \%-7*-'78*$6$.'& G$5O$%<8.% &$%A$*8 *'7/$7<58 /$7F' '-EF $%F$K9*EF$ ''7*EF$%F$*8$' 0-' E<:$*'$5 R<L8-%3KA#:1=> (:

W'7/$7<58 F<8 &<7 c<.O85-&.9 ZZW '*EF8 &*$ V8<K*9*8B8 .'& I$%9B779*EFL$*8 #*$ &*$ c<.O85-&.9$ Gcj .'& ^RU:

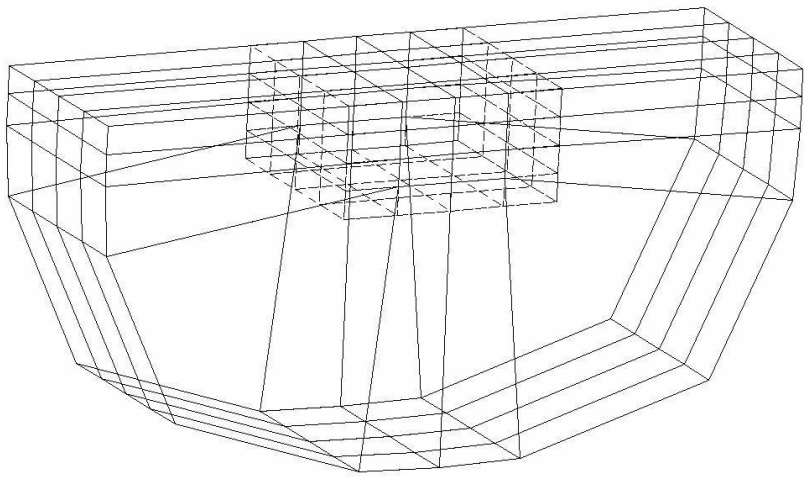


Bild 7-6: W5 O$%$*'6<EF8$' G$789<.6 K$%$EF'8 ^.6#$*8.'/ &$7 <'6B'/9*EF p<&$ %6)%5*/$' U--97*5 3Y [\ZY2]ZZW2\eO$%*5$'8 5*8 Z[PWDD^:

Y<7 U-8$'A*<9 &$7 ^'7<8A$7 *5 '$. $'8#*EL$98$']ZZW]-&.9 Z[PWDD^ L-''8$ K$%$*87 <5 T$*7O*$9 $*'$% I-%<.7%$EF'.'/ 6N% &<7 [\ZY2]ZZW2\eO$%*5$'8 ST*9& n2m 7-#*$ $*'$% D<EF%$EF'.'/ 6N%]^Z\2]@K /$A$*/8 #$%&$': T$%$*87 &*$ 0$%$*'6<EF8$ T$F<'&9.'/ 0-']ZZW <97 %$*'$7 \'$%/*$$%F<98.'/7O%-K9$5 *' A$*89*EF K$#$/8$%J &%$*&*5$'7*-'<9$% +$-5$8%*$ 6NF%8 F*$% A. p<'8*8<8*0 0*$9 0$%7O% EF'&$' \%/$K'*77$': a.LN'68*/$ \'8#*EL9.'/7<%K$*8$' 7*'&*5 c*'K9*EL <.6 &*$ '-8#$'&*/$ I$%6$*'$%.'/ &$7 +*88$%7*' Z[PWDD^J <.6 &*$ \%#$*8$%.'/ 0-' Z[PWDD^ .5 #*EF8*/$]-&99 6N%]ZZW 7-#*$*5 c*'K9*EL <.6 &*$ ZRY2Y<%78$99.'/ &$7 U--90$%F<98$'7 /$O9<'8:

7.2 Erforderliche Entwicklungsarbeiten

W5 a./$ &$% \%78$99./ ./& Y*7L.77*-' &*$7$7 T$%*EF8$7 ./& K$* &$% \%78$99./ ./& Y*7L.77*-' '$.$% ^%K$*87O%-/%<5 5$ $%6-9/8$ $*'$ 0$%78B%L8$ Y*7L.77*-' A.% V$8A./ 0-' U%*-%*8B8$': ' 5 U%*-%*8B8$' 7$8A$' A. L)''$'J F<8 7*EF &*$ \eO$%8$'/5*'7EF<68 <.6 6-9/$'&$ (%*8$%*$' /$$*'*/8C

- V*EF$%F$*878$EF'*7EF$ P$9$0<'AJ
- OFB'-5$'-9-/*7EF$ I-9978B'&*/L$*8J
- ^.7/$#-/$'F$*8 &$%]-&$998*$6$J
- 5*88$96%*78*/$ \%6-9/7<.77*EF8$'J
- ^.7/$#-/$'F$*8 K$* D.5$%*L ./& W'6-%5<8*L78%.L8.%:

T$* &$% ' 57$8A./ &$% (%*8$%*$' *78 &<7 9$8A8/$'<''8$ ''*EF8 K$%NEL7*EF8*/8 #-%&$'J &<$7 O%*'A*O*$99 #*EF8*/$% $%7EF$*'8J 0-%F<'&$'$ I$%78B'&'*72 ./&]-&$99*$%./79NEL$'k 2&$6*A*8$ A. KFK$'J <97 0-%F<'&$'$J *'F<989*EF #$*8/F'& A.6%*$&$' 78$99$'&$]-&99 -&$% Z-&K%$*EF$J <K$% 5*8 A: T: 0$%<98$8$% U%-/%<5 5*$%./J '.5$%*7EF ./& *'6-%5<8*7EF A. -O8*5*$%$': ^.7 &*$7$5 +%./& 6$F98 K$*7O*$97#$*7$ *' &$% 6-9/$'&$' a.7<5 5$'78$99./ 0-' #*EF8*/$' ^%K$*8$' &*$ D$.6-%5<8*$%./ &$7 ^$%-7-95-&$997 ^\PW(^*' Z[Z[VjV:

Y*$ ' 57$8A./ &*$7$% (%*8$%*$' 6NF%8 A. 6-9/$'&$' F*$%<%EF*7EF /$-%&'$8$' ^%K$*872 7EF#$%O.'L8$' 6N% &<7 +$K*$8 }V*EF$%F$* 87$*'7EF9.77}

1: \%F)F./ &$% ^.77</$7*EF$%F$*8 0-' o998%5<'<9_7$' J

3: I$%K$77$%./ &$7 I$%78B'&'*77$7 7-#*$ \%F)F./ &$% a.0$%9B77*/L$*8 &$% V*5.9<8*-' &$7 !$e 0$77$9;2VEF5$9A$0$%F<98$'7J

@: I$%0-9978B'&*/./ &$% V8)%6<997*5.9<8*-'J

I: Vb P27O$A*6*7EF$]-&*6*L<8*-' KA#: \%/B'A./ &$%]-&$99*$%./J

=: ^.79-8$' &$% +%$'A$' &$% !9.5O$& O<%<5$8$%;2]-&$99*$%./ ./& &$% %$<9$'])/9*EFL$*8$' '.L9$<%27O$A*6*7EF$% 7-#*$*'&.78%*$99$% ZRY2Z-&$7:

^' <'&$%$% V8$99$ #*%& *' &*$7$5 T$%*EF8 &*$ b$EF7$9#*%L.'/ A#*7EF$' R9.*&2 .'& V8%.L8.%&_'<5*L SI$%7</$' 0-' P$<L8-%&%.EL2 KA#: V*EF$%F$*87K$FB98$%J P*770$%F<98$' $8E:X K$F<'&$98:

^'F<'& &$% 0-%/$'<''8$' ^%K$*877EF#$%O.'L8$ #$%&$' *5 R-9/$'&$' &$% V8<'& &$%]-&$99*$%.'/ .'& &*$ <.7 F$.8*/$% V*EF8 0-%&%*'/9*EF '-8#$'&*/$' \'8#*EL9.'/7<%K$*8$' 7L*AA*$%8:

7.2.1 Erhöhung der Aussagegenauigkeit von Quelltermanalysen

7.2.1.1 Berechnung des pH-Wertes

W' $*'$5 P$<L8-%7.5O6 F<8 &$% Oc2b$%8 $*'$' /%-,$' *'69.77 <.6 0*$9$ f-&%$<L8*-'$': W'7K$7-'&$%$ FB'/8 &*$ T*9&.'/ &$% 69NEF8*/$' f-&7O$A*$7 $9$5$'8<%$7 f-& SW3X}.'& }%/<' *7EF$7 f-& SPWX}*' &$% b<77$%OF<7$ 78<%L 0-5 Oc 2b$%8 <K kT^M >1k: W3 .'& PW #$%&$' <.7 &$5 V.5O6*' &$' +<7%<.5 6%$*/$7$8A8 .'& 7*'& #$7$'89*EF$ T$78<'&8$*9$ &$7 f-&2o$998$%57 <.7 &$% ^'9</$: T$* L9$*'$' Oc 2b$%8$' S=J 7<.%$% V.5O6X L<' ' &*$ R%$*7$8A.'/ &$% 69NEF8*/$' f-&6-%5$' <.7 &$5 V.5O6J h$ '<EF &$5 K$8%<EF8$8$' VA$'<%*- .'& &$' A./$F)%*/$'J OF_7*L<9*7EF2EF$5*7EF %$9$0<'8$' P<'&K$&*'/.'/$'J .5 0*9 +%),$'-%&'.'/$' F)F$% <97 K$* $*'$5 F-F$' Oc2b$%8 S dJ> <9L<9*7EF$% V.5O6X 7$*': T$9<78K<%$ f-&2P$EF'.'/$' $%6-%&$%' &<F$% $*'$ 5)/9*EF78 /$'<.$ Oc2 b$%82T$78*55.'/:

Y$% Oc2b$%8 $*'$7 P$<L8-%7.5O6$7 A.5 V8)%6<99K$/*'' *78 h$ '<EF P$<L8-%8_O .'8$%7EF*$&9*EF .'& FB'/8 .'8$% <'&$%$5 0-5 Oc2b$%8 &$7 (NF95*88$97 .'& &$7 D-8$*'7O$*7$#<77$%7 <K:]*8 R-%87EF%$*8$' &$7 V8)%6<997 B'&$%8 7*EF &$% Oc2b$%8 &.%EF #$*8$%$ *'7O$*7.'/ &$% D-8LNF97_78$5$ 5*8 K-%*$%8$5 b<77$%J &.%EF *'8%</ 0-' VO<98O%-&.L8$'J &.%EF <.6/$9)78$' -&$% <.7/$9<./8$' T$8-' .'& &.%EF VB.%$' 5*8 &$5 <K9<.6$'&$' b<77$% k[\ZY >>k: Y*$ VB.%$' #$%&$' 0-%#*$/$'& K$* &$% P<&*-9_7$ 0-' 6$.EF8$% M.68 .'& 0-' -%/<'*7EF$' T$78<'&8$*9$'J #*$ 7*$ A: T: *' R<%K<'78%*EF$' .'&*' 9L8%*7EF$' (<K$9' 0-%F<'&$' 7*'&J*5 Z-'8<*'5$'8 /$K*9&$8:

Y<%NK$% F*'<.7 7*'& *5 ^99/$5$*'$' 'K' &$5 P$<L8-%7.5O6 <.EF #$*8$%$ G$*97N5O6$ *' ^'9</$'%B.5$' A. K$8%<EF8$'J &$%$' Oc2b$%8$ 7*EF 0-' &$'$' &$7 P$<L8-%7.5O67 $%F$K9*EF .'8$%7EF$*&$' L)''$'J K$*7O*$97#$*7$J #$'' F*$% &*$ Oc2 78<K*9*7*$%$'& #*%L$'&$ T-%7B.%$ '*EF8 F*'/$9<'/8:

T$* $*'$% P$*F$ <.79B'&*7EF$% P$<L8-%$' *78 <97 ^]2]<,'<F5$ &*$ a./<K$ 0-' a.7<8A78-66$' A.% \%F)F.'/ &$7 Oc2b$%87 *5 P$<L8-%7.5O6 .'& &<5*8 A.% P$&.A*$%.'/ &$7 69NEF8*/$' f-&7 0-%/7F$': Y*$7 *78 *' &$.87EF$' ^'9</$' '*EF8 &$% R<99 .'& &*$ 5)/9*EF$ V8%$.K%$*8$ &$7 Oc2b$%87 *78 &<F$% /%),$%:

Y*$ T<'&K%$*8$ 5)/9*EF$% Oc2b$%8$ *78 7-5*8 7$F% /%-, .'& 5.77 *5 ^99/$5$*'$' A$*89*EF .'&)%89*EF <.6/$9)78 0-%/$/$K$' #$%&$': c*$%6N% *78 $*'$ <.8-5<8*7EF$ Oc2 T$%$EF'.'/ '-8#$'&*/J &< &$% ^'#$'&$% &*7 L-5O9e' Oc2I$%9B.6$ *5 ^99/5*'$' '*EF8 0-' c<'& 5*8 '-8#$'&*/$% +$'<.*/L$*8 0-%/K' L<'':

Z[Z[VjVk^W] S^&0<'E$& W-&*'$]-&$9X $'8FB98 L$*'$ T$%$EF'.'/ &$7 Oc2b$%87 *' $*'$5 P$<L8-%7.5O6: Y$% A$*89*EF$ I$%9<.6 5.77 *' &$% *'/<K$ 0-%/$/$K$' #$%&$': W'8$%'<8*-'<9 $e*78*$%$' K$%$*87 $*'*/$]-&99 A.% T$%$EF'.'/ &$7 Oc2b$%87 *' P$<L8-%7N5O6$'J #*$ A: T: *' &$' f-&5-&$99$' WDVU\ZG .'& MWPWZ 7-#*$ *5 W'8$/%<9E-&$]\MZ[P: Y*$ T$%$EF'.'/ K<7*$%8 *5 b$7$'89*EF$' <.6 EF$5*7EF$' +9$*EF/$#*EF87K$8%<EF8.'/$' SVB.%$2T<7$'2T*9<'AX #BF%$'& &$7 /$7<58$' V8)%6<99<K9<.67: Y$% ^'6<'/7#$%8 #*%& <'F<'& &$7 Oc2b$%87 *5 (NF95*88$9 .'& &$5 b<77$% &$% D-8LNF97_78$5$ K$78*5 58: RN% &$' #$*8$%$' I$%9<.6 #$%&$' &*$ *5 V.5O6 /$K*9&$8$' .'& &*$ 5*8 &$5 (-'&$'7<8 A.78%)5$'&$' VB.%$' .'& T<7$' K$%$EF'$8:

Y*$ \'8#*EL9.'/ $*'$7]-&$997 A.% Oc2b$%82T$%$EF'.'/ 6N% Z[Z[VjV2^W] 7-99 &<F$% <.6 &$% T<7*7 $*'$7 0$%6N/K<%$'J 0<9*&*$%8$']-&$997 $%6-9/$': Y*$ 0-%/7F$'$' ^%K$*877EF%*88$ &<A..56<77$'C

1: ^.7#<F9 $*'$7 T<7*75-&$997 6N% Z[Z[VjVk^W]J

3: ^&<O8*-' .'& \%#$*8$%.'/ 6N% &$.87EF$ ^'9</$' .'&

@: I<9*&*$%.'/:

' Oc2]-&$99*' Z[Z[VjV 5.77 <'F<'& /$$/'8% \eO$%*5$'8$ 5*8 &$6*'*$%8$5 Oc2 I$%9<.6 /$8$78$8 #$%&$': +/6: $*/'$' 7*EF <.EF K$%$*87 0$%6N/K<%$ f-&0$%7.EF$ SPGR2J Z^W]^D2^'9</$'X A. I<9*&*$%.'/7A#EL': Y<K$* #*%& 7*EF A$*/$'J -K A.7B8A9*EF$ I$%7.EF$ SA: T: *' &$% GF^W2^'9</$X 5*8 0$%B'&$%9*EF$5 Oc2b$%8 $%6-%&$%9*EF 7*'&: Y$'LK<% *78 <.EF &$% *'7<8A 0-' %$<L8*0$' +<7$' #*$ D[eJ &*$ K$* &$% P<&*-9_7$ &$% Z-'8<*'5$'8<85-7OFB%$ $'878$F$' .'& $*'$ 7<.%$ b%L.'/ <.6 &$' Oc2b$%8 &$7 V.5O6$7 F<K$':

7.2.1.2 Jodverhalten

Kopplung des Jodmassentransports mit der Thermohydraulik

V$*8 E<: 1> f<F%$' #*%& *' Y$.87EF9<'& K$* &$% V*5.9<8*-' &*$ V8%<8$/*$ 0$%6-9/8J '$K$' &$% f-&EF$5*$ 7$9K78 <.EF &<7 G%<'7O-%8O$%F<98$' 0-' f-& A. K$7EF%$*K$': U%-A77 #*$ f-&<&7-%O8*-' .'& 2%$7.7O$'7*-' <.6 8%-EL$'$' -&$% '<77$' [K$%69BEF$' SV8<F9 -&$% R<%K<'78%*EFX .'& f-&8%<'76$% A#*7EF$' #B77%*/$% UF<7$.'& ^85-7OFB%$ FB'/$' 0-' &$' V8%)5.'/70-%/B'/$' *' &$% ^85-7OFB%$J VEF*EF8.'/$' *' ^85-7OFB%$.'& V.5O6 7-#*$ &$%$' G$5O$%<8.%$' <K: W' T*9& n2n7*'& &*$ A<F9%$*EF$' f-&5<77$'8%<'7O-%8OFB'-5$'$ <5 T$*7O*$9 &$% &$.87EF$' GF^W2I$%7.EF7<'9</$ 7EF$5<8*7EF &<%/$78$998J #*$ 7*$*' T$FB98$%' 5*8 /%-,$' I-9.5*'<A. $%#<%8$' 7*'&:

W' &$% GF^W2I$%7.EF7<'9</$ 7*'& 0-% L.%A$5 #$98#$*8 &*$ $%78$' f-&2]$F%%<.52 0$%7.EF$ 5*8 \%6-9/ &.%EF/$6NF%8 #-%&$': Z[Z[VjV S.'& $*'$% 7$*'$% I-%9B.6$%E-&$7J 'B59*EF RWUM[ZX *78 &$% $%78$ Z-&$ NK$%F<.O8J &$% &*$])/9*EFL$*8 K*$8$8J &*$ f-&EF$5*$*' ^KFB'/*/L$*8 &$% *' &$' h$#$*9*/$' a-'$' 0-%9*$/$'&$' GF$%5-F_&%<.9*L A. 7*5.9*$%$': Y*$7$ f-&2]$F%%<.50$%7.EF$ 7*'& 5*8 Z[Z[VjV $*'/$F$'& 2 #$'' <.EF '-EF '*EF8 <K7EF9*$,$'& 2 <'<9_7*$%8 #-%&$': T$7-'&$%$7 ^./$'5$%L *78 &<K$* <.6 &$' 9$8A8$' I$%7.EF &*7% P$*F$ Sf-&213X /9/8 #-%&$'J &< $% 6N% &*$7$ R%</$78$99./ #*EF8*/$ \9$5$'8$ $*'$7 7EF#$%$' V8)%6<997 *' $*'$5 MbP2 V*EF$%F$*87K$FB98$% <KK*9&$8J *'7K$7-'&$%$ &<7 A. $%#<%8$'&$ /9$*EFA$*8*/$ I-%L-55$' 8%-EL$'$% .'& '<77$% [K$%69BEF$' *' /$7EF*EF8$8$% .'& &.%EF5*7EF8$% ^85-7OFB%$: \'87O%$EF$'& $*'$% Z[Z[VjV2I-%<.7%$EF'./ F<8 7*EF *5 \eO$%*5$'8 &<7 c$9*.5 *' #$'*/$' V8.'&$' '<EF &$%W'*8**$%.'/ &$7 Y.%EF5*7EF.'/7O%-A$77$7*5 /<'A$' T$FB98$% /9$*EF5B,*/ 0$%8$*98J #-/$/$' &*$ f-&L-'A$'8%<8*-' NK$% $*'$' 9<'/$' a$*8%<.5 *'F-5-/$' 2 #*$ <.EF 0-' Z[Z[VjV 0-%<.7/$7</8 2 K9$*K8: ^.EF #$'']-&$99$ 6N% $*'A$9'$ U%-A77 '-EF 0$%K$77$%.'/7K$&N%68*/ 7*'&J .5 $*'$ <.EF p<'8*8<8*0 A.6%*$&$' 78$99$'&$ HK$ %$*'78*55.'/ A#*7EF$' \eO$%*5$'8 .'& P$EF'./ A. $%A*$9$'J 7-*78 &-EF /$%<&$ &*7% I$%7.EF $*'$ $*'&%.EL70-99$ T$78B8*/.'/ 6N% &*$ *' Y$.87EF9<'& 7$*8 f<F%$' 6N% $%6-%&$%9*EF $%<EF8$8$ (-OO9.'/ A#*7EF$' f-&5-&$99*$%.'/ .'& GF$%5-F_&%<.9*L:

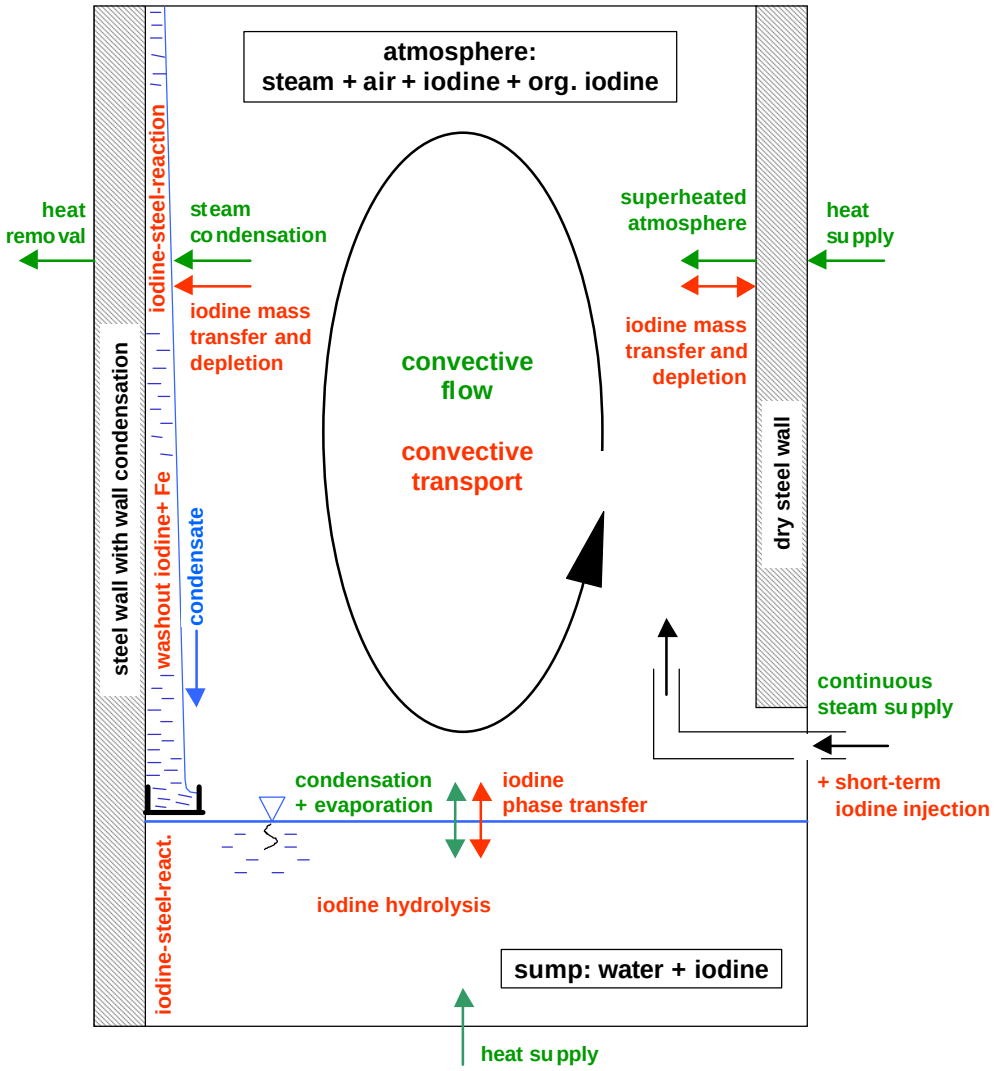


Bild 7-7: GF$%5-F_&%<.9*L .'& f-&8%<'70-%8OFB'-5$'$*' &$%
GF^W2I$%7.EF7<'9</$

\'87O%EF'& &$' \%L$''8'*77$' <.7 &$% &$%A$*8*/$' &$8<*99*$%8$' ^.7#$%8.'/ 7*'&
VEF9.776-9/$%.'/$' 6N%]-&99%8NEF8*/.'/ .'& //6: #$*8$%$ I$%7.EF$ A. A*F': Y<
<'/$'-55$' #*%&J &<77 &*7 (-OO9.'/ 0-% <99$5 6N% &*$ 69NEF8*/$' f-&7O$A*$7 0-'
T$&$.8.'/ *78J 7-998$ &*$7 A.LN'68*/ eO%*5$'8$99 K$78B8*/8 #$%&$':

Jodadsorption/Desorption auf Farbanstrichen

Y$% Y$L-'8<5*'<8*-'7<'78%*EF <.6 &$' [K$%69BEF$' *' $*'$5 MbP2Z-'8<*'5$'8 7O*$98
K$*5 f-&0$%F<98$' $*'$ #*EF8*/$ P-99$: *'$%7$*87 #*%& 69NEF8*/$7 $9$5$'8<%$7 f-& SW3X
<.7 &$% ^85-7OFB%$ <.6 &$' R<%K<'78%*EF$' 8$*9#$*7$ %0%7*K$9 <K/$9</$%8J

<’&$%$%7$*87 #*%& <.7 &$5 <K/$9</$%8$’ W3 .’& -%/<’*7EF$’ T$78<’&8$*9$’ &$% R<%K$ 69NEF8*/$7 -%/<’*7EF$7 f-& /$K*9&$8 .’& <97 7-9EF$7 6%$*/$7$8A8: W3 .’& -%/<’*7EF$7 f-& *’ &$% Z-’8<*’5$’82^85-7OFB%$ K*9&$’ &*$ #7’89*EF$’ T$*8%B/$ *5 78)%6<99K$&*’/8$’ f-&p$9 98$%5 <.7 &$% ^’9</$:

Y*$ W32^K9</$%.’/ <.6 &$5 R<%K<’78%*EF *78 $*’ L-5O9$e$% I-%/<’/J K$* &$5 &*$ 8F$%5-F_&%<.9*7EF$’ U<%<5$8$% G$5O$%<8.%J Y%.ELJ R$.EF8$J b<’&L-’&$’7<8*-’7%<8$.’& &*$ <85-7OFB%*7EF$ V8%)5.’/7/$7EF#*’&*/L$*8J <K$% <.EF &*$ (-’7*78$’A .’& &<7 ^98$% &$7 R<%K<’78%*EF7 $*’$ P-99$ 7O*9’: Y<%NK$% F*’<.7 *78 &*$ W32^.6’<F5$6BF*/L$*8 &$7 R<%K<’78%*EF7 &.%EF &*$ O<%<99$9 <K9<.6$’&$ W32P$7.7O$’7*-’ K$7EF%B’L8: T$*5 ^.68%8’ 0-’ b<’&L-’&$’7<8*-’ #*%& $*’ G$*9 &$7 <K/$9</$%8$’ W3 *’ ’*EF869NEF8*/$7 f-&*& SW2X .5/$#<’&$98 .’& *’ &$’ V.5O6 /$7ON98: Y$% T*9&.’/75$EF<’*75.7 &*$7$% f-&*&2T*9&.’/ SEF$5*7EF$ P$<L8*-’ 0-’ f-& 5*8 R<%K<’78%*EFJ EF$5*7EF$ P$<L8*-’$’ *5 b<’&L-’&$’7<8X *78 K*7F$% ’*EF8 <K7EF9*$,$’& eO%*5$’8$99 /$L9B%8:

W’ &$’ f-&5-&$99$’ #$%&$’ *’ &$% P$/$9 $*’$ $5O*%*7EF /$#-’’$’$ W32^K9</$%.’/72 /$7EF#*’&*/L$*8 .’& $*’$ W32P$7.7O$’7*-’7%<8$ 0-%/$/$K$’J h$#$*97 <KFB’/*/ ’.% 0-’ &$% G$5O$%<8.%: Y*$ P$<L8*-’7L-’78<’8$’ #$%&$’ 5$*78 *’ M<K-%$eO$%*5$’8$’ $%5*88$98: b$&$% &<7 [K$%69BEF$’2kI-9.5$’0$%FB98’*7 ’-EF &*$ V8%)5.’/72 /$7EF#*’&*/L$*8$’ 7*’& *’ &$’ L9$*’$’ P$<L8*-’7/$6B,$’ S8_O*7EF$7 I-9.5$’ 1 9X 0$%/9$*EFK<% 5*8 &$’ I$%FB98’*77$’ *’ $*’$5 P$<L8-%E-’8<*’5$’8: Y*$ (-OO9.’/ 0-’ GF$%5-F_&%<.9*L .’& f-&2]<77$’8%<’7O-%8 *78 &<F$% <.7 \eO$%*5$’8$’ *5 M<K-%5<,78<K ’*EF8 F*’%$*EF$’& <K9$*8K<%J 7-’&$%’ $%6-%&$%8 $’87O%$EF$’&$ I$%7.EF$ <.EF *’ /%-,7L<9*/$’ I$%7.EF7<’9</$’: b$*8$% *78 K$* &$% *5 M<K-% /$5$77$’$’ ^K9</$%.’/ 5*8 &$5 b<’&L-’&$’7<8 <.EF &*$ I$%#$*9&<.$% &$7 W3 *5 b<77$%6*95 .’%$<9*78*7EF L.%A: ^.EF F*$% *78 $*’$ 0$%K$77$%8$]-&$99*$%.’/ ’-8#$’&*/J &*$ <.EF &*$ +%),$’0$%FB98’*77$*5 Z-’8<*’5$’8 K$%NEL7*EF8*/8:

I$%*6*L<8*-’7%$EF’.’/$’ 5*8 Z[Z[VjVk^W] A$*/$’ $*’$.’$%#<%8$8 7EF’99 W32^K9<2 /$%.’/ <.6 &$5 R<%K<’78%*EF *’ $*’$5 Z-’8<*’5$’8: *’ I$%/9$*EF 5*8 b$%8$’ <.7 &$% M*8$%<8.% $%/<KJ &<77 0-% <99$5 &*$ ^W]2b$%8$ 6N% &*$ P$7.7O$’7*-’7%<8$ %$9<8*0 ’*$&%*/$% 7*’&: *’$ HK$%’<F5$ 0-’ M*8$%<8.%#$%8$’ *’ ^W] *78 #$/$’ &$% 5$*78 .’A.%$*EF$’& K$L<’’8$’ I$%7.EF7K$&*’/.’/$’J 0-% <99$5 <.EF &$% ‘’8$%7EF*$&$ *’ &$% EF$5*7EF$’ a.7<55$’7$8A.’/ &$% R<%K<’78%*EF$ /$/$’NK$% &$’$’ *’ &$.87EF$’ ^’9</$’ ’*EF8 K$9<78K<% 5)/9*EF:

\7 *78 &<F$% $%6-%&$%9*EF .'& <.EF 7EF-' 0-%/7F$'J I$%7.EF$ A.% W32^K9</$%.'/ .'& 2P$7.7O$'7*-' *' &$% GF^W2^'9</$ &.%EFA.6NF%$': Y*$7$ I$%7.EF$ K<.$' <.6 &$' K$%$*87 &.%EF/$6NF%8$' *'2 .'&]$F%%<.50$%7.EF$' A.% W32^K9</$%.'/ <.6 8%-EL$'$5 V8<F9 .'& <.6 V8<F9 K$* b<'&L-'&$'7<8*-' <.6 kR‘D>Ik:

Y*$ #7'89*EF$']$%L5<9$ &$% I$%7.EF$ .56<77$'C

- Y$.87EF$% Y$L-'8<5*'<8*-'7<'78%*EF S\O-e_2T<7*7XJ
- 8%-EL$'$.'& '<77$ Sb<'&L-'&$'7<8*-'X T$&*'/.'/$'J
- G$5O$%<8.%8%<'7*$'8$'J R$.EF8$$*'69.77J
- /$7EF*EF8$8$.'& &.%EF5*7EF8$ ^85-7OFB%$ 5*8 .'8$%7EF*$&9*EF$% (-'0$L8*-'72 /$7EF#*'&*/L$*8J
- A.7B8A9*EF A.% W32]$77.'/ *' &$% T$FB98$%<85-7OFB%$ <.EF]$77.'/ &$7 -%/<'*2 7EF$' f-&7:

Y*$ I$%7.EF$ #$%&$' 5*8 Z[Z[VjVk^W]<.7/$#$%8$8: Y<K$* 7-99 K$%$*87 &*$ /$O9<'8$ 0$%K$77$%8$]-&$99*$%.'/ &$7 f-&2]<77$'NK$%/<'/7<' b<'&2 .'& V.5O6-K$%69BEF$' &.%EF $*'$ $'87O%$EF$'&$ (-OO9.'/ A#*7EF$' GF$%5-F_&%<.9*L2 .'& f-&2]-&.9 A.5 *'7<8A L-55$':

Jod-Ozon-Reaktion

In einer Containmentatmosphäre werden unter radioaktiver Strahlung durch Radiolyse von Luft chemisch reaktive Produkte, darunter auch Ozon (O_3), gebildet. Vorhandenes molekulares Jod (I_2) wird durch Ozon oxidiert. Dabei entstehen verschiedene Jod-Oxide, wie I_2O_4, I_4O_9 und I_2O_5, die vereinfachend als IO_X bezeichnet werden. Unter trockenen Bedingungen bildet IO_X in der Gasphase Aerosole. Unter nassen Bedingungen bei kondensierender Atmosphäre hydrolisiert IO_X schnell zu Jodat (IO^-_3). Aus den trockenen IO_X-Partikeln entstehen dabei IO^-_3-Tröpfchen. Auch in Wasserfilme und Pools abgelagertes IO_X-Aerosol hydrolisiert zu IO^-_3.

Im Hinblick auf den Jodquellterm ist vor allem von Bedeutung, dass durch die Jod-Ozon-Reaktion flüchtiges Jod (I_2) in nicht-flüchtiges, aerosolförmiges Jod (IO_X bzw. IO_3) umgewandelt wird. Vor allem das Ablagerungsverhalten von flüchtigem und nicht-flüchtigem Jod auf den Containmentoberflächen ist sehr unterschiedlich. I_2 erfährt eine

starke Adsorption auf den Farbanstrichen im Containment. Die Jodoxid-Aerosole werden durch Sedimentation, Diffusion und Diffusiophorese abgeschieden. Ihre Abbaugeschwindigkeit hängt stark von der Partikelgröße ab.

Im internationalen Vergleich wird die Jod/Ozon-Reaktion in etlichen Jodmodellen nicht berücksichtigt. COCOSYS-Rechnungen zu einem DWR- und einem SWR-Szenario haben übereinstimmend gezeigt, dass mit Berücksichtigung der Jod/Ozon-Reaktion die luftgetragene Jodmenge aus I_2 und IO_3-Aerosol im Containment bzw. in den Anlageräumen erheblich höher ist als ohne Berücksichtigung. Der Grund dafür ist, dass in den Rechnungen I_2 erheblich schneller als das Jodoxid-Aerosol abgelagert wird. I_2 adsorbiert auf den Farboberflächen im Containment. Die im COCOSYS Jodmodul AIM verwendete Ablagerungsgeschwindigkeit von I_2 auf Farbe ist jedoch recht unsicher und soll in der ThAI-Anlage unter realistischen Verhältnissen abgesichert werden.

Internationale Aktivitäten

Im 5. Rahmenprogramm der EU ist ein PIRT (Phenomena Identification and Ranking Tables) für schwere Störfälle durchgeführt worden. Dabei sind gerade für das Jodverhalten noch zahlreiche Einzelprozesse identifiziert worden, die - obwohl höchst sicherheitsrelevant - derzeit hinsichtlich ihrer modellmäßigen Beschreibung noch mit erheblichen Unsicherheiten behaftet sind. Um die bestehenden Lücken zu schließen, ist in Frankreich (IRSN, CEA, EdF) ein großes Versuchsprogramm angelaufen, dessen Ergebnisse in das europäische Netzwerk SARNET eingebracht werden sollen und die OECD plant derzeit, unter Führung des kanadischen AECL, ein so genanntes „Center of Excellence“ zur Jodproblematik einzurichten. Nimmt man noch ein eventuelles OECD-THAI-Projekt, bei dem Jod sicherlich ein Schwerpunkt sein würde, hinzu, dann ist evident, dass die Jodmodelle AIM bzw. IODE in COCOSYS bzw. ASTEC nur dann „state-of-the-art“ bleiben, wenn an allen drei internationalen Projekten qualifiziert mitgewirkt wird.

Mittelfristig ist dann auch über eine Zusammenführung von AIM und IODE zu entscheiden.

Jodabscheidung durch Sprühtropfen

VO%NF7_78$5$ L)''$' $*'$' #7'89*EF$' T$*8%</ A.% ^K7EF$*&.'/ 0-' /<76)%5*/$5 f-& 9$*78$': Y*$7 /*98 '*EF8 '.% 6N% /%-,%B.5*/$ VO%NF7_78$5$ *5 -K$%$' U9$'.5 &$7 V*EF$%F$*87K$FB98$%7 K$* 6%<'A)7*7EF$' Y b P2^'9</$'J 7-'&$%' <.EF 6N% VO%NF7_78$5$ *' *'A$%B.5$' #*$ A: T: &$' Y<5O6$%A$./$%%B.5$' 0-' b b \P2^'9</$'J &$% V b P2 (-'&$'7<8*-'7L<55$% -&$% &$5 -K$%$' P*'/%<.5 *5 V b P2V*EF$%F$*87K$FB98$%: Y*$ ^K7EF$*&.'/7#*%L.'/ *78 <KFB'/*/ 0-' G%-O6$'/%),$.'& I$%#$*9A$*8J f-&7O$A*$72 .'& 2L-'A$'8%<8*-'J G$5O$%<8.% 0-' ^85-7OFB%$.'& G%-O6$' 7-#*$ &$% ^'#$7$'F$*8 #$*8$%$% EF$5*7EF$% VO$A*$7: b*$ *5 V.5O6#<77$% L<'' <.EF *5 G%-O6$' $*'$ c_&%-9_7$%$<L8*-' $*'8%$8$'J &*$ A.% T*9&.'/ 0-' F_O-*-&*/$% VB.%$ Sc [WX 6NF%8: Y*7 P$<L8*-' *78 <KFB'/*/ 0-5 Oc2b$%8 *5 G%-O6$'J &$% 0-5 Z[32+$F<98 &$% M.68 K$$*'69.778 #*%&: b$*8$%$ P$<L8*-'7O<%8'$% 7*'& [37-#*$ K$* V8%<F9.'/7$*'69.77 [@.'& D[e: T$* V.5O6#<77$%%$A*%L.9<8*-' $'8F<98$' &*$ G%-O6$' &*$ EF$5*7EF$' T$78<'&8$*9$ &$7 V.5O6#<77$%7 .'& L)''$'J '$K$' VO<98O%-&.L8$' .'8$% '57 8B'&$' <.EF f-&*' &*$ ^85-7OFB%$ 6%$*7$8A$': Y.%EF V.5O6#<77$%<&&*8*0$ A.% \%F)F.'/ &$7 Oc2b$%87 #*%& &*$ b*$&$%6%$*7$8A.'/ 0-' W3 K$F*'&$%8: DK' &$% G%-O6$'6%$*7$8A.'/ &.%EF &<7 VO%NF7_78$5 *78 F*$% <.EF &*$ G%-O6$'6%$*7$8A.'/ <.7 $*'$5 7*$&$'&$' V.5O6 A. '$''$'J K$* &$5 BF'9*EF$ UFB'-5$'$<.68%8':

Y*$ <85-7OFB%*7EF$ (-'A$'8%<8*-' 0-' f-& .'& f-&0$%K*'&.'/$' *78 0-' F-F$% 7*EF$%F$*878$EF'*7EF$% P$9$0<'A:W' Z[Z[VjV *78 &$%A$*8 L$*']-&$99 &$% EF$5*7EF$' f-&<K7EF$*&.'/ &.%EF VO%NF8%-O6$' 0$%6N/K<%: Y<7 0-%F<'&$'$]-&$99 6N% G%-O6$'%$7.7O$'7*-' <.7 &$5 V.5O6 *78 B.,$%78 $*'6<EF:

\7 /*K8 $*'$ P$*F$ eO%*5$'8$99$% Y<8$' A.% f-&<K7EF$*&.'/ &.%EF VO%NF7_78$5$: I-% &$5 c*'8$%/%.'& &$% \%L$''8''*77$ <.7 &$5 W'8$%'<8*-'<9$' V8<'&<%&O%-K9$5 WVU2I1 .'& &$' f-&$eO$%*5$'8$' <' &$% GF^W2^'9</$ 7*'& &*7]$77&<8$' h$&-EF L%*8*7EF A. #$%8$': ^.6/%.'& &$% F-F$' P$<L8*0*8B8 0-' /<76)%5*/$5 5-9$L.9<%$5 f-& *78 &*$]$77./' 0-' <85-7OFB%*7EF$' (-'A$'8%<8*-'$' 7EF#*$%*/: T$7-'&$%7 O%-K9$5<8*7EF $%7EF$*'8 &*$]$77./' *' 8%-O6$'K9<&$'$% ^85-7OFB%$: W' %<9' ^'9</$' &$EL8 &<7 VO%NF7_78$5 '.% $*'$' G$*9 SE<: =>¥v &$% ^85-7OFB%$ <KJ #BF%$'& *5 NK%*/$' T$%$*EF $*'$ L-'0$L8*0$ PNEL78%)5.'/ &$% ^85-7OFB%$ $%6-9/8: V-9EF$ #7'89*EF$' Y$8<*97 #.%&$' *' K*7F$%*/$' VO%NF0$%7.EF$' '*EF8 K$<EF8$8:

RN% &*$ \'8#*EL9.'/ $*'$7]-&$997 &$% f-&<K7EF$*&.'/ &.%EF VO%NF7_78$5$ 78$998 &<7 -K$' 7L*AA*$%8$ VO%NF7_78$52]-&$99 &*$ /$$*/'8 8F$%5-F_&%<.9*7EF$ T<7*7 &<%: Y*$ #7'89*EF$' (-5O-'$'8$' &$7 f-&5-&$997 7*'&

- f-& .'& <'&$%$ EF$5*7EF$ (-5O-'$'8$' *' &$% ^85-7OFB%$J
- f-& .'& <'&$%$ EF$5*7EF$ (-5O-'$'8$' *' &$' G%-O6$'J
- V8-66<.78<.7EF0-%/B'/$<' &$% [K$%69BEF$ &$% G%-O6$'J
- f-&%$<L8*-'$' *''$%F<9K &$% G%-O6$':

a.% I<9*&*$%.'/ &$7]-&$997 7*'& $%78$ VO%NF0$%7.EF$ *' &$% GF^W2^'9</$ 0-%/7F$': c*$%K$* #*%& <.EF &*$ b$EF7$9#*%L.'/ A#*7EF$' VO%NF7_78$52ZF$5*$.'& 8F$%5-F_&%<.9*7EF$' T$&*'/.'/$' <K/$L9B%8:

7.2.1.3 Resuspensionsvorgänge und ihre quantitative Bedeutung

T$* &$% b*$&$%6%$*7$8A.'/ A.0-% <K/$9</$%8$% %<&*-<L8*0$% V8-66$ L)''$' A#$* #7'89*EF$ U%-A77 .'8$%7EF*$&$' #$%&$'C '<77$.'& 8%-EL$'$ P$7.7O$'7*-': **Nasse Resuspension** KA*EF'$8 &$' ^.78%</ 7.7O$'&*$%8$% V8-66$ &.%EF 7- /$'<''8$ P$2\'8%<*'5$'8O%-A77 <.7 /<7&.%EF78%)58$' R9N77*/L$*870-%9</$'J &*$ 8%-EL$'$ &$' b*$&$%$*'8%</ 0-' <' 6$78$' V8%.L8.%$' <K/$7$8A8$' U<%8*L$9' *' &*$ ^85-7OFB%$'2 78%)5.'/:

Y*$ **nasse Resuspension** $%6-9/8*5 b$7$'89*EF$' &.%EF &$' ^.78%</ 0-' G%-O6$': a.% T$78*55.'/ &$% P<&*-<L8*0*8B876%$*7$8A.'/ <' &*$ ‘5/$K.'/ *78 &<F$% &*$ <.7/$8%</$'$ R9N77*/L$*875<77$.'& &*$ &$' #$*8$%$' G%<'7O-%8 .:<: K$78*55$'&$ G%-O6$'/%),$A. $%5*88$9':

Nasse Resuspension 7O*$98 *' 0$%7EF*$&$'$' V8)%6<992VA$'<%*$' $*'$ #7'89*EF$ P-99$: V-L-558 &*$ &$.87EF$ P*7*L-78.&*$ k+PV d>k .'8$% <'&$%$5 A. &$5 \%/$K'*7J &<77 *' &$% 7OB8$' V8)%6<99OF<7$J #$'' &*$ W'8$/%*8B8 &$7 V*EF$%F$*87K$FB98$%7 NK$% 5$F%$%$ G</$ <.6%$EF8$%F<98$' K9$*K8J *''$%F<9K &*$7$7 a$*8%<.57 &*$ (-'A$'8%<8*-' 0-' <$%-7-96)%5*/$' P<&*-'.L9*&$' .5 5$F%$%$ +%),$'-%&'.'/$' /$%*'/$% #$%&$' L<'': Y*$ P<&*-'.L9*&6%$*7$8A.'/ &.%EF G%-O6$'5*8%*77<.7 b<77$%0-%9</$' L<'' &<'' A.5 K$78*55$'&$' I-%/<'/ 6N% &*$ ^L8*0*8B87L-'A$'8%<8*-' *' &$% Z-'8<*'2 5$'8<85-7OFB%$ #$%&$': Y<%NK$% F*'<.7 L)''$' K$* ^.79$/.'/72 .'& 7EF#$%$' V8)%6B99$' *' Y%.EL#<77$%%$<L8-%$' SY b PX P$7.7O$'7*-'7O%-A77 K$*7O*$97#$*7$ K$*

M$EL</$' *5 Y%.ELF<98$% .'& *5 ^KK9<7$8<'L <.68%8': b$*8$%$ VA$'<%*$' L)''$' *' YbP K$* $*'$5 Y<5O6$%A$./$%F$*A%-F%K%.EF 5*8 R%$*7$8A.'/ *' &$' V$L.'&B%L%$*79<.6 $'878$F$': c*$%K$* L)''8$ $*'$ &*%$L8$ R%$*7$8A.'/ 0-' P<&*-'.L9*&$' <' &*$ '5/$K.'/ .'8$% '5/$F.'/ &$% V*EF$%F$*87K$FB98$%K<%%*$%$ S$'/9:C Z-'8<*'5$'8 T_O<77X $%6-9/$': ^.EF K$* V*$&$#<77$%%$<L8-%$' SVbPX F<K$' &*$ 0-%/$'<''8$' P$7.7O$'7*-'70-%/B'/$ P$9$0<'AJ &< /<7&.%EF78%)58$ b<77$%2 0-%9</$' *' &$' (-'&$'7<8*-'7L<55$%' T$78<'&8$*9$ &$% Y%.EL<KK<.7_78$5$ 0-' VbP 7*'&:

b$*8$%$])/9*EFL$*8$' A.5 ^.68%8' 0-' '<77$' P$7.7O$'7*-'7O%-A77' K$78F' #BF%$'& $*'$7 ($%'7EF5$9A.'6<997: a.5 $*'$' L)''$' P<&*-'.L9*&$ <.7 &$% ($%'7EF5$9A$*' &$% P$<L8-%/%.K$ &.%EF G%-O6$'5*8%*77 6%$*/$7$8A8 #$%&$'JA: T: &.%EF +<76%$*7$8A.'/ <.7 T$8-'A$%78)%.'/: a.5 <'&$%$' L)''$' *' &$% R-9/$ &$% &.%EF (NF95<,'<F5$' $%6-9/$'&$' HK$%69.8.'/ &$% ($%'7EF5$9A$ b<77$%0-%9</$' 5*8 /$9)78$' -&$% 7.7O$'&*$%8$' P<&*-'.L9*&$' $'878$F$': Y*$7$ L)''$' #*$&$% 6%$*/$7$8A8 #$%&$'JA: T: &.%EF V*$&$O%-A77 &$7 &.%EF &*$ D<EFA$%6<997#B%5$ &$% VO<98O%-&.L8$ KF*A8$' V.5O6$7 -&$% &.%EF &*$ <.7 &$% T$8-'A$%78)%.'/ %$7.98*$%$'&$' +<778%)5.'/$': b$*8$%F*' F<8 &*$ '<77$ P$7.7O$'7*-' $*'$ /%-,$ P$9$0<'AJ #$'' $7 *' R-9/$ &$7 Z-'8<*'5$'80$%7</$'7 A.5 ^.67EFB.5$' &$7 V.5O6$7J &$5 7- /$'<''8$' !O--9 69<7F*'/;J L-558 .'& F*$%K$* $*' 78<%L$% G%-O6$'<.78%</ 78<886*'&$8:

Trockene Resuspension L$''A$*EF'$8 &*$ U%-A77J K$* &$'$' U<%8*L$9J &*$ 7*EF <.6 6$78$' [K$%69BEF$' *5 Z-'8<*'5$'8 <'/$9</$%8 F<K$'J &.%EF V8%)5.'/$' *' &*$ ^85-7OFB%$ A.%NEL/$6NF%8 #$%&$': ^.6 U<%8*L$9 <' NK$%78%)58$' [K$%69BEF$' #*%L$' *5 b$7$'89*EF$' A#$* ^%8$' 0-' (%B68$': *'$%7$*87 #*%L$' &*$ +$#*EF87L%<68 .'& &*$ <'A*F'&$' ^&FB7*-'7L%B68$ A#*7EF$' U<%8*L$9 .'& [K$%69BEF$JA.5 <'&$%$' $%A$./8 &*$ V8%)5.'/ 9)7$'&$J <$%-&_'<5*7EF$ (%B68$ S^.68%*$K .'& b*&$%78<'&X <.6 &*$ U<%8*L$9: W'7/$7<58 $%/*K8 7*EF $*' L-5O9$e$7 a.7<55$'#*%L$' 0*$9$% OF_7*L<9*7EF$% (%B68$J &*$ <' &$' &%$* UF<7$'/%$'A$' G$*9EF$' 2 [K$%69BEF$J G$*9EF$' 2 G$*9EF$' .'& G$*9EF$' 2 R9.*& #*%L7<5 #$%&$': Y<5*8 $*'$ %$9$0<'8$ ^.79)7.'/ &$% U<%8*L$9 78<886*'&$' L<''J 5.77 &*$ +%$'A7EF*EF8 0-% &$% [K$%69BEF$ 8.%K.9$'8 7$*'J &:F: &*$ K$*5 P$7.7O$'7*-'70-%/<'/ <5 U<%8*L$9 <'/%$*6$'&$' (%B68$ #*%L$' '*EF8 L-'8*'.*$%9*EFJ 7-'&$%' 7*'& *'78<8*-'B%: ''8$%F<9K &$% +%$'A/$7EF#*'&*/L$*8J <K &$% &*$ b<'&78%)5.'/ 8.%K.9$'8 #*%&J L)''$' L$*'$ 5$%L9*EF$' P$7.7O$'7*-'7$66$L8$ 6$78/$78$998 #$%&$': Y*$ 8%-EL$'$ P$7.7O$'7*-' &$% VO<98O%-&.L8$ 0-' bB'&$' *5 V*EF$%F$*87K$FB98$% L<'' &<F$% *'7K$7-'&$%$ &.%EF F-EF8%<'7*$'8$ I-%/B'/$ #*$

c32 I$%K%$''.'/ -&$% VEF5$9A$2(NF95*88$92b$EF7$9#*%L.'/$' 0$%.%7<EF8 #$%&$':
+$%<&$ &*7 *5O.97<%8*/$' V8%)5.'/$' F<K$' <.6 /%),$%$ U<%8*L$9 $*'$' $%F$K9*EF$'
*'69.77 K$AN/9*EF *F%$% ^K9)7.'/ 0-' +%$'A69BEF$' .'& L)''$' $*'$' #7'89*EF$'
T$*8%</ A.5 o$998$%5 K* 9&$' kVZc >@k:

Y*$ 6-9/$'&$ Y<%78$99.'/ -%*$'8*$%8 7*EF *5 b$7$'89*EF$' <' &$5 \'8#*EL9.'/778<'&
&$7 &$.87EF$' Z-'8<*'5$'82Z-&$2V_78$57 Z[Z[VjVJ #<7 F*$% <K$% '*EF8 <97
*'7EF%B'L.'/J 7-'&$%' F% <97 U%BA*7*$%.'/ A. 0$%78F' *78J &< &77'
]-&$99*$%.'/ <.EF *5 $.%-OB*7EF$']<,78<K &.%EF<.7 <97 78<8$ -6 8F$ <%8; < '/7F$'
#$%&$' L<'': ^99/5*' *78 6$78A.78$99$'J &<77 A.% &$8<*99*$%8$' ^KK*9&.'/ 0-'
P$7.7O$'7*-'7O%-A77' &$%A$*8 &*$]-&$99*$%.'/ h$&-EF '-EF #$*8/F'& 6$F98:

\%78$ ^'7B8A$ A.% T$%$EF'.'/ 0-' **nassen Resuspensionsprozessen** 7*'& K$%$*87 *5
O--9 7E%.KK*'/2]-&.9 VU^PZ2T *5O9$5$'8*$%8 kRWV dikkI[V dkm^99$%&*'/7 7*'& &*$ 7$
^'7B8A$.'0-9978B'&*/: *'$%7$*87 6$F98 $*'$ '57$8A.'/ &$7 f$88%-O6$'5-&$997 <.7
kI[V dkm A.5 <'&$%$' 9*$/8 6N% &$' R*958%-O6$'<.78%</ L$*'$ (-%%$9<8*-' A.%
T$%$EF'.'/ &$% G%-O6$'/%),$'0$%8$*9.'/ 0-%: \7 #$%&$' 9$&*/9*EF /%-K$ $5O*%*7EF$
T$A*$F.'/$' 0$%#$'&$8J &*$ L$*'$ T<7*7 A.% T$%NEL7*EF8*/.'/ &$% ṡ&$%.'/ &$7
V$&*5$'8<8*-'70$%F<98$'7 *5 %$9$0<'8$' T$%$*EF &$7 5)/9*EF$' G%-O6$'/%),$'2
7O$L8%.57 &<%78$99$': Y<%NK$% F*'<.7 #*%& &$% ^.78%</ 0-' R*958%-O6$' 5*8 A:G:
&$<9*7*$%8$']-&$99<'7B8A$' K$%EF'8: W' &$' 0-%9$/$'&$' ^'7B8A$' #*%& &*$
6%$*/$7$8A8$ R9N77*/L$*875<77$ &$% R*958%-O6$' <97 U%-&.L8 &$% M<5$99$'69BEF$.'&
2&*EL$J &*$ *&$<9*7*$%8 NK$% $*'$' VEF#*'/.'/7<'7<8A S7*F A:T:k^aT dkX 5-&$99*$%8
78J K$%$EF'$8: Y$7 F<8 A.% R-9/$J &<77 &<7 M<5$99$'0-9.5$' .:': A. /$%*'/
K$%$EF'$8 #*%& .'& 7*EF 7-5*8 $*' A. /$%*'/$% R9N77*/L$*872 .'& &<5*8 <.EF
P<&*-'.L9*&<.78%</ $%/*K8: Y*$7$]-&$99*$%.'/77EF#BEF$ *78 *'7-6$%' O%-K9$5<8*7EFJ
#$*9 /$%<&$ *' R*958%-O6$'6-%5 $*' F-F$% ^'8$*9 L9$*'$% G%-O6$' 6%$*/$7$8A8 #*%&J #$9EF$
+<7 /$8%</$' *' &$% V8)%6<997OB8OF<7$ F-F$ o998%5%$9$0<'A $%F<98$' L) ''$': T$*
&$']-&$99$' A.% o<'8*6*A*$%.'/ &$7 G%-O6$'<.78%</7 K$* 8.%K.9$'8$% b*%K$978%)5.'/
K$&<%6 $7 $*'$% #$*8$%6NF%$'&$' I<9*&*$%.'/ k([Z >>kJ .5 K$9<78K<%$%$ ^.77</$' A.5
o998%5 8%66' A. L)''$':

a.% p<'8*8<8*0$' T$78*55.'/ &$% R%$*7$8A.'/7%<8$ K$* **trockenen Resuspen-
sionsprozessen** &.%EF 8%<'7*$'8$ V8%)5.'/$' 78$F$' &$%A$*8 L$*'$ 0<9*&*$%8$']-&99
A.% I$%6N/.'/: ^.6/%.'& &$% (-5O9$e*8B8 &$% K8*9*/8$' OF_7*L<9*7EF$' U%-A77 7-998$
F*$% &*$ OF_7*L<9*7EF O%-K9$5-%*$'8*$%8$.'& <' &$% 7*EF$%F$*878$EF'*7EF$'
R%</$78$99.'/ <.7/$%*EF8$8$]-&99'8#*EL9.'/ $'/ 5*8 &$% I<9*&*$%.'/ *5 V*''$ &$%

HK$%O%N6.'/ .'& c$%78$99.'/ 0-' ^.77</$2 .'& \e8%<O-9<8*-'76BF*/L$*8 0$%L'NO68 #$%&$':

W'7K$7-'&$%$ 5*8 T9*EL <.6 &*$ A.'$F5$'&$ R-%&$%.'/J &<77 &*$ ^.7#*%L.'/$' <.EF 7EF#$%$% V8)%6B99$ <.6 &*$ ^'9</$ 7$9K78 K$7EF%B'L8 K9$*K$' 5N77$' .'& 7-5*8 <.EF &*$ 7OB8$ V8)%6<99OF<7$ p<'8*8<8*0 7*EF$% <KA.K*9&$' 7$*' 5.77J #*$/8 &$ %]<'/$9 <' 0<9*&*$%8$' P$7.7O$'7*-'75-&$99$' 7EF#$%J &< $*'$ 0$%9B779*EF$ T$#$%8.'/ &$7 o$9 98$%57 -F'$ T$%NEL7*EF8*/.'/ 5)/9*EF$% P$7.7O$'7*-'7O%-A77J &*$ /$%<&$ *' &$% 7OB8$' V8)%6<99OF<7$ 0-' T$&$.8.'/ 7$*' L)''$'J '.% $*'/$7EF%B'L8 5)/9*EF *78:

a*$9 #$*8$%6NF%$'&$% ^%K$*8$' 7-998$ &*$ 0$%9B779*EF$ T$#$%8.'/ &$7 o$998$% 5K$*8%</7 <.7 P$7.7O$'7*-'7O%-A77' 7$*': ^.7/$F$'& 0-' $*'$% 0$%K$77$%8$' .'& &<5*8 K$9<78K<%$%$']-&$99*$%.'/ '<77$% #*$ 8%-EL$'$% P$7.7O$'7*-'7O-%/B'/$ 7-998$ &*$ R%</$ &$% 7*EF$%F$*878$EF'*7EF$' P$9$0<'A &$7 GF5'L-5O9e7]P$7.7O$'7*-'; &$8<*99*$%8 .'8$%7.EF8 #$%&$':

7.2.1.4 Rückwirkung katalytischer Rekombinatoren und von H_2-Verbrennungsvorgängen auf das Aerosolverhalten und die Jodchemie

*' K$7-'&$%$7]$<8.%$}0-' Z[Z[VjV *78 &*$])/9*EFL$*8J A<F9%$*EF$ b$EF7$9#*%2 L.'/$' A#*7EF$' $*'A$9'$' UFB'-5$'$' 7*5.9*$%$' A. L)''$': Y*$7 $%F)F8 '<8N%9*EF A.5 $*'$' &$' P$<9*8B87/%<& &$% P$EF'./ $%F$K9*EFJ 6NF%8 A.5 <'&$%$' h$&-EF A. $*'$% &$.89*EF $%F)F8$' (-5O9$e*8B8:

W' &$' 5$*78$' V*EF$%F$*87K$FB98$%' &$.87EF$% Y%.EL#<77$%%$<L8-%$' 7*'& 5*889$%#$*9$ 7-/: U<77*0$ <.8-L<8<9_8*7EF$ P$L-5K*'<8-%$' $*'/$K<.8J &*$ $*'$ (-5O-'$'8$'2 -&$% /<% V*EF$%F$*87K$FB98$%K$7EFB&*/.'/ /%),$%$' ^.75<,$7 &.%EF $*'$ c$_3$2I$%K%$''.'/ 0$%F*'&$%' 7-99$': b*$ 7*EF *' \eO$%*5$'8$' .'& P$EF'.'/$' /$A$*/8 F<8J K$#*%L$' 7-9EF$ P$L-5K*'<8-%$' A.5*'&$78*' &$' P<.5K$%$*EF$'J*' &$'$' 7*$*'78<99*$%8 7*'&J I$%B'&$%.'/$' &$% G$5O$%<8.%$' .'& V8%)5.'/70$%FB98'*77$: W5 W''$%$' 7-9EF$% P$L-5K*'<8-%$' L)''$' G$5O$%<8.%$' 0-' 5$F%$%$' 1>> +%<& $'878$F$':

[K#-F9 7- /.8 #*$ L$*'$ 6%$* 0$%6N/K<%$' W'6-%5<8*-'$' 0-%9*$/$'J *78 $7 7*EF$%J &<77 &*$ ^'#7'F$*8 0-' P$L-5K*'<8-%$' &<7 ^$%-7-90$%F<98$' .'& &*$ f-&EF$5*$ K$$*'69.77$': Y*$7 /*98 <.EF 6N%]5*9&$} c $_3$2I$%K%$''.'/70-%/B'/$J &*$ <.EF 8%-8A P$L-5K*'<8-%$*'7<8A$7 *' $*'$5 %<9' V*EF$%F$*87K$FB98$% *5 R<99$ $*'$7 7EF#$%$' V8)%6<997 '*EF8 <.7A.7EF9*$,$' 7*'&:

Y<A. 7-998$' A.'BEF78 &*$ '<8*-'<9 #*$ *'8$%'<8*-'<9 0$%6N/K<%$ W'6-%5<8*-' A.7<55$'/$78$998 .'& K$#$%8$8 #$%&$'JA$'8%<9$ R%</$' 2A:T: '<EF &$5 *'69.77 0-' P$L-5K*'<8-%$' <.6 &*$ U<%8*L$9/%),$'0$%8$*9.'/ &$% 9.68/$8%</$'$' ^$%-7-9$J '<EF 5)/9*EF$' EF$5*7EF$' P$<L8*-'$' K$*5 Y.%EF8%*88 0-' f-& &.%EF &*$ F$*,$' P$L-5K*'<8-%$' -&$% '<EF &$5 *'69.77 &$7 Y<5O6/$F<987*' &$% ^85-7OFB%$ <.6 &*$ a$%7$8A.'/ 0-' Z79 K$* $*'$% c32I$%K%$''.'/ 2A.5*'&$78 p<9*8<8*0 K$<'8#-%8$8 #$%&$'J <.6/%.'& &$% /$#-''$'$' \%L$''8'*77$ $*'6<EF$]-&99 -&$% (-%%$9<8*-'$' $'8#*EL$98 .'& *' $*'$ *'8$%'$ Z[Z[VjV2I$%7*-' $*'/$K<.8 #$%&$'J .5 &.%EF /$$*/'8 U<%<5$8$%0<%*<8*-'$' &*$ 7*EF$%F$*878$EF'*7EF$ P$%$0<'A &*7% b$EF7$92 #*%L.'/$' <.6A.A$*/$'J<' &$% 7*EF &<'' &<7 #$*8$%$ I-%/F' -%*$'8*$%$' 7-998$:

7.2.1.5 Aerosoldrainage: Verhalten löslicher und unlöslicher Stoffe

^.6 b<'&-K$%69BEF$' <K/$9</$%8$ ^$%-7-9$ S*' 9)79*EF$% .'& '*EF829)79*EF$% R-%5X #$%&$' .'8$% L-'&$'7*$%$'&$' T$&*'/.'/$' &.%EF <K9<.6$'&$' b<'&L-'&$'7<86*95 <K/$#<7EF$' .'& '<EF .'8$' *' &$' V.5O6 8%<'7O-%8*$%8: Y$% ^K#<7EF66L8 #*%& <97 ^$%-7-9&%<*'</$ KA*EF'$8: Y<%NK$% F*'<.7 #$%&$' &.%EF &*$ Y%<*'</$ <.EF &<7 &-%8 /$K.'&$'$ f-& 7-#*$ #$*8$%$ VO<98O%-&.L8$ <K/$#<7EF$'J 7-#$*8 &*$7$ #<77$%9)79*EF KA#:8%<'7O-%86BF*/ 7*'&:

Y*$ ^$%-7-9&%<*'</$ F<8 0*$%<EF$ T$&$.8.'/ 6N% &$' o$998$%5:]*8 &$5 ^K# <7EF$' 0-' VO<98O%-&.L8$' 0$%K.'&$' *78 $*'$ ‘50$%8$*9.'/ &$% D<EF#B%5$9$*78.'/ F*' *' &$' V.5O6J #-&.%EF $7A. $*'$% $%F)F8$' V.5O68$5O$%<8.% //6: K*7 A.5 V*$&$' L-55 8: Y<7 U-8$'A*<9 6N% &*$ 8%-EL$'$ P$7.7O$'7*-' SO-' &$% b<'&X 0-' ^$%-7-9$' #*%& &.%EF &<7 ^K#<7EF$' %$&.A*$%8: T$* &$% D<EF%$EF'./ &$% ^$%-7-9O$%8$*9.'/ *5 !o<7* ;2Z-'8<*'5$'8; K$*5 I$%7.EF Uc\T‘V2RUG1 F<8 7*EF /A*/8J &<77 -F'$]-&$99 6N% &*$ ^$%-7-9&%<*'</$ L$*'$ A.6%*$&$' 78$99$'&$ HK$%$*'78*55.'/ A#*7EF$' P$EF'./ .'& \eO$%*5$'8 $%A*$98 #$%&$' L<'':

Y*$ b*%L7<5L$*8 &$% ^$%-7-9&%<*'</$*78 0-' &$% W'8$'7*8B8 &$% (-'&$'7<878%)5./ .'& &$% b<'&K$&$EL./ &.%EF &$' b<77$%6*95 <KFB'/*/: T$* /$%*'/$' (-'&$'2 7<8*-'7%<8$' $%6-9/8 &*$ T*9&.'/ 0-' 78</'*$%$'&$' G%-O6$' <' &$% b<'&: Y*$7$ G%-O6$' 0$%$*'*/$' 7*EF '<EF 9B'/$%$5 b<EF78.5J K*7 7*$ $*'A$9' <K78%)5$': T$* F)F$%$' (-'&$'7<8*-'7%<8$' #BEF78 &*$ ^'A<F9 &$% <K78%)5$'&$' G%-O6$'J K*7 7*EF $*' A.7<55$'FB'/$'&$% R*95 $%/*K8: b<77$%9)79*EF$7 ^$%-7-95<8$%*<9 #*%& 5*8 &$' G%-O6$' 8%<'7O-%8*$%8: T$* .'9)79*EF$' V.K78<'A$' S.'& V.K78<'A$'J &*$ #$/$' &$%

VB88*/.'/ &$% G%-O6$' '*EF8 #$*8$% /$9)78 #$%&$'X *78 &$% G%<'7O-%8 0-' &$' c<68K$&*'/.'/$' &$% G$*9EF$' <' &$% b<'& .'& &$' 78%)5.'/75$EF<'*7EF$' (%B68$' &$7 <K9<.6$'&$' b<77$%7 <KFB'/*/: RN% &$' Y%<*'</$8%<'7O-%8 .'9)79*EF$% ^$%-7-9$ /98' <' 0$%8*L<9$' .'& F-%*A-'8<9$' bB'&$' .'8$%7EF*$&9*EF$ T$&*'/.'/$': ^.6/%.'& &*7%]$EF<'*75$' $%/*K8 7*EF $*' 7$F% .'8$%7EF*$&9*EF$7 G%<'7O-%80$%F<98$' *' ^KFB'/*/L$*8 0-' ^$%-7-95<8$%*<9J b<77$%78%)5.'/ .'& b<'&$*/$'7EF<68$':

W' Z[Z[VjV *78 $*']-&$99 &$% ^$%-7-9&%<*'</$ 0-%F<'&$': \7 /*K8 K*7F$% h$&-EF L$*'$ I<9*&*$%.'/7&<8$' 6N% &*$]-&$99*$%.'/ &*7% \66$L8$: ^.6/%.'& &$% A.5 G$*9 7$F% L-5O9e' .'& '.% .'/$'<. K$L<''8$' P<'&K$&*'/.'/$' *' %<9' ^'9</$' #$%&$' *' &$5]-&$99 $*'*/$ I$%$*'6<EF.'/$' 0-%/$'-55$'J &$%$' +N98*/L$*8 7-#*$ &77' *'/<K$O<%<5$8$% $%78 &.%EF I$%7.EF7&<8$' A. L9B%$' 7*'&: \%78$ \eO$%*5$'8$ A.% ^$%-7-9&%<*'</$ 7*'&*' &$% GF^W2^'9</$ /$O9<'8:

7.2.1.6 Spaltprodukt (Aerosol)-Verhalten in Betonrissen/Leckagen

T$* Z-'8<*'5$'8<.,$'#B'&$' <.7 T$8-' #*%& &*$ Y*EF86.'L8*-' $'8#$&$% &.%EF $*'$' V8<F99*'$% -&$% $*'$ W''$'K$7EF*EF8.'/ <.7 (.'7878-66 NK$%'-55$': T$* <.79$/.'/7NK$%7EF%$*8$'&$% Y%.ELK$9<78.'/ K*9&$' 7*EF*' A.'$F5$'&$5]<,$ P*77$ *' &$% T$8-'#<'&J &*$ K$* K$7EFB&*/8$5 M*'$% A. $*'$% A.'$F5$'&$' ''&*EF8*/L$*8 .'& R%$*7$8A.'/ *' &*$ '5/$K.'/ 6NF%$': Y*$ Z-'8<*'5$'8<85-7OFB%$ <.7 $*'$5 Y<5O6kM.68k '*EF8 L-'&$'7*$%K<%$ +<7$2+$5*7EF &%*'/8 *' &*7 P*77$ $*': \'87O%$EF$'& &$' G$5O$%<8.%0$%FB98'*77$' *' &$% b<'& L-'&$'7*$%8 &$% Y<5O6*' &$' P*77$': ^$%-7-9$.'& VO<98O%-&.L8$ 9</$%' 7*EF &.%EF &*$7$ (-'&$'7<8*-' .'& &$' 7$F% .'%$/$95B,*/$' I$%9<.6 &$% P*77$.'& &*$ $'87O%$EF$'&$ b<'&%<.F*/L$*8 *' &$' P*77$' <K: Y<K$* L)''$' 7*$ 8$*9#$*7$ &*$ P*77$ A.7$8A$' .'& A. $*'$% I$%%*'/$%.'/ &$% M$EL</$ 6NF%$': Y*$7$ U%-A77 K$$*'69.77$' &*$ +%),$ &$% R%$*7$8A.'/ *' &*$ '5/$K.'/:

Y<7 OF_7*L<9*7EF$ U%-K9$5 *78 *'8$%&*7A*O9*'B% 5*8 &$% V8%.L8.%5$EF<'*L A. 9)7$': ^.7 &$% 78%.L8.%5$EF<'*7EF$' T$%$EF'./ 7*'& ^.77</$' F*'7*EF89*EF &$% P*77/%),$J &$7 P*770$%9<.67 .'& &$% P*779B'/$ <KA.9$*8$': Y*$ 8F$%5-&_'<5*7EF$' I-%/B'/$ *' &$' P*77$' #*$ V8-668%<'7O-%8 &.%EF V8%)5.'/J V8%)5.'/7K$7EF%$*K.'/J bB%5NK%/B'/$ A.5 T$8-' 7*'& 5*8 *F%$' b$EF7$9#*%L.'/$' /$L-OO$98 5*8 &$5 @2&*5$'7*-'<9$' G$5O$%<8.%6$9& *5 T$8-' A. K$%$EF'$': c*$%A. 7*'& 0-%0*$/$'&$ PEF'5-&99 <.6

&$% T<7*7 eO%*5$'8$99$% \%/$K'*77$ A. $%8NEF8*/$'J A. $%/B'A$' .'& <'A.O<77$' KA#: '$.$ ^'7B8A$ A. $'8#*EL$9':

7.2.2 „Ex-Vessel“-Schmelzeverhalten

7.2.2.1 Corium-Beton Wechselwirkung (MCCI)

T$* $*'$5 7EF#$%$' V8)%6<99 L<'' '<EF I$%7</$' &$7 PYT ($%'7EF5$9A$ *' &*$ P$<L8-%L<0$%'$ /$9<'/$'J #- &*7*' &$% R-9/$ 5*8 &$' T$8-'78%.L8.%$' #$EF7$9#*%L8: bBF%$'& &*7% b$EF7$9#*%L.'/ Su]ZZW]-98$' Z-%*.5 Z-'E%$8$ W'8$%<E8*-'X L)''$' +$6BF%&.'/$' 6N% &*$ ‘5#$98*' 6-9/$'&$% c*'7*EF8$'878F'C

- T$* &$% b$EF7$9#*%L.'/ &$7 /$7EF5-9A$'$' ($%'5<8$%*<97 5*8 &$5 T$8-'6.'&<5$'8 &$% ^'9</$ K78F8 <.6/%.'& &$% L-'8*'.*$%9*EF$' U%-&.L8*-' 0-' D<EF#B%5$ *' &$% ($%'7EF5$9A$ $*' U-8$'A*<9 6N% &*$ Y.%EF&%*'/.'/ &$% T-&$'O9<88$.'& 7-5*8 6N% $*'$' R%$*7$8A.'/7O6<& 0-' %<&*-<L8*0$' VO<98O%-&.L8$' *' &<7 &<%.'8$% 9*$/$'&$ \%&%$*EF .'& +%.'&#<77$%:

- ^97 R-9/$ &$7 T$8-'A$%78)%.'/7O%-A$77$7 #$%&$' c3J c3[J Z[.'& Z[3 6%$*/$7$8A8J #-K$* &*$ %$9<8*0$' I$%FB98'*77$ &$% R%$*7$8A.'/7%<8$' 6N% &*$ $*'A$9'$' +<7L-5O-'$'8$' &.%EF [e*&<8*-'72 KA#: P$&.L8*-'7O%-A$77$ K$*5 ^.678*$/ &$% +<7$ &.%EF &*$ VEF5$9A$ K$78*55 8 #$%&$': bBF%$'& *'7K$7-'&$%$ c3[S/<76)%5*/X .'& Z[3 A.5 Y%.EL<.6K<.*5 Z-'8<*'5$'8 K$*8%</$'J L)''$' c3 .'& Z[A.&$5 $eO9-7*0$ +$5*7EF$ 5*8 &$5 *' &$% Z-'8<*'5$'82M.68 $'8F<98$'$' V<.$%78-66 K*9&$': T$*&$ \66$L8$ L)''$' A. $*'$5 HK$%&%.EL0$%7</$' &$7 Z-'8<*'5$'87 .'& &<5*8 A. $*'$% 6%NFA$*8*/$' ^L8*0*8B76%$*7$8A.'/ 6NF%$':

D-8#$'&*/$ a*$97$8A.'/ 6N% $*'$' Z-&$ A.% ^'<9_7$ 0-']ZZW2I-%/B'/$' SA: T: *' Z[Z[VjVX *78 *' $%78$% M*'*$J &<77 &<7 A$*80*EF$ I$%F<98$' &$% -K$' K$7EF%*$K$'$' U%-A77 5)/9*EF78 %$<9*8B87'<F #*$&$%/$K$' #*%&: R$%'$% *78 $*'$ o<'8 *6*A*$%.'/ &$% V8-662 .'& bB%5NK%/<'/7O%-A77 A#*7EF$']ZZW2U--9 .'& Z-'8<*'5$'82 ^85-7OFB%$ S^.6F$*A.'/ &$% ^85-7OFB%$J ^$%-7-92 .'& VO<98O%-&.L86%$*7$8A.'/ <.7 &$5 U--9X 6N% &*$ L-%%$L8$ \%6<77.'/ <99$% %$9$0<'8$' G%<'7O-%8O%-A77 .'& o99' *''$%F<9K $*'$% /$L-OO$98$' T$%$EF'.'/ 0-' Z-'8<*'5$'8OFB'-5$'$' SA: T: *''$%F<9K &$% Z[Z[VjV2]-&.9$ Gcj .'& ^RUX .'.5/B'/9*EF:

Y*$ K*7F$%*/$'J8%<&*8*-'99']-&$99*$%.'/7<'7B8A$ S A: T: b \x& b \Z cVMXJ Z [PZ [DX $e8%<O-9*$%$' *5 b$7$'89*EF$' eO%*5$'8$99$ Y<8$' 0-' \eO$%*5$'8$' 5*8]$8<992 7EF5$9A$' SA: T: <.7 &$' &$.87EF$' T\G^2I$%7.EF$'X -&$% 0-' $*'&*5$'7*-'<9$' [e*&2\eO$%*5$'8$' S^Z\k]^Z\2G787%*$ K$* ^DMJ 'V^XJ #-K$* 6N% &*$ D<EF%$EF'.'/ &$% \eO$%*5$'8$ &*$ *' &$' Z-&$7 0$%6N/K<%$' Y$8<*95-&$99$ 5*8 $5O*%*7EF $%5*88$98$' U<%<5$8$%' 0$%7F' #.%&$'J &*$ 8$*97 '.% 6N% $*'$' K$78*5 58$' \eO$%*5$'88_O <'/$O<778 7*'&: *'$ L-'7*78$'8$ Y<%78$99.'/ <99$% 0$%6N/K<%$' \eO$%*5$'8$ 7EF$*'8 <'/$7*EF87 &$% <L8.$99$' I<9*&*$%.'/7$%/$K'*77$ K*7F$% '*EF8 5)/9*EF: W' *'A$9eO%*5$'8$' #$%&$' <.EF F$.8$ *55$% '-EF K$* &$% D<EF%$EF'.'/ &$% A$*89*EF$' \%-7*-'78*$6$.'& &$% U--98$5O$%<8.% ''7*EF$%F$*8$' K*7 A. $*'$5 R<L8-% 3 K$* &$% \%-7*-'78*6 KA#: 1=> (K$* &$% U--98$5O$%<8.% K$-K<EF8$8:

RN% $*'$ A.0$%9B77*/$%$]-&$99*$%.'/ 6$F9$' K*79<'/ <.EF eO%*5$'8$99$ Y<8$' A.5 A#$*&*5$'7*-'<9$' *'&%*'/$' $*'$% VEF5$9A$ *' &<7 T$8-'6.'&<5$'8: \7 78$F8 A. $%#<%8$'J &<77 &*7 MNEL$ 5*8 &$' 5-5$'8<' 9<.6$'&$' \eO$%*5$'8$' ZZW S*''$%F<9K &$7 [\ZY2]ZZW2U%-h$L8$7X 7-#*$ Z [ ]\G M1 .'& M3 S*''$%F<9K &$7 \'2M^Z [ ]\P^2 I-%F<K$'7X '.% A.5 G$*9 /$7EF9-77$' #$%&$' L<'':

Bewertung des Einflusses von Thermochemie

Y*$ *' Y$.87EF9<'& &.%EF/$6NF%8$' T\G^2\eO$%*5$'8$ A$*/$' $*'$ 78<%L 8%<'7*$'8$ ^KLNF9.'/ &$%]$8<997EF5$9A$ 7-#*$J <KFB'/*/ 0-' &$% M$*78.'/7$*'L-OO9.'/J 8$*9#$*7$ $*'$ <.7/$O%B/8$J '<EF .'8$' /$%*EF8$8$ \%-7*-' *' &$' T$8-': ^.6 T<7*7 &*7% I$%7.EF7$%/$K'*77$ #.%&$']-&$99$ $'8#*EL$98J &*$ &*7 UFB'-5$'-9-/*$ #*&$%7O*$/$9': V*$ K$%.F$' *5 b7'89*EF$' <.6 8F$%5-F_&%<.9*7EF$' ^'7B8A$'Q &</$/$' K$%NEL7*EF8*/$' 7*$ 8F$%5-EF$5*7EF$ ^7O$L8$ &$% VEF5$9A$2T$8-'2 #$EF7$9#*%L.'/ '.% 78<%L 0$%$*'6<EF$'&:

Y*$ *5 6-9/$'&$' f<F%A$F'8 <5 ^%/-''$ D<8*-'<9 M<K-%<8-%_J 'V^ *5 P<F5$' &$% ^Z\ .'&]^Z\ U%-/%<55$ &.%EF/$6NF%8$' /%-,5<,78BK9*EF$' I$%7.EF$ A$*/$'J &<77 7*EF KF*A8$ O%-8-8_O*7EF$ [e*&2VEF5$9A$' #BF%$'& &$% b$EF7$9#*%L.'/ 5*8 &$5 T$8-'J *5 I$%/9*EF A.]$8<997EF5$9A$'J '.% /$%*'/6N/*/ <KLNF9$': Y*$7$7 \%/$K'*7 #*%& &.%EF &*$ *5 P<F5$' &$% I-%F<K$' Z[P\V^J Z[P\V^2@ 7-#*$ \Z[VG^P 5*8 O%-8-8_O*7EF$' VEF5$9A$' &.%EF/$6NF%8$' 9<K-%5<,78BK9*EF$' \eO$%*5$'8$' .'8$%78N8A8:

Y<7 /$'<''8$ I$%F<98$' 9B778 $*'$' 7*/''*6*L<'8$' *'69.77 &$% GF$%5-EF$5*$ <.6 &*$ UFB'-5$'-9-/*$ &$% VEF5$9A$2T$8-' b$EF7$9#*%L.'/ 0$%5.8$': R$%'$% &$.8$' 7O$A*$99 &*$ 5*8 /$69.8$8$% VEF5$9A$'-K$%69BEF$ &.%EF/$6NF%8$']^Z\ \eO$%*5$'8$ <.6 $*'$ *7-8%-O$ bB%5$78%-50$%8$*9.'/ *5 VEF5$9A$O--9 .'& &<5*8 <.6 /9$*EF$ \%-7*-'7%<8$' *' <e*<9$% .'& %<&*<9$% P*EF8.'/ F*':

*'$ (-OO9.'/ &$%]-&$99$J #$9EF$ $5O*%*7EF$ ^'O<77.'/$' #$*8/F'& 0$%5$*&$8J *78 $%785<97 *' &$5 A.% V*5.9<8*-' &$% VEF5$9A$2T$8-'2b$EF7$9#*%L.'/ $'8#*EL$98$' Z-&$ Z[V^Z[kDW\ >3k %$<9*7*$%8 #-%&$':

Y$% K$* Z[V^Z[K$7EF%*88$'$ b$/ K<7*$%8 <.6 &$% &*%$L8$' W5O9$5$'8*$%.'/ $*'$% }$$<9 7-9.8*-'} Y<8$'K<7*7J #$9EF$ 2 *5 R<99$ &$7 Z[V^Z[2 <.6 &$' 8F$%5-EF$5*7EF$' Y<8$' &$% GYTZP ddk3 Y<8$'K<7*7 kZc\ ddk <.6K<.8: Y*7% ^'7<8A $%9<.K8 $*'$ <&Bp<8$ Y<%78$99.'/ &$% L-5O9e'J6N% &*$ UFB'-5$'-9-/*$ &$% VEF5$9A$2T$8-'2b$EF7$9#*%L.'/ #7'89*EF$' 8F$%5-EF$5*7EF$' I-%/B'/$ *' &$% VEF5$9A$: a. &*$7$' /$F)%$' O<%<99$9 <K9<.6$'&$ EF$5*7EF$ P$<L8*-'$' 7-#*$ &*$ \'878$F.'/ .'& (-$e*78$'A0-'6$78$' .'&69N77*/$' UF<7$':

+9$*EFA$*8*/ K*9&$8 &*$ ZF<%<L8$%*7*$%.'/ &$7 %$<9$' 8F$%5-EF$5*7EF$' a.78<'&7 &$% VEF5$9A$ $*'$ #7'89*EF$ I-%<.77$8A.'/ 6N% &*$ L-FB%$'8$ (-OO9.'/ 0-' GF$%5-EF$5*$.'& GF$%5-F_&%<.9*L: Y<K$* #$%&$'J*5 R<99 -e*&*7EF$% VEF5$9A$'J &*$ 7*EF K*9&$'&$' 6$78$' UF<7$' &$' h$#$*9*/$' bB%5$7$'L$' &$% VEF5$9A$ A./$-%&'$8: bB%5$7$'L$' $e*78*$%$' <.,$% <' &$' P<'&69BEF$' A.5 $%-&*$%$'&$' T$8-' .'& <' &$% 6%$*$' [K$%69BEF$ <.EF *''$%F<9K &$7 I-9.5$'7 &$% VEF5$9A$J <.6/%.'& &$% L-'8*'.*$%9*EF$' a.5*7EF.'/ 0-' }<98$'} T$8-'A$%7$ 8A.'/7O%-&.L8$': bBF%$'& <' &$' PB'&$%' &*$ 7*EF K*9&$'&$' 6$78$' UF<7$' $*'$ L%.78$'<%8*/$ +%$'A7EF*EF8 K*9&$' .'& 7-5*8 A. $*'$5 &.%EF bB%5$9$*8.'/ &-5*'*$%8$' bB%5$8%<'7O-%8 6NF%$'J $%F)F$' &*$ *5 I-9.5$' &$% VEF5$9A$ 0$%K9$*K$'&$' 6$78$' UF<7$' &*$ I*7L-7*B8 .'& %$&.A*$%$' 7-5*8 &$' bB%5NK%/<'/ <.7 &$5 I-9.5$' <' &*$ P<'&69BEF$':

*'$ D<EF%$EF'.'/ %$O%B7$'8<8*0$%J 5*8 -e*&*7EF$' VEF5$9A$' &.%EF/$6NF%8$% \eO$%*5$'8$ 5*8 &$5 Z-&$ Z[V^Z[A$*/8$ 5$*78$'7 $*'$ /.8$ HK$%$*'78*55.'/ K$* &$' #7'89*EF$' I$%7.EF7/%),$' VEF5$9A$'8$5O$%<8.% .'& \%-7*-'76%-'86-%87EF%*88 kDW\ >3k:

Y*7% .'& <.EF <'&$%$ 0-%F<'&$'$ ^'7B8A$ A.% T$7EF%$*K.'/ &$7 8F$%5-EF$5*7EF$' I$%F<98$'7 &$% VEF5$9A$ 5N77$' F*'7*EF89*EF *F%$% P$9$0<'A .'&

*/'./ S&$%A$*8 $%F$K9*EF$% P$EF$'A$*8K$&<%6X 6N% &*$ %$<9*78*7EF$ b*$&$%/<K$ &$% #*EF8*/$' U%-A77 #BF%$'& &$7]ZZW S\%-7*-'J G$5O$%<8.%0$%F<98$' &$% VEF5$9A$J +<76%$*7$8A.'/X $*'/$F$'& /$O%N68 .'& K$#$%8$8 #$%&$':

Neuentwicklung des MCCI-Moduls in COCOSYS

Y$%A$*8 *78 *5 c<.O85-&.9 ZZWJ &$% &<7 !$e 0$77$9;2VEF5$9A$0$%F<98$' *' Z[Z[VjV K$7EF%$*K8J &<7]ZZW2]-&$99 b\x 2 $*'$ b$*8$%$'8#*EL9.'/ &$7]-&$997 b\ZcVM 2 $*'/$K<.8: RN% &*$]ZZW2V*5.9<8*-' *' Z[Z[VjV #*%& $*'$ D$.$'8#*EL9.'/ 0-%/$'-55$'J K$* &$% <.6 K$#BF%8$ Y$8<*95-&$99$ <.7 b\kb\ZcVMJ Z[PZ[D -&$%]\YWZWVS]ZZW2]-&.9*' ^VG\Z <98$%'<8*0A. b\xkA.%NEL/$/%*66$' #$%&$'7-99:

Y<7 '$.A.$'8#*EL$9'&$]ZZW2]-&.9*' Z[Z[VjV 7-99 $*'$0$%9B779*EF$.'&%-K.78$ b*$&$%/<K$ &$% O%*5B% *'8$%$77*$%$'&$' +%),$' \%-7*-'J G$5O$%<8.% &$7 U--97 .'& +<76%$*7$8A.'/ 7-#*$ &*$ T$%$EF'./ 0-' bB%52 .'& V8-668%<'7O-%8O%-A77' A#*7EF$']ZZW2U--9 .'& Z-'8<*'5$'8<85-7OFB%$ $%5)/9*EF$' .'& A. &*$7$5 a#EL <99$ F*$%6N% %$9$0<'8$' UFB'-5$'$ .56<77$': Y$% \'8#*EL9.'/ 7-99 6-9/$'&$7 (-'A$O8A. +%.'&$ 9*$/$'C

- \'8#*EL9.'/ $*'$7 /$-5$8%*7EF$']-&$997 A.% ^KK*9&.'/ &$% A$*89*EF K$#$/8$' \%-7*-'769BEF$*' @Y <97 B.,$%$ (-'8.% &$7 VEF5$9A$O--97: Y*$7$7]-&$99 78$998 &*$ /$-5$8%*7EF$ T<7*7 A.% M)7./ &$7 5<8F$5<8*7EF$' J5-0*'/ K-.'&< %_;2 U%-K9$57 &$7 \%-7*-'70-%/<'/$7 &<%:

  - D*EF82<e*<97_55$8%*7EF$ +$-5$8%*$'J A: T: *' K$'<EFK<%8$' PB.5$' '<EF Y.%EF7EF5$9A$' $*'$% 7$*89*EF$' b<'& &$% P$<L8-%/%.K$J L)''$' K$F<'&$98 #$%&$'J

  - (-'7*78$'A &$% +*88$%78%.L8.% 5*8 5-&$%'$']$8F-&$' S\%A$./.'/ &.%EF $*'$' +*88$%/$'$%<8-%6N% ZRY2]-&$99$XJ

  - ^'L-OO9.'/ $*'$7 /$$*/'8']-&$997 6N% &*$ T$#$/.'/ &$% \%-7*-'769BEF$ S^.67EF5$9A$'kVO<99<8*-'k(<9L78$*'K%$''$'XJ

  - T$%$EF'./ <99$% G$*969BEF$'J b*'L$9 .'& I-9.5*'<:

- W' $*'$5 $%78$' \'8#*EL9.'/77EF%*88C (-OO9.'/ &$7 /$-5$8%*7EF$']-&$997 5*8 $*'$% 0$%$*'6<EF8$']-&$99*$%.'/ $*'$7 5$F%7EF*EF8*/$' VEF5$9A$O--97 .'8$% I$%#$'&.'/ F$%L)55 9*EF$% T.9L2^'7B8A$:

  -]-&$99<'7B8A$ 6N%]ZZW2UFB'-5$'$ #*$]<77$'8%<'76$%J]*7EF.'/78$52 O$%<8.%S$'XJ \'8#*EL9.'/ &$7 +<7/$F<98$7 .'& &$% U--9$*/$'7EF<68$' -%*$'8*$%$' 7*EF<' 0$%6N/K<%$' T.9L2^'7B8A$' #*$ A:T:*' b\x.'&] \YWZWVJ

  -)%89*EF$ I$%8$*9.'/ &$% bB%5$78%-5&*EF8$' &.%EF (-%%$9<8*-'$' <.7 <.72 /$#$%8$8$' \eO$%*5$'8$' .'8$% I$%#$'&.'/ /$$*/'8% V_55$8%*$<''<F5$' ST$*7O*$9C ^KFB'/*/L*8 &$% D.77$982a<F9 0-5 b*'L$9 A#*7EF$' R9BEF$'2 '-%5<9$.'& +%<O*8<8*-'70$L8-%XJ

  - &$%]-&$99.56<'/ 7-99 7*EF <.6 %$9$0<'8$ UFB'-5$'$ L-'A$'8%*$%$'J 6N% &*$ $*'$ <.7%$*EF$'&$ I<9*&*$%.'/7K<7*7 K$%$*87 0-%F<'&$' *78 -&$% *' '<F$% a.L.'68<K7$FK<% 5)/9*EF*78J

  - $7 #$%&$' L.%A$ PEF'A$*8$' $%#<%8$8J &< *5 I$%/9$*EF A. 0-%F<'&$'$' Z-&$7 <99$'6<997 $*' /$%*'/$%]$F%<.6#<'& 6N% &*$ Y<%78$99.'/ &$% @Y2 [K$%69BEF$J '*EF8 <K$% 6N% &*$ T$%$EF'./ 0-' @Y2G%<'7O-%8O%-A77' $%6-%&$%9*EF*78:

- W' $*'$5 6-9/$'&$' \'8#*EL9.'/77EF%*88C I$%#$'&.'/ &$7 K$%$*87 0-%F<'&$'$' @Y2 +*88$%7*5 '$.$']ZZW2]-&.9 S<.7 $%78$5 \'8#*EL9.'/77EF%*88X 6N% &*$ b*$&$%/<K$ 0-' @Y2G%<'7O-%80-%/B'/$':

  - HK$%O%N6.'/k\'8#*EL9.'/ 0-' $66*A*$'8$']-&$99$' 6N% @Y2G%<'7O-%80-%/B'/$ *5 $e20$77$92VEF5$9A$O--9 5*8 ZRY SZ[ ] \GXJ

  - ^KK*9&.'/ &$7 &$8<*99*$%8$' @Y2U--90$%F<98$'7 SA:T: (-'0$L8*-'X *' p<7* 2 78<8*-'B%$% U--9/$-5$8%*$ 5*8 ZRY SZ[ ] \GX:

Y*$ I<9*&*$%.'/ &$7 +$7<585-&$997 7-99<' <.7/$#BF98$' \eO$%*5$'8$' 0-%/$'-55$' #$%&$'J &*$ 6N% &*$ I<9*&*$%.'/ <97 %$9$0<'8 K$.%8$*98 #$%&$':RN% $*'$ 7-9EF$ ^.7#<F9 $*/'$' 7*EF &*$ G787%*$' ^Z\ SUF<7$ ZXJ]^Z\J T\G^J [\ZY2]ZZW .'& M^Z[ ]\P^: *'$ +%.'&O%-K9$5<8*L *78 &*$ 8$*97 .'A.%$*EF$'& /$'<.$ ($''8'*7 #*EF8*/$% V8-66#$%8$ S#*$ A:T: &$% a$%78)%.'/7$'8F<9O*$ &$% T$8-'$X .'& P<'&K$&*'/.'/$' S\'$%/*$K*9<'AXJ &*$ A. $*'$5 K$%BEF89*EF$' G$*9 A.% +$7<582

.'7*EF$%F$*8 K$*8%B/8: W' &*$7$5 U.'L8 #B%$ $*'$ \%#$*8$%.'/ &$% eO%*5$'8$99$' Y<8$'K<7*7 .5 \eO$%*5$'8$ 5*8 /.8 K$L<''8$' V*5.9<878-66$' KA#: <.EF .5 /.8 *'78%.5$'8*$%8$ \eO$%*5$'8$ *5 (9$*'5<,78<K S6N% &*$ O%BA*7$ \%5*889.'/ 0-' \'$%/*$K*9<'A$'X 7*''0-99:

7.2.2.2 Kühlbarkeit

Optionen im Unfallablauf und durch AM

T$/%$'A8$ (NF9.'/72 .'& PNELF<98$2[O8*-'$' 7*'& K$%$*87 *5 ''6<99<K9<.6 .'& *' ^]2]<,'<F5$' -F'$A.7B8A9*EF$L-'78%.L8*0$]<,'<F5$' <'/$9$/8: T$%$*87 <.7 &$5 ^.67EF5$9A$' 0-' T$8-' $%/*K8 7*EF $*'$ (NF9#*%L.'/: T$* $*'$5 R9.8$' 5*8 b<77$% 0-' -K$' <97 ^]2]<,'<F5$ #$%&$' <.7 &$5 a.7<55$'#*%L$' 0-' (%.78$'K*9&.'/ .'& +<76%$*7$8A.'/ <.7 &$% VEF5$9AkT8-'2b$EF7$9#*%L.'/ $%F$K9*EF$ (NF9$66$L8$ $%#<%8$8: ^97]$EF<'*75$' F*$%6N% #$%&$' $*' #*$&$%F-98$7 $%.O8*0$7 ^.7#$%6$' 0-' VEF5$9A$ *'6-9/$ Y%.EL<.6K<.7 .'8$% &$% (%.78$ S!I.9L<'2\66$L8;X -&$% $*' L-'8*'.*$%9*EF$% U%-A$77 0-' \'8%<*'5$'8 0-' VEF5$9A$*5 +<778%-5 .'& ^.778%)5$' &.%EF g66'.'/$' *' &$% (%.78$ <'/7F$'J K$* K$*&$' U%-A77' 5*8 '<EF6-9/$'&$% T*9&.'/ 0-' LNF9K<%$' VEFN88.'/$' <.6 &$% (%.78$: b$*8$%$]$EF<'*75$' 7*'& $*' *'&%*'/$' 0-' b<77$% NK$% P*77$ *' &$% (%.78$.'& $*' #*$&$%F-98$7 ^.6K%EF' /$K*9&$8$% (%.78$' 5*8 6-9/$'&$5 b<77$%A.78%-5 A.% 69N77*/$' VEF5$9A$ '<EF ^K7$'L.'/$' &$7 VEF5$9A$7O*$/$97 *'6-9/$ &$% T$8-'2\%-7*-': Y*7 \66$L8$.'& (NF9#*%L.'/$' #<%$' +$/$'78<'& &$%]^Z\2\eO$%*5$'8$ K$* ^DM .'& #$%&$' &-%8*' 6-%8/$7$8A8$' \eO$%*5$'8$' *5 P<F5$' $*'$7 [\ZY2I-%F<K$'7 #$*8$% .'8$%7.EF8: *'$ <.7%$*EF$'&$ (NF9.'/ *78 <99$%&*'/7 *' &*$7$' \eO$%*5$'8$' 5*8 O%-8-8_O*7EF$5]<8$%*<9 K*7F$% '*EF8 K$9$/K<%: W' &$' U\PZ[M^2\eO$%*5$'8$' &$% Z\^ #.%&$' A#<% 5*8 V*5.9<8*-'769.*&$' %$9<8*0 F-F$ \'8%<*'5$'82P<8$' 6$78/$78$998J <99$%&*'/7 K9$*K8 &*$ R%</$ &$% T*9&.'/ 0-' VEFN88.'/$' -66$': W'7/$7<58 K9$*K$' &*$ $%)%8$%8$']$EF<'*75$' 5*'&$78$'7 F*'7*EF89*EF *F%$% <'F<98$'&$' b*%L.'/ SA: T: #*$&$%F-98$% VEF5$9A$kb<77$%2(-'8<L8 &.%EF #*$&$%F-98$7 (%.78$'<.6K%EF'X .'& *F%$% \66$L8*0*8B8 6N% $*'$ +$7<58LNF9.'/ 6%</9*EF: RN% K$/%$'A8$ VEF5$9A$5<77$' L)''8$ <99$%&*'/7 $*'$<.7%$*EF$'&$ (NF9.'/ $%%$*EF8 #$%&$':

Z[Z[VjV $'8FB98 K*7F$% L$*'$ 7O$A*$99$']-&$99$ A.% (NF9K<%L$*8 .'& PNELF<98.'/ 0-' VEF5$9A$: Y*$ T$7EF%$*K.'/ &$7 I$%F<98$'7 0-' VEF5$9A$*5 V*EF$%F$*87K$FB98$% *78 K*7F$% *5 b7'89*EF$' <.6 &*$ ^.7K%$*8.'/ 0-' VEF5$9A$ S7O%$<&*'/;X .'& <.6 &*$

VEF5$9A$kT$8-'2b$EF7$9#*%L.'/ K$7EF%B'L8: ^.7 *' Y$.87EF9<'& &.%EF/$6NF%8$' ^%K$*8$' A. (\VV .'& ^GcM\G2ZY 6N% &*$ ^K9B.6$*5 PYT 9*$/$']-&$99$.'& Z-&$7 0-% A.% VEFN88K$88K*9&.'/ *' $*'$5 b<77$%O--9 &.%EF R%</5$'8*$%.'/ 0-' VEF5$9A$78%<F9$' SW(\f\GkW(\]Wk.'& A.% VEFN88K$88LNF9.'/ Sb^T\J]\b^X: Y<7]\b^2]-&$99 K$*'F<98$8 <.EF &<7 ^.68%$8$' /$7EF5-9A$'$% ^'8$*9$J <.7 '*EF8 <.7%$*EF$'& 6%</5$'8*$%8$% .'& <K/$LNF98$% VEF5$9A$ -&$% <.7 #*$&$% <.6/$7EF5-9A$'$5]<8$%*<9: Y< $7 $*' 0$%$*'6<EF8$7 VEF5$9A$7$$2]-&$99 $'8FB98J *' &$5 &$% $'87EF$*&$'&$ bB%5NK%/<'/ <' &$' PB'&$%' NK$% $*' <'/$O<778$7 +%$'A7EF*EF85-&$99 69$e*K$9 6N% 0<%*<K9$ T$%<'&.'/ K$%EF'8 #*%&J*78 <.EF $*' *'7<8A A.% T$%$EF'.'/ &$% T*9&.'/ 0-' VEF5$9A$7$$' -&$% 27EF*EF8$' *' Z-%$2Z<8EF$%' 7-#*$ *F%$% (NF9K<%L$*8 5)/9*EF: \%#$*8$%.'/$' A.5 ^.67EF5$9A$' 0-' [O6$%5<8$%*<9 7*'&$%6-%&$%9*EF:

W' $*'$% \%#$*8$%.'/ &$7]\b^2]-&$997 6N% &<7 Z[ ]\G2(-'A$O8 #*%& &*$ T*9&.'/ 0-' U-%-7*8B8 *' &$% VEF5$9A$ <.6/%.'& $*'$7 ^'7<8A$7 $%6<778J &$% &*$ 9-L<9$ P<8$ &$% U-%-7*8B87A.'<F5$ O%-O-%8*-'<9 A.5 9-L<9 <.6/$K<.8$' %B.59*EF$' Y%.EL/%<&*$'8$' <'7$8A8: Y$% 9-L<9$ Y%.EL<.6K<. #*%& <97- <97 $'87EF$*&$'& 6N% $*'$ <.EF 7$*89*EF <.7/$&$F'8$ U-%-7*8B87K*9&.'/ <'/7F$': Y<5*8 #*%& &*$ K$-K<EF8$8$ \66$L8*O*8B8 &$% b<77$%$*'7O%*8A.'/ 0-' .'8$' 5*8 6-9/$'&$% %<7EF$% I$%&<5O6.'/ 0$%78B'&9*EFJ *5 ''8$%7EF*$& A. $*'$5 K9-,$' ^.678*$/ 0-' +<7$'J &$% F% $*'$ T*9&.'/ $*'A$9'$% (<'B9$ 78<88 0$%A#$*/8$% U-%-7*8B8$' .'8$%78N8A8: Y<A. L-55 8 &<7 %<7EF$ *'6%*$%$' /$K*9&$8$% U-%-7*8B8 <.6/%.'& F-F$' bB%5NK%/<'/7 K$*5 (-'8<L8 5*8 b<77$%: Y*7% \66$L8 7-#*$]<8$%*<9$66$L8$J #*$ &$% *'69.77 &$% I*7L-7*8B8 &$% VEF5$9A$J #$%&$' *5]-&$99 $%6<778: W' D<EF%$EF'.'/$' 0-' *' Y$.87EF9<'& 7-#*$ <5 PWG SY\Z[TWX \eO$%*5$'8$' #.%&$ '<EF U<%<5$8$%2^'O<77.'/$' $*'$ /.8$ HK$%$*'78*55.'/ NK$% $*'$ /%),$%$ T<'&K%$*8$ 0-' T$&*'/.'/$' $%%$*EF8: Y<7]-&$99 *78 <.EF A.% ''8$%7.EF.'/ 0-' [O8*-'$' &$% U-%-7*8B87K*9&.'/ .'& (NF9.'/ K$* &$']^Z\2\eO$%*5$'8$' .'& $'87O%$EF$'&$' (-'78$99<8*-'$' .'8$% P$<L8-%K$&*'/.'/$' $*'7$8AK<%:

7.2.2.3 Schmelzeaustrag aus dem Reaktordruckbehälter

T$* $*'$5 7EF#$%$' V8)%6<99 5*8 I$%7</$' &$7 P$<L8-%&%.ELK$FB98$%7 #*%& ($%'7EF5$9A$.'8$% F-F$5 Y%.EL *' &$' V*EF$%F$*87K$FB98$% <.7/$8%*K': Y*7% I-%/<'/2 K$*7$F% F-F$' Y%NEL$' <97 YZc SY*%$E8 Z-'8<*'5$'8 c$<8*'/X .'& cU]\ Sc*/F U%$77.%$]$98 \h$E8*-'X KA*EF'$8 2 9*$6$%8 &*$ P<'&K$&*'/.'/$' 6N% &*$ 6%NF$

!$e 0$77$9;2UF<7$ 6N% ^85-7OFB%$'K$&*'/.'/$' .'& VEF5$9A0%8$*9.'/ *5 V*EF$%2 F$*87K$FB98$%: V$9K78 K$* O9<'5B,*/$% b*%L7<5L$*8 0-' $'87O%$EF$'&$' !<EE*&$'8 5<'</$5$'8;2]<,'<F5$' L<'' <.EF*' &$.87EF$' ^'9</$' &$% VEF5$9A$<.78%</ <.7 &$5 P$<L8-%&%.ELK$FB98$% K$* Y%NEL$' K*7*5 5$%F*' '-EF 3> K<% $%6-9/$':

T*9& n2i A$*/8 &*$ #*EF8*/78$' I-%/B'/$ K$*5 ^.78%</ &$% ($%'7EF5$9A$ <.7 &$5 Y%.ELK$FB98$%J &$% .'8$% $*'$5 Y%.EL K*7 A. 3> ^85-7OFB%$' 78$F8: Y*$ +<7OF<7$ $%FB98 <97 A.7B8A9*EF$ (-5O-'$'8$'J V8*EL78-66J V<.$%78-66 .'& b<77$%78-66: Y*$ V8%.L8.% #*%& *5 T$%$*EF &$7 M-EF$7*' &$% Y%.ELK$FB98$%#<'& 0$%B'&$%9*EF: Y<7 M-EF L<'' &.%EF ^K7EF5$9A$' 0$%/%),$%8 #$%&$':

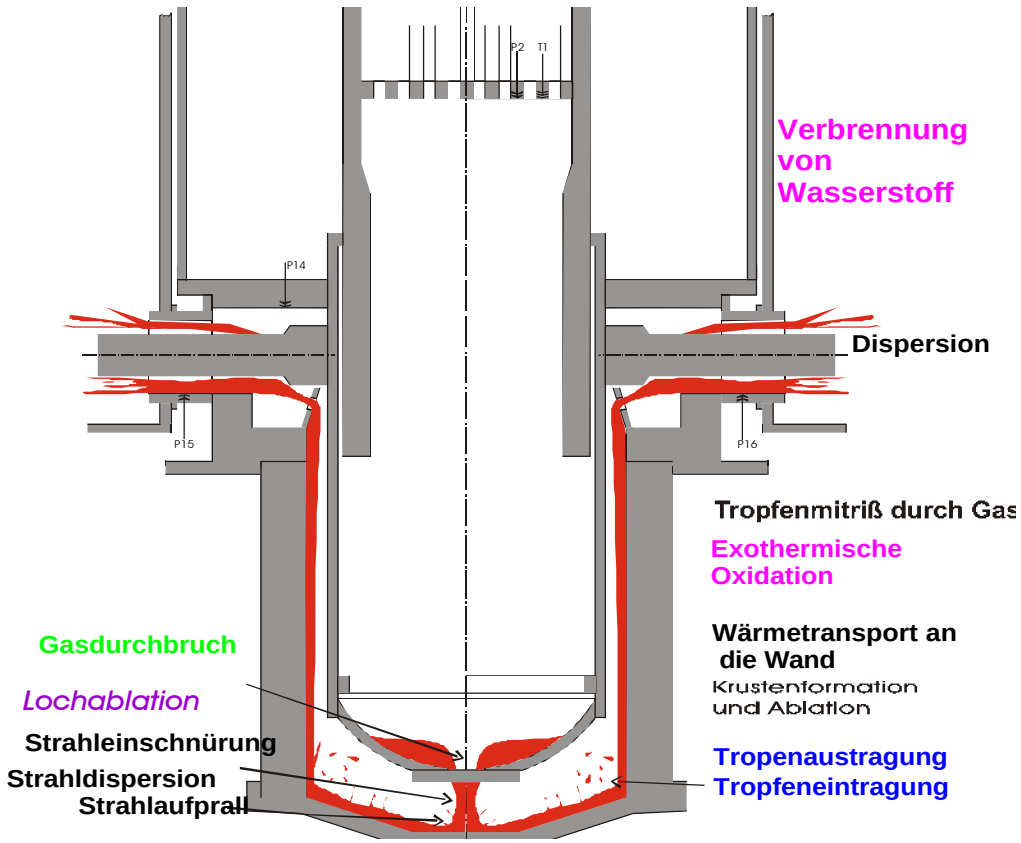


Bild 7-8: UFB'-5$'$ K$*5 ^.78%</ &$% ($%'7EF5$9A$ <.7 &$5 Y%.ELK$FB98$%

V$*8 $*'*/$' f<F%$' #$%&$' *' Y$.87EF9<'& A. &*7% U%-K9$5<8*L &*$ YWVZ [2I$%7.EF$ &.%EF/$6NF%8: YWVZ [#*%& <'<9_8*7EF K$/9$*8$8 &.%EF &*$ \'8#*EL9.'/ &$7 $*'7EF9B/*/$' PEF'O%-/%<5 57 ^RY]:

Y<7] .98*OF<7$'O%-/%<5 5 ^RY] S^&0<'E$& R9.*& Y_'<5*E7] -&$9X <.7 &$% VW]] \P R<5*9*$ F<8 A#$* Y*5$'7*-'$' .'& K$F<'&$98 F-EF 8%<'7*$'8$ V8%)5.'/$' 5*8 &%$* (-5O-'$'8$' *' &%$* +$7EF#*'&*/L$*876$9&$%': Y*$ \'8#*EL9.'/ &$7 Z-&$7 #.%&$ 0-' R-%7EF.'/7$*'%*EF8.'/$' *' 'V^J f<O<'J R%<'L%$*EFJ Y$.87EF9<'& .'& &$5 f-*'8 P$7$<%EF Z$'8%$ &$% \' SfPZX *' W7O%< .'8$%78N8A8: Y$% Z-&$ $%9<.K8 &*$ T$F<'&9.'/ $*'$% $%78$' (-5O-'$'8$ *5 6$78$'J 69N77*/$' .'& Y<5O6A.78<'&J $*'$% A#$*8$' (-5O-'$'8$ *5 69N77*/$' .'& *5 Y<5O6A.78<'& .'& $*'$% &%*88$' (-5O-'$'8$ *5 Y<5O6A.78<'&: Y*$ V8<'&<%&0$%7*-' &$7 U%-/%<5 57 5-&$99*$%8 &*$ 6-9/$'&$' U%-A77C L-5O%$77*K9$ V8%)5.'/ 5*8].98*L-5O-'$'8$'J].98*/$7EF#*'&*/L$*8$' .'&].98*OF<7$'J bB%5$2 .'& V8-66NK$%8%</.'/J VEF5$9A$'J \%78<%%$'J I$%&<5O6.'/ .'& (-'&$'7<8*-'J .'& -%872 .'& A$*8<KFB'/*/$ +%$'A69BEF$' 5*8 o$99 8$%5: Y*$ '.5$%*7EF$ M)7.'/75$8F-&$ SO%$&*E8-% E-%%$E8-% 5$8F-&X $%9<.K8 &$5 T$'.8A$% $eO9*A*8$]-&99 F*'A.A.6N/$': Y*$ YZc2I$%7*-' &$7 U%-/%<5 57 5-&$99*$%8 Y<5O6K*9&.'/ *5 PYTJ V8%)5.'/ &.%EF &<7 T%.EF9-EFJ ^.6#$*8$' &$% T%.EF78$99$ &.%EF ^K9<8*-'J V8%<F9<.69)7.'/J a.%NELF<98$' &$% VEF5$9A$ <' bB'&$'J \'8%<*'5$'8 &$% R9N77*/L$*8J (%.78$'K*9&.'/J 8F$%5*7EF$.'& EF$5*7EF$ b$EF7$9#*%L.'/ 0-' Y<5O6 .'& R9N77*/L$*8 Sb<77$%78-66$%A$./.'/X .'& b<77$%78-66O$%K%$''.'/:

Y*$ K9*'&$' I-%<.7%$EF'.'/$' 0-' YWVZ[2I$%7.EF$' F<K$' &*$ M$*78.'/76BF*/L$*8 &$7 Z-&$7 .'8$% T$#$*7 /$78$998: Y*$ <.7 &$' \%/$K'*77$' /$#-''$'$' W'6-%5<8*-'$' #$%&$' O$%5<'$'8 A.% ^'<9_7$ &$% \eO$%*5$'8$ F*'A./$A-/$': Y*$ I*7.<9*7*$%.'/ $%9<.K8 &*$ T$-K<EF8.'/ &$% Y$8<*97 &$% U%-A77: M<.6$'&$ T*9&$% A$*/$' &*$ (*'$8*L &$% I-%/B'/$: Y*$ .56<77$'&$' Y<8$' &$7 Z-&$7 #$%&$' A.% \'8#*EL9.'/ $*'6<EF$% '.99&*5$'7*-'<9$%]-&99 0$%#$'&$8J &*$ &$' V_78$5E-&$7 F*'A./$6N/8 #$%&$' L)''$':

W5 W'8$/%<9E-&$ ^VG\Z #*%& A.% T$7EF%$*K.'/ &$7 VEF5$9A$$*'8%</7 *' &$' V*EF$%F$*87K$FB98$% &<7]-&$99 P'U'WZ'I *' a.7<55$'F<'/ 5*8 &$% Z-'8<*'5$'82 GF$%5-F_&%<.9*L &$7]-&.97 ZU^ /$'.8A8: V$*8 ^O%*9 3>>@ #*%& &<%<' /$<%K$*8$8J <.6 &$% T<7*7 &$% *' Z[DG^WD .'& P'U'WZ'I 0-%9*$/$'&$']-&$99*$%.'/$'J ^'7B8A$ 6N% *'A$95-&$99$ A. *7-9*$%$'J A. 8$78$' .'& 6N% &*$ *'K*'&.'/ *' Z[Z[VjV <.6A.2 K$%$*8$': a$'8%<9$ <'78F'&$ ^L8*O*8B8 *78 &*$ \%#$*8$%.'/ &$7 Y*66$%$'8*<92 /9$*EF.'/77_78$57*' Z[Z[VjVJ 5*8 &$5 a*$9J $*'$ /%.'&7B8A9*EF 9<.66BF*/$ I$%7*-' A. $%78$99$': Y<'<EF 0$%K9$*K8 &*$ ^.6/<K$J &*$ *'A$95-&$99$ A. NK$%O%N6$'J A. $%#$*8$%' .'& 7*EF$%9*EF <.EF $*'*/$ '$. A. 6-%5.9*$%$':

7.2.2.4 Schmelze-Kühlmittel-Wechselwirkung (Dampfexplosion)

W5 V*EF$%F$*87K$FB98$% L)''$' 0-5 U%*'A*O F$% Y<5O6$eO9-7*-'$' *'7K$7-'&$%$ K$*5 *'69*$,$' 0-' VEF5$9A$ <.7 &$5 0$%7</$'&$' PYT *' $*'$ b<77$%0-%9</$ *' &$% P$<L8-%/%.K$ <.68%8': ^5 L%*8*7EF78$' #*%& &$% R<99 $*'$7 8*6' b<77$%O--97 K$.%8$*98 SV*EF$%F$*87L-'A$O8 K$* 7EF#$&*7EF$' .'& 6*''*7EF$' V b PX: Y*$ F<.O87BEF9*EF$ R%</$78$99.'/ *78 &<K$*J -K $*'$ 7- 78<%L$ Y<5O6$eO9-7*-' <.68%$8$' L<''J &<77 #$7$'89*EF$ V8%.L8.%$' -&$% /<% &$% V*EF$%F$*87K$FB98$% $%F$K9*EF K$7EFB&*/8 #$%&$' L)''$': a$%78)%.'/$' .5/K'&$% bB'&$ L)''8$' K$%$*87 &<7 V*EF$%F$*87A*$9 &$% (NF9.'/ *5 8*$6$' b<77$%O--9 /$6BF%&$': *'$ A. /%-,$]<77$ A. 6$*'$% R%</5$'8$J *'7K$7-'&$%$ <K/$9</$%8 <.6 &$% VEFN88.'/J L)''8$ &*$ (NF9K<%L$*8 *' R%</$ 78$99$': Y<5O6$eO9-7*-'$' 7*'& <97- <97 +$/$'66L8 A.]<,'<F5$' &$% (NF9.'/ 5*8 b<77$% A. K$8%<EF8$': ^.EF K$AN/9*EF &$% <'&$%$' (NF9.'/75$8F-&$' 5*8 b<77$% *' Z-%$2 Z<8EF$%2(-'A$O8$' 7*'& 5)/9*EF$ +$6BF%&.'/$' A. K$8%<EF8$': ^.EF K$*5 R9.8$' 0-' VEF5$9A$ 5*8 b<77$% 0-' -K$' L)''$' Y<5O6$eO9-7*-'$' <.68%$8$'J <99$%&*'/7 *78 '.% $*'$ %$9<8*0 /$%*'/$ V8B%L$ A. $%#<%8$'J #$*9 /%),$%$]*7EF.'/$' 0-' VEF5$9A$.'& b<77$% 0-% &$% $eO9-7*0$' W'8$%<L8*-' #$*8/F'& <.7A.7EF9*$,$' 7*'&:

V-9EF$ I-%0$%5*7EF.'/$' *' /%)K$%$% VL<9< A#*7EF$' VEF5$9A$.'& b<77$%J <97-T*9&.'/ $eO9-7*0$%]*7EF.'/$'J #$%&$' <97 I-%<.77$8A.'/ 6N% F$68*/$ Y<5O62 $eO9-7*-'$' /%),$%$% K8*9*/8$% VEF5$9A$5<77$' 5*8 5)/9*EF$% /%-,$% VEF<&$'7#*%L.'/ <'/$7F': ^.6/%.'& &$% F-F$' G$5O$%<8.%$' &$% VEF5$9A$ *78 K$%$*87 K$* 7-9EF$' /%-K$' R%</5$'8*$%.'/72 .'&]*7EF.'/70-%/B'/$'J A: T: <97 R-9/$ $*'$7 V8%<F9<.6K%EF'7 K$*5 *'69*$,$' 0-' VEF5$9A$78%<F9$' *' b<77$%J $*'$ 78<%L$ I$%&<5O6.'/ 0-' b<77$% A. $%#<%8$': *' %$7.98*$%$'&$% F-F$% Y<5O6/$F<98 *' &$%]*7EF.'/ #*%L8 <99$%&*'/7 &$% \eO9-7*0*8B8 .'& &$% +%),$ 0-' 7*EF *' $*'$%]*7EF.'/ <.6K<.$'&$' \eO9-7*-'72Y%NEL$' $'8/$/$' S}#<8$% &$O9$8*-';XJ A:T: &.%EF \%2 7EF#$%.'/ &$7 Y<5O6L-99<O7 <97 G%*//$%0-%/<'/ 7-#*$ &.%EF &*$ F-F$ (-5O%$77*K*9*8B8: T$AN/9*EF &$% \'878$F.'/ LNF9K<%$% VEFN88.'/$' L<'' 7*EF $*' F-F$% Y<5O6/$F<98 <99$%&*'/7 <.EF '$/<8*0 <.7#*%L$'J *'&$5 $% $*'$ A. 78<%L$ T$/%$'A.'/ &$% R%</5$'8*$%.'/ &$% VEF5$9A$.'& &$% ^KLNF9.'/ &$% R%</5$'8$ K$*5 ^K7$8A$' K$#*%L8: RN% &*$]-&$99*$%.'/ *78 &<F$% 'K' &$% +%),$.'& ^KLNF9.'/ &$% R%</5$'8$ &$% Y<5O6/$F<98 *' VEF5$9A$k(NF95*88$92]*7EF.'/$' 0-' $'87EF$*&$'&$% T$&$.8.'/:

W5 V\P\D^2I-%F<K$' &$% [\ZY #$%&$' 0$%/9$*EF$'&$ ''8$%7.EF.'/$' 0-' PEF'O%-/%<55$' A.% I-%0$%5*7EF.'/72 .'& \eO9-7*-'7OF<7$ <'F<'& 0-' \eO$%*5$'8$' .'& P$EF$'6B99$' &.%EF/$6NF%8: Y$.87EF9<'& *78 &<K$* 5*8]-&$99$'

W(\ f \ GkW(\ ] Wx S I - %0$%5*7EF . ' / XJ WY \ ] [23Y S \ eO9 - 7* - ' 7OF<7$X . '&] ^GGWD^ SY<5O6$eO9 - 7* - ' X 0$%8%$8$': T$AN/9*EF &$% I - %0$%5*7EF . ' / 9B778 7*EF <.7 &$' P$EF' . ' /$' &*$ VEF9.776 - 9/$%. ' / A*$F$' J &<77 &*$] - &99 $*' $' $%F$K9*EF A. F - F$' Y<5O6/$F<98 9*6%' S^%K$*87O<O*$% A. G<7L 3 kT ' \ >IkX: I$%7EF*$&$' $ \ %L9B%. ' /72 5) /9*EFL$*8$' 7*' & *' &$% Y*7L.77* - ' J A: T: A. F - F$ D$88 - 2Y<5O6O% - &. L8* - ' <.6/%. '& 0$%7EF*$&$' $%] - &$92Y$6*A*8$J A. /$%*' /$ I$%8$*9. ' / &$% VEF5$9A$8% - O6$' . '& &$% I$%&<5O6. ' / *5 /$7<58$' b<77$%2T.9LJ A. /$%*' /$ Y<5O6<K6.F% <.7 &$5 b<77$%: Y*$ 9$8A8$%$ \ %L9B%. ' / #.%&$ *' kT ' \ >Ik <97 $' 87EF$*&$' & 6N% &<7 *5 I - %&$%/%. '& 78F' &$ \ eO$%*5$' 8 R^P [2M3i &<%/9/8J #$*9 &<0 - ' <.7/$/<' /$' #.%&$J &<77 F*$% &*$ \ *' 78$99. ' / $*' $7 L - ' 78<' 8$' Y%.EL<' 78*$/7 NK$% = 7J . ' 8$% O%<L8*7EF K$*K$F<98$' $' VB88*/. ' /7K$&*' /. ' /$' J $*' $ $' 87O%$EF$' &$ Y<5O6O% - &. L8* - ' . '& /9$*EFA$*8*/ $*' $ T$/%$' A. ' / &$7 Y<5O6/$F<987 *' &$%] *7EF. ' / A.% ^.6%$EF8$%F<98. ' / $*' $7 p<7* 2 78<8* - ' B%$'] .78$%7 &$% b B%5NK%8%</. ' /J Y<5O6O% - &. L8* - ' . '& Y<5O6<K6.F% $%6 - %&$%8: Y<%<.7 #N%&$ 6 - 9/$' J &*$ b$*8$%$' 8#*EL9. ' /$' . '& HK$%O%N6. ' /$' A.5 P$*K. ' /75 - &$99 A. K$8 - ' $': ' ' 7*EF$%F$*8$' *' &$% T$7EF%$*K. ' / 0 - ' a#*7EF$' 25.78$%' A#*7EF$' $*' $5 #<77$%L - ' 8*' .*$%9*EF$' V8%) 5. ' /75.78$% SY<5O6K9<7$' *' b<77$%X . '& $*' $5 &<5O6L - ' 8*' .*$%9*EF$' S b<77$%8% - O6$' *' Y<5O6X 78$F$' &<' ' *5 I - %&$%/%. '&J A: T: &*$ K*7F$% ' *EF8 K$7EF%*K' $])/9*EFL$*8 . ' 8$%7EF*$&9*EF$% Y<5O62 /$7EF#*' &*/L$*8$' K$* $*' $% (- $e*78$' A &*7%] .78$%:

T$AN/9*EF &$% V*EF$%F$*8 78$998 7*EF 9$8A89*EF &*$ R%</$J - K 7*EF . ' 8$% %$<9*78*7EF$' T$&*' /. ' /$' $*' $ I - %0$%5*7EF. ' / /%-,$% K8*9*/8$% VEF5$9A$5<77$' 5*8 <.7%$*EF$' & ' *$&%*/$5 Y<5O6/$F<98 $*' 78$99$' L<' ' J #$9EF$ \ eO9 - 7* - ' $' L%*8*7EF$% V8B%L$ $%A$./$' L<' ': RN% &*$ (NF9K<%L$*8 78$998 7*EF . 5/LF%8 &*$ R%</$J - K *' %$<9*78*7EF$' VA$' <%*$' &$% Y<5O6/$F<98 L9$*' /$'./ K9$*K$' L<' ' J . 5 <.7%$*EF$' &$ R%</5$' 8*$%. ' / . '& ^KLNF9. ' / A.% \ %A$./. ' / LNF9K<%$% VEFN88. ' /$' A. . ' 8$%78N8A$':

b$/$' &$% (- 5O9$e*8B8 #*%& &*$ VEF5$9A$2 (NF95*88$9#$EF7$9#*%L. ' / <.EF A.LN' 68*/ *' 7 - /: Y$8<*9E - &$7 7*5.9*$%8: I - ' W' 8$/%<9E - &$7 #*$ ^VG \ Z - &$%] \ MZ [P . '& V_78$5E - &$7 #*$ Z [Z [VjV - &$% Z [DG^WD #$%&$' &*$ P<' &K$&*' /. ' /$' K$%$*8/$78$998:

7.2.3 Vervollständigung der Störfallsimulation

7.2.3.1 Übergang von Sättigung zu Überhitzung, Abtrocknen von Kondensatfilmen

c$.8*/$% V8<'& &$% G$EF'*L *78 &*$ I$%#$'&.'/ &$7 D*EF8/9$*EF/$#*EF875-&$997 A.% %$<9*78*7EF$%$' T$7EF%$*K.'/ &$7 a.78<'&7 &$% Z-'8<*'5$'8<85-7OFB%$ *' &$' MU2P$EF$'O%-/%<55$': c*$%K$* #$%&$' 6N% ^85-7OFB%$.'& <K/$9</$%8$7 b<77$% 7$O<%<8$]<77$'2 .'& \'$%/*$K*9<'A$' 5*8 $*'$% .'<KFB'/*/$' G$5O$%<8.%2 $'8#*EL9.'/ K$%EF'8: Y*7]-&99 K$%$EF'$' h$&-EF 8%-8A <99$% K*7F$%*/$' T$5NF.'/$' K$* NK$%F*8A8$' P<.5A.78B'&$' &$.89*EF A. 8%-EL$'$ a.78B'&$: a.% I$%K77%.'/ &$%]-&$99$ 7*'& &*$ *'69N77$ 0-' 0$%&<5O6$'&$' (-'&$'7<8k2 b<77$%6*95$'J &*$ I$%&.'78.'/ <' V.5O62 .'& b<77$%9<EF$'-K$%69BEF$' .'& &*$ I$%&.'78.'/ 0-' VO%NF%$/$' .'& Y%<*'</$%$/$' A. .'8$%7.EF$'J I$%K$77$%.'/$' *' &*$]-&99 $*'A.K%*'/$' .'& A. 0<9*&*$%$': ^97 I$%/9$*EF7K<7*7 .'& \%6<77.'/ &$% %$<9$' I$%FB98'*77$ 9*$/$' K*7F$% F<.O87BEF9*EF]$77*'6-%5<8*-'$' <.7 I$%7.EFO%-/%<55$' 0-%J K$* &$'$' L9<77*7EF$]778EF'*L $*'/$7$8A8 #.%&$: Y*7]$77*'6-%5<8*-'$' 7*'& F*'7*EF89*EF &$% A. K$<'8#-%8$'&$' R%</$78$99.'/ #$'*/ K$9<78K<%J &< &*$]$77.'/ &$% %$9<8*0$' R$.EF8$.'& $*'$% NK$%F*8A8$' G$5O$%<8.% 5*8 &$% L9<77*7EF$']778EF'*L K$L<''8$%5<,$' 7EF#*$%*/ *78 SGF$%5-$9$5$'8$ 5$77$' -68 (-'&$'7<88%-O6$'8$5O$%<8.%X: c*$% 7*'&]$77$%/$K'*77$ <.7 '$.$%$' I$%7.EF7O%-/%<55$' 5*8 *''-0<8*0$%]778EF'*L S#*$ A: T: &*$ GF^W2I$%7.EF$C G<.O.'L85$77.'/X<.7A.#$%8$'.'& 6N% &*$ I<9*&*$%.'/ $*'A.7$8A$':

7.2.3.2 Sumpfmodellierung

+%-,$ b<77$%0-%9</$'J #*$ A: T: &$% +$KB.&$7.5O6 *' $*'$% Y bP2^'9</$J L)''$' *' ^KFB'/*/L$*8 0-' &$% b<77$%8$5O$%<8.% /%-,%B.5*/$ (-'0$L8*-'778%)5.'/$' *' &$% ^85-7OFB%$ <.79)7$'J &*$ 6N% &$' G%<'7O-%8 0-' VO<98O%-&.L8$' .'& &*$ Y.%EF5*7EF.'/ 0-' AN'&6BF*/$' +<75*7EF.'/$' 0-' T$&$.8.'/ 7*'&: Y*$ ^K7EF$*&.'/ 0-' /<76)%5*/$5 f-& <.7 &$% ^85-7OFB%$ <' &$% b<77$%-K$%69BEF$ &$7 V.5O67 .'& 7$*'$ b*$&$%6%$*7$8A.'/ #$%&$' &.%EF &$' I$%8$*9.'/7L-$66*A*$'8$' K$78*55 8J &$77$' +%),$ 0-' &$% b<77$%8$5O$%<8.%<' &$% V.5O6-K$%69BEF$ <KFB'/*/ *78: W' &$% M<'/A$*8OF<7$ 0-' (NF95*88$90$%9.7878)%6B99$' #*%& V.5O6#<77$% A.% (NF9.'/ &$7 P$<L8-%L$%'7 %$A*%L.9*$%8: T$* VbP2^'9</$' #*%& b<77$% <.7 &$5 V.5O6 &$7 V8$.$%78<K<'8%*$K7%<.57 *5 V8)%6<99 K$* T$&<%6 *' &*$ (-'&$'7<8*-'7L<55$% -&$%

&*%$L8 *' &<7 U%*5B%7_78$5 /$0.5O8: Y*$ P$A*%L.9<8*-' 0-' V.5O6#<77$% $%6-9/8 NK$% D-8LNF97_78$5$: a.% (-'8%-99$ &$% (NF9#*%L.'/$' &$7 P$A*%L.9<8*-'7#<77$%7 *78 $7 '-8#$'&*/J &*$ V.5O6#<77$%8$5O$%<8.%*5 I-%9<.6 &$% U.5O$ A. L$''$':

^99$ F*$% /$'<''8$'J 7*EF$%F$*878$EF'*7EF K$&$.87<5$' I-%/B'/$ #$%&$' 0-' $*'$% 5)/9*EF$' 8F$%5*7EF$' VEF*EF8.'/*5 V.5O6#<77$% #7'89*EF K$$*'69.778:]$77&<8$' <.7 &$' /%-,7L<9*/$' &$.87EF$' I$%7.EF7<'9</$']-&$99E-'8<*'5$'8 .'& c$*,&<5O62 P$<L8-% ScYPX A$*/$'J &<77 7*EF *' &$% P$/$9 $*'$ G$5O$%<8.%7EF*EF8.'/*5 V.5O62 #<77$% $*'78$998J &*$ '.% &.%EF K$7-'&$%$ *'/%*66$ #*$ A: T: TF*A.'/<5 T-&$' -&$% M.68$*'7O$*7.'/ <.6/$K%-EF$' #*%&: Y*7 G$5O$%<8.%7EF*EF8.'/$' *5 V.5O6#<77$% L)''$' 5*8 &$' <L8.99' Z[Z[VjV2]-&99' '*EF8 &<%/$78$998 #$%&$'J 78<88&77' #*%& $*'$ F-5-/$'$ Y.%EF5*7EF.'/ &$7 b<77$%7 <'/$'-55$': Y*7 .'%$<9*78*7EF$ ^''<F5$ 6NF%8 A. R$F9$%' K$* &$% b$EF7$9#*%L.'/ 5*8 &$% GF$%5-F_&%<.9*L &$% ^85-7OFB%$J K$*5 VO<98O%-&.L88%<'7O-%8 .'& K$* &$% G$5O$%<8.% &$7 P$A*%L.9<2 8*-'7#<77$%7Q &*$ R$F9$% 7*'& '*EF8 *' h$&$5 R<99$ <97 L-'7$%0<8*0$ DBF$%.'/ $*'A.78.6$':

T$* %$<9$' V8)%6B99$' #*%& &*$ V.5O6#<77$%8$5O$%<8.% <.EF &.%EF &*$ bB%5$6%$*7$8A.'/ 0-' *5 b<77$% K$6*'&9*EF$' VO<98O%-&.L8$' K$$*'69.778: a. &*$7$5 UFB'-5$' 9*$/$' L$*'$ eO%*5$'8$99$' Y<8$' 0-%: [K &*7 bB%5$6%$*7$8A.'/ A. $*'$% Y.%EF5*7EF.'/ &$7 V.5O6#<77$%7 6NF%8 -&$% F% $*'$ 78B%L$%$ VEF*EF8.'/ K$#*%L8J *78 &<F$% .'K$L<''8: RN% &*$ R.'L8*-'76BF*/L$*8 &$% V.5O6#<77$%%$A*%L.9<8*-' *78 <.EF &*$ I$%8$*9.'/ 0-' 6$78$' U<%8*L$9' *5 b<77$% K$&$.87<5J &*$ A: T: <.7 /$7EFB&*/8$5 W7-9*$%5<8$%*<9 0-' P-F%9$*8.'/$'J I$%7EF5.8A.'/<.7 &$5 9<'/A$*8*/$' ^'9</$'K$8%*$K -&$% ^K9</$%.'/ 0-' .'9)79*EF$' ^$%-7-9$' 78<55$': ^99 &*$7$ UFB'-5$'$ L)''$' 5*8 &$5 0-%F<'&$'$' F-5-/$'$' V.5O65-&$99 '*EF8 $%6<778 #$%&$':

^.6/%.'& &$% 0-%<'/$F$'&$' HK$%9$/.'/$' *78 $7 '-8#$'&*/J $*' '$.$7 V.5O65-&$99 6N% Z[Z[VjV A. $'8#*EL$9': Y*$7$7]-&$99 5.77 6-9/$'&$ (-5O-'$'8$' K$7*8A$'C

- Y<%78$99.'/ &$% 0$%8*L<9$' G$5O$%<8.%0$%8$*9.'/*5 b<77$%J
- Y<%78$99.'/ &$% V8%)5.'/70$%8$*9.'/*5 b<77$%J
- T$%NEL7*EF8*/.'/ 0-' K$9*$K*/$' ś&$%.'/$' &$7 b<77$%78<'&7 J
- T$%NEL7*EF8*/.'/ 0-' A.9<.6$'&$5 (-'&$'7<8 KA#: M$EL</$#<77$% .'& ^K7<.2 /.'/ &.%EF &<7 P$A*%L.9<8*-'77_78$5:

Y*7 8F$%5-F_&%<.9*7EF$ V*5.9<8*-' K*9&$8 &*$ T<7*7 6N% &*$ #$*8$%/F'&$]-&$99*$%.'/ &$7 VO<98O%-&.L8O$%F<98$'7: a.% Y<%78$99.'/ &$% V8%)5.'/70$%8$*9.'/ *78 $*'$ @2&*5$'7*-'<9$]-&$99*$%.'/ &$7 V.5O67 5*8 %B.59*EF .'& A$*89*EF 0$%B'&$%9*EF$% b<77$%8*$6$ $%6-%&$%9*EF:

I-%F<'&$'$ S*'&.78%*99X ZRY2U%-/%<55$ 7*'& O%*'A*O*$99 *' &$% M</$J &*$ '-8#$'&*/$' I-%/B'/$ <KA.K*9&$': VEF#*$%*/L$*8$' K78F$' &<K$* *' &$% (-OO9.'/ 5*8 Z[Z[VjV .'& *' &$5 F-F$' PEF'A$*8K$&<%6: b$/$' &*7% VEF#*$%*/L$*8$' 7-998$' <.EF &*$ I-%2 .'& D<EF8$*9$ $*'$% */$'$'8#*EL9.'/ *' T$8%<EF8 /$A-/$' #$%&$': W'7K$7-'&$%$ &.%EF *'7<8A 0-' 0$%$*'6<EF8$'J O%-K9$57O$A*6*7EF$' M)7.'/70$%6<F%$' $%7EF$*'8 $7 5)/9*EFJ $*' &%$*&*5$'7*-'<9$7 V.5O65-&$99 *5 P<F5$' &$% K$* Z[Z[VjV NK9*EF$' P$EF$'A$*8<'6-%&$%.'/$' A. $'8#*EL$9' .'& &<'' A. '.8A$':

a.% I<9*&*$%.'/ $*'$7 &$8<*99*$%8$' V.5O65-&$997 78F' $*'*/$ I$%7.EF$ <.7 &$5]-&$99E-'8<*'5$'8 .'& &$% cYP2^'9</$ A.% I$%6N/.'/: T$* &*$7$5 I$%7.EF$' /*K8 $7 <99$%&*'/7 '.% $*'$ 7$F% K$/%$'A8$ ^'A<F9 0-' G$5O$%<8.%5$77.'/$' *5 b<77$%: ‘5 &*$ Y<8$'K<7*7 6N% &*$]-&$990<9*&*$%.'/ A. 0$%K$77$%'J #B%$' $'87O%$EF$'&$ V.5O6#<77$%0$%7.EF$ A: T: *' &$% GF^W2^'9</$ 5*8 \%6<77.'/ 0-' V8%)5.'/7/$2 7EF#*'&*/L$*8$' *5 b<77$% .'& *' &$% &<%NK$% 9*$/$'&$' ^85-7OFB%$ A#$EL5B,*/:

7.2.3.3 Partikeltransport in Wasser („sump clogging“)

^.6/%.'& $*'$7 V8)%6<997 *' VEF#$&$' /<K $7 $*'$ I*$9A<F9 0-']<,'<F5$' A.% R%$*F<98./ &$% V*K *' &$% V.5O6#<77$%<'7<./.'/: a.% T$.%8$*9.'/ &*7%]<,'<F5$' 7*'& ^K7EFB8A.'/$' &$% G%<'7O-%8O%-A$77$ 0-' 6$78$' U<%8*L$9' #*$ A: T: W7-9*$%5<8$%*<9 SV8$*'#-99$6<7$%' .'& 2</9-5$%<8$X &.%EF &$' V*EF$%F$*87K$FB98$% *' &$' V.5O6 $%6-%&$%9*EF: Y$% G%<'7O-%8 $%6-9/8 #BF%$'& &$% !K9-#&-#';2UF<7$ &.%EF &*$ ^85-7OFB%$J <'7EF9*$,$'& &.%EF &<7 <K9<.6$'&$ (-'&$'7<8 -&$% M$EL</$#<77$%: I$%8$*9.'/ 0-' U<%8*L$9/%),$.'& 2/$-5$8%*$ 7-#*$ VEF#*55 6BF*/L$*8J b<77$%2 5<77$'78%-5 .'& /$-5$8%*7EF$ ^'-%&'./ 7*'& #*EF8*/$ G%<'7O-%8O<%<5$8$%: T$* PNELF<98$7*K' .'8$%F<9K &$7 V.5O6#<77$%7O*$/$97 L<'' $7 &.%EF b<77$%2 78%)5.'/$' .'& G.%K.9$'A A. $*'$% I$%9</$%./ 0-' U<%8*L$9' .'& A.'$F5$'&$% I$%7O$%%./ &$% V8%)5./7#$/$ &$7 P$A*%L.9<8*-'77_78$57 L-55$': Y*7 I$%7O$%%./ *78 0-' 7*EF$%F$*878$EF'*7EF$% T$&$.8./J #$*9 7*$ &*$ R.'L8*-'76BF*/L$*8 &$% D-8LNF9./ K$$*'8%BEF8*/8:

^.6/%.'& &$% #$*8/F'& .'K$78*5 58$' R-%52 .'& +%),$'O<%<5$8$% &$% U<%8*L$9 L<''
<.EF $*'$ 5$EF<'*78*7EF$ T$8%<EF8.'/ &$% G%<'7O-%80-%/B'/$ '.% ^'F<987#$%8$ 6N% &*$
V*$K0$%78-O6.'/ /K': Y<7 8F$%5-F_&%<.9*7EF$]-&$99 &$7 V*EF$%F$*87K$FB98$%7
9*6%8 h$&-EF #$7$'89*EF$ +%.'&*'6-%5<8*-'$' #*$ &*$ <85-7OFB%*7EF$' +$7EF#*'2
&*/L$*8$' K$* !K9-#&-#'; .'& &*$ Y%<*'</$2]<77$'78%-50$%8$*9.'/: Y*$ I$%9</$%.'/
*''$%F<9K &$7 V.5O6#<77$%7 L<'' '.% 5*8 c*96$ $*'$7 &$8<*99*$%8$' V.5O65-&$997
<K/$7EFB8A8 #$%&$': [K $*'$ /$7EF9-77$'$ 5$EF<'*78*7EF$]-&$99*$%.'/ &$7
U<%8*L$98%<'7O-%87 A#$EL5B,*/ *78J 7-998$ &.%EF /$$*/'8 I-%NK$%9$/.'/$' /$L9B%8
#$%&$': *'$7-9EF$]-&$99*$%.'/ 5N778$6-9/$'&$ (-5O-'$'8$' K$7*8A$'C

- T$%NEL7*EF8*/.'/ $*'$7 VO$L8%.57 0-' U<%8*L$9/%),$' .'&?6-%5$'J

- U<%8*L$98%<'7O-%8 5*8 ^85-7OFB%$'2 .'& b<77$%78%)5.'/J

- PNELF<98.'/ &.%EF V*K .'& +*88$%%-78$:

Y$% G%<'7O-%8 NK$% F-%*A-'8<9$ T)&$' #*%& *5 ^99/$5$*'$' &.%EF $*'$ T*9<'A A#*7EF$'
V8%)5.'/7L%B68$' .'& T-&$'F<68.'/ &$% U<%8*L$9 K$78*5 58: T$* 0$%8*L<9$' b$/$' L<''
$*' 6%$*$% R<99 <'/$'-55$' #$%&$': \'87O%$EF$'&$]-&99 7*'& 6N% Z[Z[VjV '$.
A.$'8#*EL$9':

\eO$%*5$'8$99$ Y<8$' A.% I<9*&*$%.'/ 7-9EF$% G%<'7O-%85-&$99$ 7*'& '.% *' /$%*'/$5
'56<'/ 0-%F<'&$': a.%A$*8 .'8$%7.EF8 R%<5<8-5$ ^DU *5 ^.68%</$ &$% I+T &<7
I$%F<98$' 0-' W7-9*$%5<8$%*<9 *5 V.5O6 .'& &*$ ^.7#*%L.'/$' <.6 &$' Y%.EL0$%9.78 <'
&$' ^'7<./7*$K$'Q 5-&$998$EF'*7EF$ ''8$%7.EF.'/$' #$%&$' F*$%A. 0-' $*'$%
&$.87EF$' c-EF7EF.9$ 5*8 ZRx &.%EF/$6NF%8: +%.'&9$/$'&$ UFB'-5$'$ &$7
U<%8*L$98%<'7O-%87 5*8 &$5 <K9<.6$'&$' b<77$% .'& *''$%F<9K &$7 V.5O67 9<77$' 7*EF
*'8$/%<9 A: T: <.EF *' &$% GF^W2^'9</$.'8$%7.EF$':

7.2.3.4 Sprühsystem

VO%NF7_78$5$ #$%&$' A.% Y%.EL<K7$'L.'/ &.%EF (NF9.'/ &$% ^85-7OFB%$.'& A.5
^.7#<7EF$' 0-' VO<98O%-&.L8$' $*'/$7$8A8: T$* &$% (-'&$'7<8*-' 0-' b<77$%&<5O6
<' &$' VO%NF8%-O6$' L<'' $7A. $*'$%9-L<9$' ^'%$*EF$%.'/ 0-' '*EF8L-'&$'7*$%$'&$'
+<7$' L-55$': W5 R<99$ 0-' AN'&6BF*/$' b<77$%78-662M.682]*7EF.'/$' L<'' &<&.%EF
$*' $%F)F8$7 P*7*L-6N% 7EF'99 Y$69</%<8*-'$' $'878$F$': VO%NF7_78$5$ K$#*%L$'
<.EF (-'0$L8*-'778%)5.'/$' *' &$% ^85-7OFB%$J &*$ A. $*'$% K77%$'

Y.%EF5*7EF.'/ .'& $*'$5 ^KK<. 0-' 9-L<9$' (-'A$'8%<8*-'75<e*5< AN'&6BF*/$% +<75*7EF.'/$' 6NF%$': ^.7 7*EF$%F$*878$EF'*7EF$% V*EF8 $%/$K$' 7*EF 6N% &$' *'7<8A 0-' VO%NF7_78$5$' &<F$% 6-9/$'&$ R%</$'C

- \66$L8*O*8B8 &$% (NF9#*%L.'/J

- ^.7#*%L.'/$' <.6 &*$ I$%8$*9.'/ 0-' AN'&6BF*/$' +<7$'J

- \66$L8*O*8B8 &$% ^.7#<7EF.'/ 0-' VO<98O%-&.L8$':

Y*$ K$*&$' $%78$' U.'L8$ 7*'& 8F$%5-F_&%<.9*7EF$% D<8.% .'& K*9&$' &*$ T<7*7 6N% &$' &%*88$':

T$* &$' <L8.$99*' Z[Z[VjV 0-%F<'&$'$' VO%NF7_78$5 5-&99' 5.77 &$% ^'#$'&$% $*'$ I*$9A<F9 0-' U<%<5$8$%' 0-%/$K$'J &*$ &$' ^.7K%$*8.'/7#$/ &$% G%-O6$' L*'$5<8*7EF K$7EF%$*K$': Y*$ R<99/$7EF#*'&*/L$*8 &$% G%-O6$' #*%& <.7 (-%%$9<8*-'$' 6N% $*'$ %.F$'&$ ^85-7OFB%$ $%5*88$98: Y*$ #7'89*EF$' VEF#BEF$' &*$7$7]-&$99<'7<8A$7 7*'&C

- Y$% G%-O6$'8%<'7O-%8 5*8 &$% <85-7OFB%*7EF$' V8%)5.'/ #*%& 0$%'<EF9B77*/8J .'&

- $7 K$78$F8 &*$ +$6<F% *'L-'7*78$'8$% *'/<K$' 6N% ^85-7OFB%$'2 .'& G%-O6$'78%)5.'/:

^.6/%.'& &$% I$%'<EF9B77*/.'/ &$7 G%-O6$'8%<'7O-%87 5*8 &$% <85-7OFB%*7EF$' V8%)5.'/ #$%&$' &*$ 0-5 VO%NF7_78$5 0$%.%7<EF8$' Y.%EF5*7EF.'/7O-%/B'/$ '*EF8 L-%%$L8 &<%/$78$998: c*$%<.7 %$7.98*$%$' 7_78$5<8*7EF$ R$F9$% K$* &$% ^K7EFB8A.'/ &$% \66$L8*O*8B8 &$% (NF9#*%L.'/ .'& K$* &$% ^.7#<7EF.'/ 0-' VO<98O%-&.L8$': Y*$ W'L-'7*78$'AO%-K9$5<8*L #*%& K$* &$% L-5O9e' P<.5/$-5$8%*$ %<9% ^'9</$' /%<0*$%$'&$% <97 K$* &$' K*7F$% 6N% I<9*&*$%.'/7%$EF'.'/$' 0$%#$'&8' $*'6<EF$' I$%7.EF7<'9</$':

a.% I$%K$77$%.'/ &$7 VO%NF7_78$5 5-&$997 .'& A.% T$%NEL7*EF8*/.'/ &$% b$EF7$9#*%L.'/ 5*8 &$% <85-7OFB%*7EF$' V8%)5.'/ *78 $*'$ /%.'&9$/$'&$ HK$%<%K$*8.'/ '-8#$'&*/: U%*'A*O*$99 K*$8$8 Z[Z[VjV 5*8 &$5 ^$%-7-95-&$99 ^\P(^ K$%$*87 $*'$' ^'7<8AJ .5 &<7 I$%F<98$' 0-' G%-O6$' &_'<5*7EF L-%%$L8 .'& *' 0-99$% (-'7*78$'A 5*8 &$% <85-7OFB%*7EF$' V8%)5.'/ A. 5-&$99*$%$': T$* &*$7$5 ^'7<8A 6$F98 h$&-EF $*'$ $*/$'$ bB%5$K*9<'A &$% G%-O6$':

^.6/%.'& &$% 0-%<'/$F$'&$' HK$%9$/.'/$' $%7EF$*'8 $7 '-8#$'&*/J &*$]-&$99*$%.'/ *' Z[Z[VjV A. $%8NEF8*/$' -&$% 7-/<% $*' '$.$7]-&$99 A. $'8#*EL$9': Y*$7$7]-&$99 5.77 6-9/$'&$ (-5O-'$'8$' K$7*8A$'C

-]<77$'K*9<'A &$% G%-O6$' *''$%F<9K &$%]-&$99A-'$Q ^.78<.7EF 5*8 &$% ^85-7OFB%$ NK$% I$%&<5O6.'/ .'& (-'&$'7<8*-'Q G%-O6$'<K7EF$*&.'/ <' bB'&$' .'& T)&$'J

- \'$%/*$K*9<'A &$% G%-O6$' *''$%F<9K &$%]-&$99A-'$J bB%5$<.78<.7EF 5*8 &$% ^85-7OFB%$J

- W5O.97K*9<'A &$% G%-O6$'J HK$%9</$%.'/ 0-' G%<'7O-%8 5*8 &$% ^85-7OFB%$'2 78%)5.'/ .'& &$% V$&*5$'8<8*-'7K$#$/.'/J

- T$%NEL7*EF8*/.'/ &$7 G%-O6$'K$*8%</7A.%<85-7OFB%*7EF$' Y*EF8$J

- T*9<'A/9$*EF.'/ 6N% &$' 5*889$%$' G%-O6$'&.%EF5$77$%:

a.% I<9*&*$%.'/ &$7 VO%NF7_78$55-&$997 L-55$' I$%7.EF$ <.7 &$5 9<.6$'&$' 6%<'A)7*7EF$' G[Vð D 2U%-/%<55 -&$% A.LN'68*/$ I$%7.EF$ <' &$% &$.87EF$' GF^W2 ^'9</$ *' T$8%<EF8: R%NF$%$ I$%7.EF$ #*$ A: T: W''$'7O%NF$' *' &$% cYP2^'9</$ L)''$' K'6<997 /$'.8A8 #$%&$'J K*8' <K$% <.6/%.'& &$% W'78%.5$'8*$%.'/ '.% K$/%$'A8$])/9*EFL$*8$' &$%]-&$990<9*&*$%.'/: W'7K$7-'&$%$ &*$ 0-5 VO%NF7_78$5 <.7/$)78$ /%-,%B.5*/$ (-'0$L8*-'778%)5.'/ #.%&$ K$* 6%NF$%$' VO%NF$eO$%*5$'8$' .'/$'N/$'& $%6<778: T$* VO%NF0$%7.EF$' A.% <85-7OFB%*7EF$' Y.%EF5*7EF.'/ <' L9$*'2 .'& 5*88$97L<9*/$' I$%7.EF<'9</$' #*$ G[Vð D -&$% GF^W *78 $*'$ 7-%/6B98*/$ VL<9*$%.'/7<'<9_7$ $%6-%&$%9*EFJ #*$ 7*$ $%785<97 0-' f:]<9$8 *5 P<F5$' &$7 VZ^Z\x2U%-h$L87 &.%EF/$6NF%8 #.%&$ kRWV >3k:

7.2.3.5 H_2-Verbrennungsvorgänge

Modellierung von Wasserstoffverbrennungsvorgängen

Y*$ A.%A$*8 0$%6N/K<%$' ZRY2Z-&$7 7*'& /%.'&9$/$'& /$$*/''$8J UFB'-5$'$ &$% b<77$%78-66O$%K%$''.'/ *5 a.7<55$'F<'/ 5*8 V*EF$%F$*87<'<9_7$' 0-' ($%'2 %$<L8-%$' A. .'8$%7.EF$': b$*8$ T$%$*EF$ 0-' I$%K%$''.'/7%$/*5$7 L)''$' 5*8 <.7%$*EF$'&$% +$'<.*/L$*8 0-%F$%/$7</8 #$%&$': Y*$7 #.%&$ *' &$8<*99*$%8$' V8.&*$'J

A: T: *5 c j Z [ ] U%-h$L8 &$7 =: \ ‘ P<F5$’O%-/%<5 5 7 kVZc >@kJ <.6/A*/8: ^99$%&*’/7 #.%&$’ <.EF ’-EF -66$’$ U%-K9$5$*&$’8*6*A*$%8:

+B’/*/$ U%<e*7 K$* &$% D.8A.’/ <’#$’&.’/7-%*$’8*$%8$% Z-&$7 *78 &*$ I$%#$’&.’/ 0-’ 0$%$*’6<EF8$’ G.%K.9$’A2 .’& I$%K%$’’.’/75-&99’J A: T: &$7 L2e]-&$997 6N% &*$ G.%K.9$’A .’& A<F9%$*EF$% ^K#<’&9.’/$’ &$7 \&&_2Y*77*O<8*-’7 .’&k-&$% &$7 \&&_2 T%$<L ‘O2]-&$997 6N% &*$ I$%K%$’’.’/7%<8$: Y$% +N98*/L$*87K$%$*EF 7-9EF$%]-&99 #.%&$ ’<EF/$#*$7$’ .’& p<’8*8<8*0 K$78*5 58: ^’#$ ’&.’/7%$EF’.’/$’ 5*8 ZRY2 Z-&$7 <.6 &$% T<7*7 &*7% 0$%$*’6<EF8$’]-&$99$ *’’$%F<9K *F%$% +N98*/L$*87K$%$*EF$ /<%<’8*$%$’ &*$ a.0$%9B77*/L$*8 &$% $%A$./8$’ \%/$K’*77$: ^99$%&*’/7 9*$/$’ $*’*/$ #*EF8*/$ I$%K%$’’.’/7OFB’-5$’$ <.,$%F<9K &$% K*7F$% ’<EF/$#*7’$’ +N98*/L$*872 K$%$*EF$:

‘’8$% &$’ #*EF8*/78$’ U%-A$77$’ -&$% UFB’-5$’$’ *5 T$%$*EF &$% V*5.9<8*-’ 8.%K.9$’8$% I$%K%$’’.’/J &*$ ’-EF ’*EF8 <.7%$*EF$’& <K/$&$EL8 7*’& -&$% &*$.’8$% ‘578B’&$’ ’-EF $*’ 0$%K77%8$7 I$%78B’&’*7 K$’)8*/$’J 7*’&A. ’$’’$’

- I$%K%$’’.’/7%$/*5$7 5*8 F-F$% G.%K.9$’A*’8$’7*8B8 SP$/*5$7 5*8 Y< » 1XJ
- R9<5 5$’K$7EF9$.’*/.’/*’ F<9K-66$’$’ -&$% -66$’$’ +$K*$8$’J
- 9-L<9$7 -&$% /9-K<9$7 M)7EF$’ 0-’ R9<5 5$’6%-’8$’J
- R9<5 5$’<.7K%$*8.’/*’ 8$*9/$5*7EF8$’ V_78$5$’ 5*8 (-’A$’8%<8*-’7/%<&*$’8$’J
- HK$%/<’/ 0-’ Y$69</%<8*-’A.% Y$8-’<8*-’ SYYGXJ
- b<77$%78-66L-’A$’8%<8*-’ d v J
- *’69.77 0-’ VO%NF8%)O6EF$’:

Y*$ 6-9/$’&$’ Y$8<*95-&$99$ 5N77$’ #$*8$%$’8#*EL$98 #$%&$’J .5 &*$ \66$L8$J &*$ K$* &$’ -K$’ /$’<’’8$’ U%-A$77$’ $*’$ P-99$ 7O*9’ L)’’$’J /$’<.$% A. K$%NEL7*EF8*/$’C

- I$%K%$’’.’/75-&99J
-]-&99 6N% bB%5$0$%9.78$J
- G.%K.9$’A5-&$99$:

T$/N'78*/8 &.%EF &*$ 78$8*/ #<EF7$'&$ Z-5O.8$%9$*78.'/ *78 &*$ /B'/*/$ V8%<8$/*$J 0$%$*'6<EF8$]-&99 &.%EF <.6#B'&*/$%$ A. $%7$8A$'J &*$ &<'' <99$%&*'/7 <.EF 5$F% PEF'<.6#<'& K$')8*/$': ''8$% &*$7$' +$7*EF87O.'L8$' L)''$' &*$ 6-9/$'&$']-&$99O$%K77%.'/$' 6N% &*$ 'BEF78$ Z-&$/$'$%<8*-' <97 0-%&%*'/9*EF <'/7F$' #$%&$'C

- W5O9$5$'8*$%.'/ .'& #$*8$%$ \'8#*EL9.'/ &$% I$%K%$''.'/75-&$99$ *5 P<F5$' &$7]D%$ 27.5$& UYR; ^'7<8A$7J 5*8 b2UYR <97 &$% R.'L8*-' 5*8 &$5 #$*8$78$' T$%$*EF 0-'])/9*EFL$*8$': Y*$7$ ^%K$*8 7$8A8 &*$ (9B%.'/ &$% ^KFB'/*/L$*8 &$% 5-5$'8<'$' EF$5*7EF$' P$<L8*-'7%<8$ 0-' G$5O$%<8.% .'& (-'A$'8%<8*-'$' 7-#*$ &*$ \'8#*EL9.'/ 0-' /$L-OO$98$' A#$*2 .'& 5$F%&*5$'7*-'<9$' UYR7 0-%<.7J A: T:*' &$% G$5O$%<8.% .'& &$% P$<L8*-'76-%87EF%*8870<%*<K9$'J

- /$'<.$ T$%NEL7*EF8*/.'/ &$% L-'0$L8*0$' bB%50$%9.78$ *' &$% 8.%K.9$'8$' +%$'A7EF*EF8: \eO$%*5$'8$99$ T$6.'&$ A$*/$' $*'$' %$9<8*0 /$%*'/$' -&$% 7-/<% 0$%'<EF9B77*/K<% L9$*'$' *'69.77 &$% bB%5$0$%9.78$ &.%EF V8%<F9.'/: Y$7F<9K #*%& &*$ \'8#*EL9.'/ .'& W5O9$5$'8*$%.'/ 0-' V8%<F9.'/75-&$99$' <97 #$'*/ #*EF8*/ <'/7F$'J

- &*$ (-'0$%7*-' 0-' P^DV]-&$99$'A. M\VkIM\V]-&$99$':

T$* &$% I$%#$'&.'/ 0-' ZRY2Z-&$7 6N% V*EF$%F$*87<'<9_7$' 5.77 K$7-'&$%$ ^.65$%L7<5L$*8 <.6 &*$ o<9*8B87L-'8%-99$ 0$%#$'&$8 #$%&$': \7 #$%&$' &$8<*99*$%8$.'& %*/-%-7 6-%5.9*$%8$ I-%7EF%*68$' 6N% &*$ T$.%8$*9.'/ 0-' ZRY2Z-&$7 K$')8*/8J &*$ NK$% &*$ P$/$9' L-'7p'8$% I<9*&*$%.'/7O%-A$&.%$' 6N% V*EF$%F$*87<'<9_7$' 0-' ($%'%$<L8-%$' .'& NK$% &*$ T$78 U%<E8*E$ +.*&$9*'$7 6N% ZRY2^'#$'&.'/$' *' &$% W'&.78%*$ F*'<.7/F':W' Y$.87EF9<'& 7*'& ^%K$*8$' *' &*$7$% P*EF8.'/*5 +<'/$:

'$' #*EF8*/$' T$*8%</ A.% (9B%.'/ .'& I$%K77%.'/ &$% <.6/$A$*/8$' U%-K9$5$ L<'' &<7 [\ZYkZVDW W'8$%'<8-'<9 V8<'&<%& U%-K9$5 SWVUX 5*8 &$5 GF$5< &$% V*5.9<8*-' 0-' c32I$%K%$''.'/70-%/B'/$' K%*'/$'J &<7 &$%A$*8 0-' &$.87EF$' R-%7EF.'/7*'78*8.8*-'$' 0-%K$%$*8$8 #*%&: T$* I$%K%$''.'/70-%/B'/$' *5 V*EF$%F$*87K$FB98$% SVcTX $*'$7 ($%'%$<L8-%7 L<'' 9-L<9$ R9<55$'K$7EF9$.'*/.'/*' T$%$*EF$' 5*8 $%F)F8$% G.%K.9$'A .'&k-&$% c32(-'A$'8%<8*-' <.68%$8$'J A: T: *' Y<5O6$%A$./$%%B.5$' -&$% G%OO'FB.7$%': Y<'<EF K$#$/8 7*EF &*$ R9<55$ *' +$K*$8$ 5*8 &$.89*EF '*$&%*/$%$% c32(-'A$'8%<8*-'J A: T:*' &$' Y-5 -&$%*' P*'/%B.5$J 5*8 <K'$F5$'&$% +$7EF#*'&*/L$*8: Y*$ I$%K%$''.'/70-%/B'/$ &-%8 K$$*'69.77$' 5*8 &*$ T$9<78.'/ &$% VcT bB'&$: ZRY2U%-/%<55$ A.% c32I$%K%$''.'/ #*$ A: T:

Z [ ] @Y 7*'& 6N% &*7 (-'A$'8%<8*-'7K$%$*EF$ '*EF8 0<9*&*$%8J <.EF #$'' <'A.'$F5$' *78J &<77 7*$.'8$% &*7' ‘ 578B'&$' L-'7$%0<8*0$ \%/$K'*77$ 9*6%': +.8<EF8$%K$F)%&$' 7$F$' &<%*' $*'$ P$9$0<'A 6N% &$' D<EF#$*7 &$% VcT T$9<78.'/ K$* c32 I$%K%$''.'/:

a.% eO%*5$'8$99$' ^K7*EF$%.'/ L)''$' <98$ T<88$99$ \eO$%*5$'8$ F$%<'/$A-/$' -&$% '$.$ \eO$%*5$'8$ &$6*'*$%8 #$%&$'J &*$ A: T: *' &$% GF^W2^'9</$ &.%EF/$6NF%8 #$%&$' L)''8$': M$8A8$%$7 K)8$ 'K' &$% K$77$%$' W'78%.5$'8*$%.'/ &*$])/9*EFL$*8J <.EF +%<&*$'8$' A. %$<9*7*$%$'J $8#< *5 *''$%$' a_9*'&$% F-F$ c32(-'A$'8%<8*-' .'& <.,$%F<9K /$%*'/$ (-'A$'8%<8*-': D$.$ /%-,$ I$%7.EF7K$FB98$% 5*8 K*7 A. 1>> K<% 78<8*7EF$5 ^.79$/.'/7&%.EL .'7 11> 5@ I-9.5$' 78$F$' *' Y$.87EF9<'& 6N% O%<L8*7EF h$&$ $%&$'L9*EF$ ‘ '6<997p'A .'& b<77$%78-66L-'A$'8%<8*-' A.% I$%6N/.'/: T$* '$.$' \eO$%*5$'8$' #B%$ <.EF &*$])/9*EFL$*8 &$% K9*'&$' I-%<.7%$EF'.'/ /$/K' .'& &<5*8 &$% D<EF#$*7 &$% $%6-9/%$*EF$' I-%<.7K$%$EF'.'/ .'6<998_O*7EF$% I$%K%$''.'/$' /$/K':

7.2.3.6 Pyrolyse (Öl-, Kabelbrand)

T%<'&7*5.9<8*-'7%$EF'.'/$' .'& %EF'%*7EF$ D<EF#$*70$%6<F%$' F<K$' 0-% <99$5 *5 a.7<55$'F<'/ 5*8 &$% HK$%O%N6.'/ &$% T%<'&7*EF$%F$*8 *' T$8%*$K K$6*'&9*EF$% ($%'L%<68#$%L$ $*'$ A.'$F5$'&$ T$&$.8.'/ $%9<'/8: Y*$7 /*98 *'7K$7-'&$%$ <.EF 6N% &8%5*''*78*7EF$ T%<'&/$6<F%$'<'<9_7$': Y$%<%8*/$ %EF'%*7EF2<'<9_8*7EF$ I$%6<F%$' F<K$' K$%$*87 *'/<'/ *' '$.$%$ P$/$9#$%L$ /$6.'&$'J 7-#-F9 *'8$%'<8*-'<9 SA: T: *' &$' P*EF89*'*$' &$% W'8$%'<8*-'<9 ^8-5*E \'$%/_ ^/$'E_ W^\^X <97 <.EF '<8*-'<9 SA: T: *5 <L8.99' P$/$9$'8#.%6 &$% ‘:V: D.E9$<% P$/.9<8-%_ Z-55*77*-' -&$% *' &$% &$.87EF$' (G^ 31>1J G$*9 12@X: V*$ /98' 5*889$%#$*9$ <97 A.9B77*/$ ^'<9_7$F*9675*88$9 K$* &$% T$#$%8.'/ &$% T%<'&7*EF$%F$*8: Y$% D.8A$' %$EF'$%*7EF$% I-%F$%7</$' K78F8 *''7K$7-'&$%$ 6N% +.8<EF8$% .'& T$F)%&$' *' $*'$% '<EF0-99A*$FK<%$' .'& %$O%-&.A*$%K<%$' T$#$%8.'/ &$7 0-%F<'&$'$' KA#: //6: <.EF /$O9<'8$' T%<'&2 7EF.8A$7:

^'&$%$%7$*87 F<K$' <99$ 0$%6N/K<%$' ^'<9_7$F*9675*88$9 *F%$ ^'#$'&.'/7/%$'A$' .'& 7*'& -F'$ 0$%8*$68$ ($''8'*7 &$% .'8$%7EF*$&9*EF$' UFB'-5$'$.'& P<'&K$&*'/.'/$' '*EF8 -F'$ #$*8$%$7 6N% h$&$ U%-K9$578$99.'/ <'A.#$'&$': a*$9 &$% #$*8$%$' \'8#*EL9.'/ 7-9EF$% U%-/%<55$ 5.77 $7 7$*'J &$' ^'#$'&.'/7K$%$*EF A. $%#$*8$%'

.'& &*$ ^.77</$7*EF$%F$*8 &$% U%-/%<55$ A. 0$%K$77$%' KA#: /$'<.$% A. p<'8*6*A*$%$':

+%.'&7B8A9*EF /*K8 $7 5$F%$%$ G_O$' 0-' T%<'&7*5.9<8*-'7O%-/%<55$': Y*$7$ 7*'&C

- ZRY U%-/%<55$ SA: T: RYVJ ZRXk J

- M.5O$& O<%<5$8$%2U%-/%<55$ SA: T: Z[Z[VjVJ c^YZPGXJ

- a-'$'5-&$99$ SA: T: ZR^VGJ RM^]]\2VJ]^+WZX:

Y*7 U%-/%<55$.'8$%7EF$*&$' 7*EF *5 Y$8<*99*$%.'/7/%<& <K$% <.EF *5 PEF'A$*8K$&<%6: Y< O%-K<K*9*78*7EF$ ^'<9_7$' <' T$&$.8.'/ /$#*''$' 7*'& U%-/%<55$ 5*8 '*$&%*/$5 PEF'A$*8K$&<%6 <K$% &$''-EF F-F$5 Y$8<*99*$%.'/7/%<& /$6%</8: c*$% *78 /$%<&$ &$% I-%8$*9 *5 9.5O$& O<%<5$8$%2^'7<8A A. 7$F$'J #$9EF$% K$*&$' T$&*'/.'/$' /$'N/$' L<''J #-K$* <K$% '-EF $%F$K9*EF$% \'8#*EL9.'/7K$&<%6 K78F8:

c<.O8<.6/<K$ &$% T%<'&7*5.9<8*-'7O%-/%<55$*78C

- V*5.9<8*-' &$7 8F$%5-&_'<5*7EF$' I$%F<98$'7J

- 8F$%5-&_'<5*7EF$7 I$%F<98$' 0$%7EF*$&$'$% G<%/$8-Kh$L8$ S(<K$9J V8%.L8.%$'XJ

- V*5.9<8*-' &$% I$%K%$''.'/ .'& &$% U_%-9_7$.'8$% .'8$%7EF*$&9*EF$' I$'8*9<8*-'7K$&*'/.'/$'J

- V*5.9<8*-' &$% +$/$'5<,'<F5$' SVO%*'L9$%<'9</$X .'& .'8$%7EF*$&9*EF$%]<8$%*<9*$' SRPDZ (<K$9J YB557EF*EF8K*9&'$%X:

]*8 T9*EL <.6 &<7 Z[Z[VjV2U%-/%<55 #$%&$' 6-9/$'&$ \'8#*EL9.'/77EF#$%O.'L$ /7F$'C

Einbau eines Plumemodells

Bei den bereits durchgeführten benchmark-Rechnungen im Rahmen des ICFMP-Projekts wurden relativ gute Ergebnisse in größerer Entfernung des eigentlichen Brandes erzielt. Größere Abweichungen treten in Nähe des Plumes auf, da der Impulsaustausch und die Durchmischung mit Luft in den aufsteigenden Plume nicht

richtig berücksichtigt werden. Hier ist der Einbau einzelner Modelle und Modellkonzepte basierend auf Zonenmodellen sinnvoll.

Berücksichtigung des HCl-Verhaltens

Bisher werden die korrosiven Eigenschaften des freiwerdenden HCl nicht berücksichtigt. Dadurch treten unrealistisch hohe Konzentrationen von HCl in der Atmosphäre auf, sodass die tatsächliche Atmosphärenzusammensetzung (also auch die Sauerstoffkonzentration) verfälscht wird. Daher sind entsprechende Modelle zu entwickeln und einzubauen.

Simulation des Rußverhaltens

Sowohl bei dem Kabelbrand- als auch bei dem Ölbrandmodell ist eine Berechnung der Rußbildung bisher nicht vorgesehen. Damit ist die Berechnung der Rauchgasverteilung mit dessen Einfluss auf die Strahlungswärme der Flamme und die Berechnung der optischen Dichte zur Beurteilung der Sicherheit von Rettungswegen nicht möglich. Die Angabe der Zugänglichkeit von Rettungswegen bzw. anderer Raumbereiche ist für die Beurteilung möglicher Brandbekämpfungsmaßnahmen notwendig. Das Russverhalten soll mit Hilfe der vorhandenen Aerosolmodelle berechnet werden. Ansätze zur Berechnung der optischen Dichte sind ebenfalls notwendig.

7.2.3.7 Unsicherheitsanalyse

V$'7*8*O*8B872 .'& ''7*EF$%F$*87<'<9_7$' 7*'& '*EF8 '.% *' &$% GF$%5-F_&%<.9*L $%6-%&$%9*EFJ 7-'&$%' <.6 <99$' +$K*$8$' &$% P$<L8-%7*EF$%F$*8J #- P$EF$'$%/$K'*77$ 5*8 /%),$%$' ''7*EF$%F$*8$' K$F<68$8 7*'&J &*$ '*EF8 $*'&$.8*/ L-'7$%O<8*O 8<K/$7EFB8A8 #$%&$' L)''$': ^.EF &-%8J #- '*EF8 (-'7$%O<8*O*8B8 7-'&$%' 5)/9*EF78$ P$<9*8B87'BF$ /$6%</8 *78J $8#< K$* P$EF'.'/$' A. ''6<997p'A$' 6N% UV^ -&$% D-86<997EF.8A2 5<,'<F5$'J7*'& ''7*EF$%F$*87<'<9_7$' <'/A*/8:

RN% &*$ UFB'-5$'$J &*$ *5 V*EF$%F$*87K$FB98$% O-' P9O<'A 7*'&J *78 *' &$% I$%/<'/$'F$*8 '.% $*'$ V$'7*8*O*8B872 .'& ''7*EF$%F$*87<'<9_7$ A.5 ^$%-7-9<KK<. SGF$%5-F_&%<.9*L .'& ^$%-7-95-&$99*$%.'/X &.%EF/$6NF%8 #-%&$': Y$%A$*8 #*%& $*'$ 7-9EF$ ''8$%7.EF.'/A.5 cYP2I$%7.EF G@1:=A.5 ^K7EF9.77 /$K%<EF8:

a.LN'68*/ 7*'& 7-9EF$ ''8$%7.EF.'/$' A. $*'$5 L-5O9e' GF$%5-F_&%<.9*LO$%7.EF 2A:T: &$5 GF^W2I$%7.EF A.5 WVU2In2 .'& A. $*'$5 I$%7.EF K$AN/9*EF &$7 f-&O$%F<98$'7 '-8#$'&*/J .5 NK$% &*$ h$#$*9*/$ P9O<'A O-' *'A$9O%-A$77$'k

2OFB'-5$'$' T$78B8*/.'/ KA#: ^.67EF9.77 A. $%F<98$':]*88$96%*78*/ 7-998$' <.EF <'&$%$ GF5'K$%$*EF$ *' V$'7*8*0*8B872 .'& ''7*EF$%F$*87<'<9_7$' $*'K$A-/$' #$%&$':

7.2.3.8 Gesamtsystem Kühlkreislauf - Sicherheitsbehälter

a.% ^KK*9&.'/ &$7 +$7<587_78$57 (NF9L%$*79<.6 2 V*EF$%F$*87K$FB98$% #$%&$' ^GcM\Gk^GcM\G2ZY .'& Z[Z[VjV /$L-OO$98J A.5 $*'$'J .5 &$']<77$'2 .'& \'$%/*$$*'8%</ *' *F%$% 0*$%B98*/$' R-%5 SY<5O6J +<7$J VO<98O%-&.L8$X *' &*$]-&99 6N% &$' V*EF$%F$*87K$FB98$% 5)/9*EF78 6$F9$%6%$* A. /$#BF%9$*78$'J A.5 <'&$%$' A:T:6N% ^'<9_7$' A.5 7-/:!7.5O E9-//*'/;: \%78$ ^'#$'&.'/$' 6N% &<7 /$L-OO$98$ V_78$5 /*K8 $7 6N% &$' I$%7.EF Uc\T'V2RUG21 F*'<.7 <.EF 6N% ^'9</$' &$7 G_O7 ([DI[W .'& VbP2dh

\7 /*98 F*$%J A.LN'68*/ 5*8 &$5 /$L-OO$98$' V_78$5 \%6<F%.'/$' A. 7<55$9'J $7 #$*8$% A. $%8NEF8*/$'J $7 6N% $*' #$*8$7 VO$L8%.5 0-' V8)%6<997A$'<%*$' <'A.#$'&$' .'& <.6 <'&$%$ ^'9</$'8_O$' <.7A.&F'':

7.2.4 SWR-spezifische Modifikation bzw. Ergänzung der Modellierung

7.2.4.1 Blasensäulen in der SWR-Kondensationskammer

T$* &$% Y%.EL$'89<78.'/ &.%EF Y<5O6$*'7O$*7.'/ *' &*$ VbP2(-'&$'7<8*-'7L<55$% K*9&$' 7*EF T9<7$'7B.9$' .'& &<5*8 0$%K.'&$'$ a*%L.9<8*-'778%)5.'/$' *5 b<77$%: Y*7 V8%)5.'/$' K$78*55$' &*$ I$%#$*9A$*8 &$% T9<7$' *5 b<77$% .'& &<5*8 &*$ V8B%L$ &$% ^K7EF$*&.'/ 0-' ^$%-7-98$*9EF$'J &*$ 5*8 &$5 +<7 *' &*$ b<77$%0-%9</$ $*'/$7O$*78 #$%&$' SO--9 7E%.KK*'/2\66$L8X: b$*8$%$ ^.7#*%L.'/$' &$% T9<7$'7B.9$' 7*'& &*$ Y.%EF5*7EF.'/ &$7 b<77$%7 .'& &*$ ^.6#*%K$9.'/ 0-' <K/$9</$%8$' G$*9EF$'J &*$ 0'8.$99 A. $*'$% I$%78-O6.'/ &$% ^'7<./7*K 0-' D-8LNF97_78$5$' 6NF%$' L)''$': Y*$ Y_'<5*L &$% T9<7$'7B.9$' F<8 &<F$% 7*EF$%F$*878$EF'*7EF$ T$&$.8.'/ 6N% &$' VO<98O%-&.L88%<'7O-%8 .'& &*$ D-8LNF9.'/:

W5 Z[Z[VjV2]-&$99 6N% ^$%-7-9%NELF<98.'/ *' b<77$%0-%9</$' SVU^PZ2TX #$%&$' &*$ ^.7#*%L.'/$' &$% a*%L.9<8*-'778%)5.'/$' <.6 &*$ I$%#$*9A$*8 &$% T9<7$' &.%EF $*'$ (-%%$9<8*-' &<%/$78$998J &*$ 0-%#*$/$'& <.6 U9<.7*K*9*8B87NK$%9$/.'/$' /$/%N'&$8 *78: \eO$%*5$'8$99$ Y<8$' A.% I<9*&*$%.'/ &*7% (-%%$9<8*-' 7*'& '.%*' /$%*'/$5]<,$

0-%F<'&$': RN% &$' U<%8*L$98%<'7O-%8 *5 V.5O6#<77$% <.6/%.'& &$% T9<7$'6%$*7$8A.'/ 7*'& #$&$%]-&99 '-EF I<9*&*$%.'/7&<8$' 0$%6N/K<%:

R-9/$'&$ ^%K$*8$' 7*'& '-8#$'&*/J &<5*8 /$'<.$%$ 7*EF$%F$*878$EF'*7EF$ ^.77</$' A.&$' ^7O$L8$' ^$%-7-9%NELF<98.'/ .'& U<%8*L$98%<'7O-%8 .'8$% I$%#$'&.'/ 0-' Z[Z[VjV5)/9*EF #$%&$'C

- \eO$%*5$'8$ 5*8 T9<7$'7B.9$' A.% \%5*889.'/ &$% V8%)5.'/70$%8$*9.'/ *5 b<77$%J

- \%78$99.'/ $*'$7 A#$*OF<7*/$' V8%)5.'/75-&$997 6N% &<7 V.5O6#<77$%:

Y<7 A#$*OF<7*/$ V8%)5.'/75-&$99 78$998 $*'$ b$*8$%$'8#*EL9.'/ &$7 -K$' 7L*AA*$%8$' $*'OF<7*/$' V8%)5.'/75-&$997 6N% &<7 V.5O6#<77$% &<%: Y$% $*'6<EF78$ ^'7<8A K78F8 *' &$% ^'#$'&.'/ $*'$%]-&$997 &$% F-5-/$'$' T9<7$'78%)5.'/J K$* &$5 Y<5O6L-'&$'7<8*-'J ^.68%*$K7L%B68$.'& VEF9.O6 K$%NEL7*EF8*/8 #$%&$': RN% &*$ I<9*&*$%.'/ &*$7$7]-&$997 L)''$' &*$7$9K$' Y<8$' 0$%#$'&$8 #$%&$'J &*$ <.EF 6N% &*$ I<9*&*$%.'/ &$% (-%%$9<8*-' 6N% &*$ T9<7$'0$%#$*9A$*8 $*'/$7$8A8 #$%&$':

7.2.4.2 Durchmischungsvorgänge bei Gaseinbringung über Kondensationsrohre

T$* ^.778%)5$' 0-' Y<5O6 .'&k-&$% D*EF8 L-'&$'7*$%K<%$' +<7$' <.7 G<.EF%-F%$'k(-'&$'7<8*-'7%-F%$' 2 0-%'$F59*EF *' Y%.EL<KK<.7_78$5$' 2 #$%&$' Y.%EF5*7EF./70-%/B'/$ *5 .5/K'&$' b<77$%O--9 <.7/$9)78: RN% &$' M<'/A$*8K$%$*EF 7O*$9$' &<K$* &*$ \'8#*EL9.'/ &$% G$5O$%<8.%O$%8$*9.'/J*'7K$7-'&$%$ &*$ &$% [K$%69BEF$'8$5O$%<8.% .'& &*$ ^K9</$%.'/70-%/B'/$ 0-' ^$%-7-9$' .'& VO<98O%-&.L8$' .'& f-& *5 b<77$% $*'$ #*EF8*/$ P-99$: RN% &*$ I$%&.'78.'/ <' &$% [K$%69BEF$ *78 &*$ [K$%69BEF$'8$5O$%<8.% $'87EF$*&$'&J #<7 #*$&$%.5 &*$ R$.EF8$.'& &*$ G$5O$%<8.%$'8#*EL9.'/ *' &$% ^85-7OFB%$ NK$% &$5 b<77$% 5*8K$78*55 58: T$6*'&$' 7*EF ^$%-7-9$.'& VO<98O%-&.L8$ '-EF*5 b<77$%*' &$% VEF#KJ L)''$' 7*$ &.%EF $*'78%)5$'&$]$&*$' #*$&$% '$. <.6/$#*%K$98 #$%&$' .'& 78F' $*'$5 PNEL8%<'7O-%8*' &*$ ^85-7OFB%$ &.%EF I$%&<5O6.'/9B'/$% A.% I$%6N/.'/:

Y*$ Y.%EF5*7EF./70-%/B'/$ 7$9K78 7*'& 78<%L 0-' &$% P-F%<.78%*887/$-5$8%*$J ^.78%*887/$7EF#*'&*/L$*8 S]<77$'78%-5X .'& a.7<55$'7$8A.'/ &$7 A.78%)5$'&$']$&*.57 <KFB'/*/: +$%*'/$]<77$'78%)5$ O$%9$' .5 &*$ P-F%$ F$%.5 <.6J K*9&$' $O89: b<%5#<77$%78%BF'$' .5 &<7 P-F%: b<%5$7 b<77$% 7EF#*55 8 #$'*/ 0$%5*7EF8

<.6 &$% U--9-K$%69BEF$ <.6: \7 K*9&$8 7*EF $*'$ c$*,#<77$%7EF*EF8 <' &$% [K$%69BEF$J &*$ I$%&.'78.'/72 .'& I$%&<5O6.'/70-%/B'/$.'& ^$%-7-9kVO<98O%-&.L88%<'7O-%8 K$78*55 8: T$* T$*5*7EF.'/ 0-' '*EF8 L-'&$'7*$%K<%$' +<7$' *78 &*$ PNF%#*%L.'/ 78B%L$%J &*$ b<77$%7EF*EF8$' -K$%F<9K &$% P-F%5N'&.'/ #$%&$' 78B%L$% <' &$% Y.%EF5*7EF.'/ K8*9*/8: \K$'6<997 K$* /%),$%$' a.78%)5.'/$' 6*'&$8 *5 b<77$% -K$%F<9K &$%]N'&.'/ $*'$ 78<%L$ Y.%EF5*7EF.'/ 78<88J K$* '-EF /%),$%$% a.78%)5.'/ #$%&$' <.EF 8*$6$%$ b<77$%7EF*EF8$' &.%EF5*7EF8J ^$%-7-9$.'& VO<98O%-&.L8$ $089: #*$&$% <.6/$#*%K$98: b-F*$% &*$ HK$%/<'/7K$%$*EF$ A#*7EF$' &$' 0$%7EF*$&$'78<%L$' Y.%EF5*7EF.'/70-%/B'/$' 9*$/$'J *78 A. .'8$%7.EF$' .'& $'87O%$EF$'&$]-&99 A. $%78$99$': Y*$ &.%EF a.78%)5.'/ $%A#.'/$'$' Y.%EF5*7EF.'/70-%/B'/$ 7*'& 5*8 $089: L-'0$L8*0$' V8%)5.'/$' A. NK$%9</$%': Y*$ &*%$L8$ (-'&$'7<8*-' 0-' Y<5O6 *5 b<77$%O--9 6NF%8 <.,$%&$5 A. (-'&$'7<8*-'70.97<8*-'$'J&*$ *F%$%7$*87 $*'$ PNF%#*%L.'/ F$%0-%%.6$':

7.2.4.3 SWR-spezifische Jodmodellierung

W' &*$ f-&5-&$99*$%.'/ 7*'& K$78*55 8$ P$<L8*-'$'J &*$ F<.O87BEF9*EF *' V*$&$#<77$%%$<L8-%$' #$/$' &$% &-%8 0$%#$'&8']<8$%*<9*$' <.68%8'J $*'A.K%*'/$': c*$%A. ABF9$' &*$ K$* \'8AN'&.'/ -&$% I$%&<5O6.'/ &$% /%-,$' (<K$95$'/$' $'878$F$'&$' ZF9-%/<7$.'& *F%$ EF$5*7EF$' P$<L8-%$' 5*8 f-&: ^.EF &$% EF$5*7EF$ *'69.77 &$7 ^K7-%K$%5<8$%*<97 T¡Z <.6 &*$ f-&EF$5*$ *78 A. .'8$%7.EF$' .'& //6: A. 5-&$99*$%$':

7.2.5 Grenzen der „lumped parameter“ - Modellierung und reale Möglichkeiten nuklear-spezifischer sowie industrieller CFD-Codes

7.2.5.1 Anwendung und Perspektiven von lumped parameter- und CFD-Codes

‘ 56<77$'&$ ^'<9_7$' 0-' V8)%6<99<K9B.6$' 6N% ($%'L%<68#$%L$ $%6-%&$%' ? #*$ K$%$*87 5$F%6<EF K$8-'8 2 &$' *'7<8A 0-' P$EF$'O%-/%<55$'J &*$ $'87O%$EF$'& &$5 h$#$*9*/$' <L8.$99$' V8<'& 0-' b*77$'7EF<68 .'& G$EF'*L $*'$ 5)/9*EF78 %$<9*8B87'<F$ V*5.9<8*-' &$% ^K9B.6$.'& &$% 7*EF $*'78$99$'&$' a.78B'&$ $%9<.K$':

]*8 T9*EL <.6 &*$ L.%A2 .'& 5*88$96%*78*/$' R-%7EF.'/77EF#$%O.'L8$ #*%& 'K' &$% OFB'-5$'2 -&$% %*7*L--%*$'8*$%8$' OF_7*L<9*7EF$' U%-K9$5K$7EF%$*K.'/ .'& 25-&$99*$%.'/ A.'$F5$'& <.EF &*$ %EF'8$EF'*7EF$ V$*8$J .'& 7O$A*$99 &*$ R%</$ &$% D.8A.'/ 0-' 9.5O$& O<%<5$8$% SMUX2 -&$% ZRY2Z-&$7 A.5 \%%$*EF$' $*'$% -O8*5<9$' V*5.9<8*-' &$% I-%/B'/$ *5 V*EF$%F$*87K$FB98$%J A:G: L-'8%-0$%7 &*7L.8*$%8: W' &$' #$7$'89*EF$' U.'L8$'J &*$ *5 R-9/$'&$' &<%/$78$998 7*'&J K78F8 #$*8/$F$'&$% (-'7$'7 K$* &$' &$.87EF$' \eO$%8$':

+%.'&7B8A9*EF 7*'& A.'BEF78 5*8 T9*EL <.6 &*$ h$#$*9*/$ ^'#$'&.'/ &*$ 5-&$995B,*/$' ^'7B8A$ 0-' MU2 .'& ZRY2Z-&$7 $'87O%$EF$'& &$% ^.6/<K$'78$99.'/ .'& &$% a*$90-%78$99.'/ A.K$#$%8$' .'& *F%$ */'.'/ A.EF<%<L8$%*7*%$':

T$* &$' MU2Z-&$7 #*%& &*$ W5O.97/9$*EF.'/ '*EF8 K$%NEL7*EF8*/8J 7-&<77 *'7EF%B'L.'/$' K$* &$% V*5.9<8*-' *5O.97&-5*'*$%8$% V8%)5.'/$' .5 L-5O9$e$ /$-5$8%*7EF$ T$%<'&.'/$' 7-#*$ 9-L<9$% +$7EF#*'&*/L$*876$9&$% K$78F':

Y*$ ^'#$'&.'/ 0-' ZRY2Z-&$7 *78 K*79<'/ <.6/%.'& *F%$7 F-F$' PEF'<.6#<'&$7 <.6 <.7/$#BF98$ R%</$78$99.'/$' K$7EF%B'L8J #BF%$'& &*$ MU2Z-&$7 0-9978B'&*/$ V8)%6<99<K9B.6$*' <LA$O8<K9$% a$*8&<.$% 7*5.9*$%$' L)''$':

[K#-F9 <.EF A.LN'68*/ MU2]-&99 &*$ T<7*7 6N% &*$ V*5.9<8*-' 7EF#$%$% V8)%6B99$ *5 V*EF$%F$*87$*'7EF9.77 &<%78$99$' #$%&$'J 9<77$' &*$ /%.'&7B8A9*EF$' *'7EF%B'L.'/$' &$7 MU2^'7<8A$7 &*$ I$%#$'&.'/ 0-' ZRY2]-&99' 6N% #*EF8*/$ G$*9/$K*8 '-8#$'&*/ $%7EF$*'$'J #*$ A:T:6N%

- &*$ &$8<*99*$%8$]-&$99*$%.'/ 0-' (-'0$L8*-' .'& VEF*EF8.'/ *5 V.5O6J 5*8 6%$*$% [K$%69BEF$ A#*7EF$' V.5O6 .'& ^85-7OFB%$J

- c32I$%K%$''.'/70-%/B'/$J 8.%K.9$'8$ c32Y$69</%<8*-'J

- &*$ \%5*889.'/ &$% c<.O878%)5.'/7O6<&$ *' L-5O9e' +$-5$8%*$' .'&k-&$% K$* '-EF 8%<'7*$'8$' T$&*'/.'/$'J A:T: V8%)5.'/ *5 K9-#&-#'2P<.5 .'& 7$*'$% 'BF$%$' ‘5/$K.'/J

- $*'$']R%$*78%<F9; 5*8 b<'&L-'8<L8 7-#*$

- //6:&*$ +<70$%8$*9.'/ S9-L<9$]*7EF.'/70-%/B'/$X:

Y.%EF &*$ *'K*'&.'/ 0-' R$9&5-&$99$' SZRY2]-&$99$XJ K$* &$'$' &*7 *'7EF%B'L.'/$' '*EF8 K$78F'JL)''$' &$%$' I-%8$*9$ #*$ &*$ Y<%78$99.'/ L-5O9$e$% %B.59*EF$% b$EF7$9#*%L.'/$' 6N% G$*9K$%$*EF$ &$7 V*EF$%F$*87K$FB98$%7 6N% MU2Z-&$7 /$'.8A8 #$%&$': Y<K$* *78 6N% 7-9EF$ c_K%*&9)7.'/$' <.6 $*'$ 7<EF/$%$EF8$ (-OO9.'/ &$7 2 9-L<9 .'& A$*89*EF K$/%$'A8$' 2 ZRY2]-&$997 5*8 &$5 /9-K<9$' MU2]-&$99 6N% &$' /$7<58$' V*EF$%F$*87K$FB98$% A. <EF8$'J 7-&<77 &*$ \'8#*EL9.'/ /$$*/'8% (-OO9.'/7*'8$%6<E$7 '-8#$'&*/ #*%&:

Y$% MU2^'7<8A #*%& <.EF 5*88$92 K*7 9<'/6%*78*/ &*$ +%.'&9</$ h$&$% *'8$/%<9$' (-'7p'A<'<9_7$ 7$*'J &< &<7 #$7$'89*EF$ a*$9J &*$ T$78*55.'/ &$7 o$9 98$%57J 5*8 $*'$% +$'<.*/L$*8 $%%$*EF8 #*%&J &*$ &$' ^'6-%&$%.'/$' *:&:P: /$'N/8: MU2^'7B8A$ #$%&$' .:<: $%6-9/%$*EF <'/$#$'&$8J #$'' I<%*<8*-'7%$EF'.'/$' 6N% 0$%7EF*$&$'$ VA$'<%*$' .'& V$'7*8*0*8B8778.&*$' NK$% #$*8$ U<%<5$8$%K$%$*EF$ &.%EF/$6NF%8 #$%&$':

Y<%NK$% F*'<.7 L<'' $7 *' &$% *'8$/%<9$' (-'7p'A<'<9_7$ U%-/'-7$OF<7$' .'& \'87EF$*&.'/7O.'L8$ /K'J &*$ #7'89*EF &$8<*99*$%8$%$ ^'<9_7$' $%6-%&$%'J <97 7*$ 5*8 MU2]-&99' 5)/9*EF 7*'&: Y*$7 /*98 *'7K$7-'&$%$ K$AN/9*EF &$7 A$*89*EF$' .'&)%89*EF$' I$%7</$'70$%F<98$'7 KA#: &$7 I$%7</$'75-&.7 0-' T<%%*$%$' -&$% *' c*'K9*EL <.6 &*$ T$9<78.'/ .'& &<7 5)/9*EF$ ^'7O%$EF0$%F<98$' 0-' V*EF$%F$*872 $*'%*EF8.'/$' #*$ P$L-5K*'<8-%$'J VO%<_7_78$5$ -&$% (NF9$*'%*EF8.'/$': G$*9#$*7$ 7*'& Y$8<*95-&$99$ K$%$*87 *' MU2V_78$5$ $*'/$K<.8: W' <'&$%$' RB99$' #*%& $7 '-8#$'&*/ #$%&$'J 0$%78B%L8 &*$ /5*'7<5$ D.8A.'/ 2 -K /$L-OO$98 -&$% h$#$*97 7$O<%<8 2 0-' MU2 .'& ZRY2Z-&$7 <'A.78%$K$':

Y$% HK$%/<'/ A. 5$F%&*5$'7*-'<9$'J %$EF$'A$*8*'8$'7*0$' ZRY2Z-&$7 #*%& &.%EF $*'$ M$*78.'/778$*/$%.'/ &$% PEF'O9<886-%5$' <88%<L8*0$%: W5 ^99/5*'$' #*%& &$%A$*8 $*' F)F$%$7 U-8$'A*<9 7O$A*$99 <.6 &*$ R%</$78$99.'/ <K/$78*55 8$% ZRY2Z-&$7 /$/$'NK$% <99/5*'$%$' L-55$%A*$99$' ZRY2Z-&$7 /7F$'J &*$ FB.6*/ '-EF $*'$' \'8#*EL9.'/7K$&<%6 /$%<&$ K$AN/9*EF %$<L8-%8_O*7EF$%k%$<L8-%7O$A*6*7EF$%]-&99 .'& (-%%$9<8*-'$' <.6#$*7$':

T$* &$% Y*7L.77*-' &$% %$EF$'8$EF'*7EF$' V$*8$ *78 7EF9*$,9*EF A. K$&$'L$'J &<77

- &*$ (-5O9$e*8B8 &$% OF_7*L<9*7EF$' U%-K9$5$ 7$9K78 A:G: *&$<9*7*$%8$ T$2 7EF%$*K.'/$' $%6-%&$%8 .'& DBF$%.'/7<''<F5$' 5*8 R-L.77*$%.'/ <.6 &*$ $'87EF$*&$'&$' OF_7*L<9*7EF$' U%-A$77$ 2 <.EF 5*8 7O$A*6*7EF$5 eO%*5$'8$99$' T$*8%</ 2 F$%<.7/$<%K$*8$8 #$%&$' 5N77$'J

- K$* MU2 .'& ZRY2Z-&$7 &.%EF<.7 *: ^99/: O%*'A*O*$99 BF'9*EF$ I$%$*'6<EF.'/$' K$* &$% ^KK*9&.'/ &$% I$%7.EF7/$-5$8%*$ 0-%/$'-55$' #$%&$'J

- &<7 OF_7*L<9*7EF$ I$%78$F$' *' &$% Z-&$2\'8#*EL9.'/ $'87EF$*&$'& *78: *' <&Bp<8$7 I$%78B'&'*7 .'& $*'$ <&Bp<8$ T$7EF%$*K.'/ &$% 7EF#$%$ V8)%6B99$ K$78*55$'&$' UFB'-5$'$ L<'' '.% &.%EF &*$ T$8-'.'/ OF_7*L<9*7EF$% V*EF8#$*7$'J -%*$'8*$%8 <5 U%-K9$5 .'& <5 a*$9J $%%$*EF8 #$%&$': D.% $*'$ <.7%$*EF$'&$ OF_7*L<9*7EF$ T<7*7 6N% &*$ T$7EF%$*K.'/ &$% 7*EF$%F$*878$EF'*7EF #*EF8*/$' U%-A$77$ /<%<'8*$%8 $*'$ O%-K9$5-%*$'8*$%8$ ^.77</$6BF*/L$*8:

R-9/9*EF *78 &*$ %EF'8$EF'*7EF$ V$*8$ A#<% 0-' $%F$K9*EF$% T$&$.8.'/ KA/9: &$% O%<L8*7EF$'])/9*EFL$*8$' &$%]-&$99*$%.'/J <K$% &$''-EF '.% $*' c*%75*88$9J $*' b$%LA$./:

Y< &.%EF &*$ b$*8$%$'8#*EL9.'/ &$% PEF'O%-/%<55$ 6N% V8)%2 .'& ''6<99<'<9_7$' A.'$F5$'& L-'7$%0<8*0$ ^''<F5$' .'&]-&$99$ &.%EF %$<9*8B87'<F$ V*5.9<8*-'$' $%7$8A8 #$%&$'J /$#*''8 &*$ .56<77$'&$ I<9*&*$%.'/ .'& W'8$%O%$8<8*-' &$% U%-/%<557_78$5$ #$*8$% <' T$&$.8.'/: V$'7*8*0*8B87<'<9_7$' 7*'& F*$% $*' /$$*/''$8$7 b$%LA$./J .5 VEF#<EF78$99$' 0-' //6: <.EF /$L-OO$98$' P$EF$'5-&$99$' A. K$78*55$' .'&7-5*8 &*$]-&$992 .'& U%-/%<55$'8#*EL9.'/ A. .'8$%78N8A$':

Y*$ ^'#$'&.'/$' .'& <.EF &*$ U$%7O$L8*0$' 0-' MU2 .'& ZRY2U%-/%<55$' 7-998$' 7*EF A.5 D.8A$' 6N% &*$ P$<L8-%7*EF$%F$*8 7*''0-99 $%/B'A$' .'& '*EF8 <97 (-'L.%%$'AO%-&.L8$ 0$%78<'&$' #$%&$'J A.5<9 &$.87EF$ W'78*8.8*-'$' 5*8 *F%$' h$#$*9*/$' !U%-&.L8$'; Z[Z[VjV .'& +^VRM[b #$98#$*8 6NF%$'&7*'&:

7.2.5.2 Rückwirkungen aus ISP-47, Perspektiven für CFD

Y*$ $%78$' \%/$K'*77$ <.7 &$5 WVU2InSVEF%*88 3C Z-'8<*'5$'8 2GF$%5-F_&%<.9*L2 I$%7.EF <' &$% GF^W2^'9</$X A$*/$'J &<77 6N% ZRY2]-&$99$ '-EF #$*8/$F$'&$ \'8#*EL9.'/7<%K$*8$' $%6-%&$%9*EF 7*'&J .5 $*'$ &$.89*EF$ I$%K$77$%.'/ /$/$'NK$% &$' 9.5O$& O<%<5$8$%2]-&99' A. $%%$*EF$': [K#-F9 $*'*/$ ZRY2Z-&$7 /$/$'NK$% &$' 0-%<'/$/<'/$'$' P$EF'.'/$' A. &$' G[VðD 2 .'&]WVGP^2I$%7.EF$' SVEF%*88 1X K$* &$% T$%$EF'.'/ 0-' VEF*EF8.'/70-%/B'/$'J 9-L<9$' (-'A$'8%<8*-'$' .'& (-'&$'7<80$%8$*9.'/$' 8$*9#$*7$ &$.89*EF$ I$%K$77$%.'/$' <.6A$*/$'J 78F' &*7' I$%K$77$%.'/$' O<%8*99 R$F9O%-/'-7$' -&$% '*EF8 0-%F<'&$'$ G$*95-&$99$

/$/$'NK$%: b$/$' &$7 F-F$' '.5$%*7EF$' ^.6#<'&7 &$% ZRY2]-&99 #$%&$' -6885<97 (-5O%-5*77$ K$* &$% D-&<9*7*$%.'/0-%/$'-55$'J&*$ '$/<8*0$ ^.7#*%L.'/$' <.6 &*$ +$'<.*/L$*8 &$% U%-/'-7$ 0-' 9-L<9$' a.78<'&7/%),$' F<K$': Y*$ 0$%#$'&8']-&$99L-%%$9<8*-'$' 6N% 8.%K.9$'8$ Y*66.7*-'J bB%5NK%/<'/ -&$% b<'&%$*K.'/ A$*/$' K$* &$' ZRY2]-&99' BF'9*EF$ Y*7L%$O<'A$' #*$ K$* &$' 9.5O$& O<%<5$8$%2]-&$99$': b$*8$% '-8#$'&*/ A.% \%F)F.'/ &$% U%-/'-7$/$'<.*/L$*8 0-' 8F$%5-F_&%<.9*7EF$' U%-A77' *5 V*EF$%F$*87K$FB98$% 7*'& &<F$% 6-9/$'&$]<,'<F5$'C

- HK$%<%K$*8.'/ .'& I<9*&*$%.'/ 0-']-&$99L-%%$9<8*-'$' 6N% 8.%K.9$'8$ b$EF7$92 #*%L.'/$' SbB%5$NK$%/<'/J b<'&%$*K.'/J +<7&*66.7*-'XJ

- I$%K$77$%.'/ &$% V*5.9<8*-' 0-' L-'&$'7*$%8$5 b<77$%J

- \'8#*EL9.'/ 0-' (%*8$%*$' A.% T$.%8$*9.'/ 0-' +*88$%'$8A#$*8$':

Y*$]-&990%K77%.'/$' 7*'& 0-' /%.'&7B8A9*EF$% T$&$.8.'/J #$*9 &*$ V*5.9<8*-' &$% 8F$%5-F_&%<.9*7EF$' I-%/B'/$ &*$ T<7*7 6N% A<F9%$*EF$ <'&$%$ T$%$EF'.'/$' A.5 I$%F<98$' 0-' VO<98O%-&.L8$' 7-#*$ A.5 P*7*L-O-8$'A*<9 K*9&$8: Y<7 WVU2In 0$%&$.89*EF8 &<%NK$% F*'<.7 &*$ VEF#*$%*/L$*8$'J /$$*/'8]$77&<8$' 6N% &*7]-&99'8#*EL9.'/$' A. $%F<98$': U<%<99$9 A.% b$*8$%$'8#*EL9.'/ &$% ZRY2]-&$99$ 5.77 &<F$% <' &$% b$*8$%$'8#*EL9.'/ &$% \eO$%*5$'8*$%8$EF'*L /$<%K$*8$8 #$%&$'J .5 A:T: &$' T$#$/.'/7A.78<'& &$% ^85-7OFB%$ <97 P<'&K$&*'/.'/ 6N% &$' b<'&#B%5NK%/<'/ A. $%6<77$': \'87O%EF'&$ ^L8*0*8B8$' 7*'&*5 9<.6$'&$' GF^W2 ‘'8$%7.EF.'/7O%-/%<55 0-%/7F$':

7.2.5.3 Analyse der Versuche HDR-E11.2 und ThAI-TH10: Einfluss von Wandkondensation auf Schichtung

T$*5 GF^W2I$%7.EF Gc1> 7*'& /%.'&7B8A9*EF$ *'A$9O%-A$77$ S*'7K$7-'&$%$ &$% *'69.77 0-' b<'&L-'&$'7<8*-' <.6 &*$ VEF*EF8.'/X &$7 cYP2I$%7.EF7 \11:3J &$% K*7F$% '<8*-'<9 #*$ *'8$%'<8*-'<9 #$'*/ K$6%*$&*/$'& '<EF/$%EF'8 #$%&$' L-''8$J*5 A#<% L9$*'$%$']<,78<KJ &<6N% <K$% 5*8 $*'&$.8*/$' P<'&K$&*'/.'/$' eO%*5$'8$99 .'8$%7.EF8 #-%&$': Y*$!K9*'&$'; I-%<.7%$EF'.'/$' A.5 GF^W2I$%7.EF Gc1> 5*8 Z[Z[VjV #<%$' .'K$6%*$&*/$'&: bBF%$'& &*$ G$5O$%<8.%7EF*EF8.'/$' '-EF A.6%*$&$' 78$99$'& 7*5.9*$%8 #-%&$' 7*'&J *78 &*$ K$%$EF'8 Y.%EF5*7EF.'/ &$7 c$9*.57 &$.89*EF NK$%7EFB8A8 #-%&$': W'7K$7-'&$%$ &*$ ^.6L-'A$'8%<8*-' &$7 c$9*.57

#BF%$'& &$% (NF9OF<7$ &.%EF &*$ -K$%$' (NF95B'8$9 &$% I$%7.EF7<'9</$ 7*'& '*EF8 %*EF8*/ 7*5.9*$%8 #-%&$': W5 I$%9<.6 &$% D<EF%$EF'.'/$' F<8 7*EF /A*/8J &<77 &*$ T$%NEL7*EF8*/.'/ &$% Y*66.7*-' *' &$' I$%K*'&.'/$' .'<KFB'/*/ 0-' &$' 8<87BEF9*EF 0-%F<'&$'$' Y%.EL&*66$%$'A$' .'& V8%)5.'/$' &*$ #7'89*EF$ '%7<EF$ 6N% &*$ 7EF9$EF8$' \%/$K'*77$ #<%: D<EF ^.77EF<98$' &*$7$7 G$%57 7*'& &*$ \%/$K'*77$ $%F$K9*EF K77% /$#-%&$':

a.LN'68*/ 5.77 &$% Y*66.7*-'7<'7<8A *' &$' I$%K*'&.'/7/9$*EF.'/$' &.%EF (-OO9.'/ 5*8 &$' h$#$*97 <L8.99' V8%)5.'/7K$&*'/.'/$' $%#$*8$%8 #$%&$': Y*$ 5*8 +^VRM[b K'6<997 &.%EF/$6NF%8$!K9*'&$; I-%<.7%$EF'.'/ F<8*5 +$/$'7<8A A. Z[Z[VjV &$' I$%7.EF p<9*8<8*0 K$7EF%$*K$' L)''$': o<'8*8<8*0 A.6%*$&$' 78$99$'&$ \%/$K'*77$ L-''8$' 5*8 $*'$% D<EF%$EF'.'/ 5*8 $*'$5 '.5$%*7EF$' M)7.'/70$%6<F%$' F)F$%$% [%&'.'/ $%A*$98 #$%&$'J #-A. <99$%&*'/7 $*'$ PEF'A$*8 0-' E<: @]-'<8$' K$')8*/8 #-%&$' *78:

7.3 Zusammenfassung zum Forschungsbereich „Stör-/Unfallanalyse Sicherheitsbehälter“

Y*$ <.7 F$.8*/$% V*EF8 6N% '-8#$'&*/ $%<EF8$8$' ^%K$*8$' A.5 GF$5$'7EF#$%O.'L8 !V*EF$%F$*87$*'7EF9.77; 7*'& &$' K$%$*87 A. T$/*'' $%#BF'8$' VEF#$%O.'L8$'

1: \%F)F.'/ &$% ^.77</$7*EF$%F$*8 0-' o998%5<'<9_7$'

3: I$%K$77$%.'/ &$7 I$%78B'&'*77$7 7-#*$ \%F)F.'/ &$% a.0$%9B77*/L$*8 &$% V*5.9<8*-' &$7 !$e 0$77$9;2VEF5$9A$0$%F<98$'7

@: I$%O-9978B'&*/.'/ &$% V8)%6<997*5.9<8*-'

I: Vb P27O$A*6*7EF$]-&*6*L<8*-' KA#: \%/B'A.'/ &$%]-&$99*$%.'/

=: ^.79-8$' &$% +%$'A$' &$% !9.5O$& O<%<5$8$%;2]-&$99*$%.'/ .'& &$% %$<9$'])/9*EFL$*8$' '.L9$<%27O$A*6*7EF$% 7-#*$*'&.78%*$99$% ZRY2Z-&$7

A./$-%&'$8: b*$ *' &$' 0-%<'/$/<'/$'$' ^.76NF%.'/$' &$.89*EF #*%&J #$%&$' #*EF8*/$ 2 <K$% <.EF 8$.%$ 2 \eO$%*5$'8$ 5$F% .'& 5$F% *5 *'8$%'<8*-'<9$' P<F5$' &.%EF/$6NF%8: Y< &$% '<8*-'<9$ &$.87EF$ *'69.77 <.6 7-9EF$ *'8$%'<8*-'<9$' U%-h$L8$ '<8.%/$5B, K$/%$'A8 *78J L)''$' 8$5O-%B%$ ^K#$*EF.'/$' <.EF K$* &$% <'<9_8*7EF$' T$<%K$*8.'/ &$% -:/: VEF#$%O.'L8$ <.68%8': ^'&$%$%7$*87 8%B/8 /$%<&$ &*$

*'8$%'<8*-'<9$ R<EF&*7L.77*-' 5<,/$K9*EF &<A. K$*J &*$ &$.87EF$ RNF%.'/7O-7*8*-' K$* &*$7$5 GF$5$'7EF#$%O.'L8 A. K$F<.O8$' .'& //6:<.7A.K<.$':

7.4 Literatur zum Forschungsbereich Stör-/Unfallanalyse Sicherheitsbehälter

k^aT dk ^AK$9J Y: V:Q M$$J V: M:Q M$$J G: V:
^E-.78*E P$7-'<'E$ GF$-%_6-%8F$ P.O8.%$ -6R*95 Z<O-6<+<7T.KK9$ <8
c-%*A-'8<9 +<72M*p*&W'8$%6<E$:
G#-2UF<7$]-5$'8.5J c$<8<'&]<77 G%<'76$%*' ZF$5*E<9J U%-E$77<'&
\'$%/_ \'/*'$$%*'/ V_78$57J I-9:1J 1dd

kT^M >1k f:T<99 $8<9:
W'8$%'<8*-'<9 V8<'&<%& U%-K9$5 SWVUX D-:l1 R-99-# 'O \e$%E*7$C
Z-'8<*'5$'8W-&*'$ Z-5O.8$% Z-&$ \e$%E*7$C U<%<5$8%*E V8.&*$7
^\ZM21313l SD-0:3>>1X

kT'\>lk]:TN%/$%C
G<7L32Z-5O<%*7-' -60<%*-.7 <OO%-<EF$7 6-%E<9E.9<8*'/ h$8 K%$<L2.O<'&
O%$5*e*'/J ^%K$*87O<O*$%J V\P\D^

kZc\ddk ZF$0<9*$%J U:j:J
„TDBIV - TDBCR - Thermodynamic Databases for Nuclear Chemistry - Documentation“
\' l8F R%<5$#-%L U%-/%<5 5$ WDl2ZWGSddX2U>@dJ V$O8$5K$% 1ddd

kRWV dik R*7EF$%J (:
]-&$99*$%.'/0-' ^K7EF$*&$0-%/B'/$'*' b<77$%0-%9</$':
^K7EF9.77K$%*EF8A.5 R-%7EF.'/70-%F<K$' T]TR 1=> 1>im^J
TR2P:mnl11 21J T<88$99$ W'/$'*$.%8$EF'*L +5KcJ Y$A$5K$% 1ddi

kRWV >3k (:R*7EF$% $8<9:J
VE<9*'/-6Z-'8<*'5$'8 \eO$%*5$'87:R*'<9 U%-h$E8 P$O-%8 V^]2VZ^Z\x2
U>>3J =8F R%<5$#-%L U%-/%<5 5$J YE5K$% 3>>3

kR'D >lk R:R.'L$ $8<9:
GF^W2l$%7.EF7<'9</$.'& U%-/%<5 5 A.% ''8$%7.EF.'/ -66$'$% R%</$'
A.5 VO<98O%-&.L8O$%F<98$' *5 V*EF$%F$*87K$FB98$%J ^K7EF9.77K$%*EF8 G$*9 3C
f-&2l$%7.EF$
R%<5<8-5$ ^DUJ \%9<'/$'J1=> 131i2V3 S^O%*9 3>>lX

k+PV d>k +$7$997EF<68 6N% P$<L8-%7*EF$%F$*8:

Y$.87EF$ P*7*L-78.&*$ ($%'L%<68#$%L$J UF<7$ T:

W5 ^.68%: &: T.'&$75*'*78$%*.57 6N% R-%7EF.'/ .'& G$EF'-9-/*$: ()9'J

I$%9/: GH I PF$*'9<'&J 1dd>

k([Z >>k (-EFJ]: (:Q I-,'<EL$J ^:Q V8<%69*'/$%J fQ VEFN8AJ b:Q ''/$%J c:C

P<&*-'.E9*&$ P$2\'8%<*'5$'8 <8 T.KK9*'/ b<8$% U--9 V.%6<E$7:

f-.%'<9 -6 ^$%-7-9 VE*$'E$J I-9: @1J D-: dJ OO: 1>1=21>3 iJ 3>>>

kDW\ >3k D*$J]:J R*7EF$%J]:J M-F'$%8J +:J

*„Advanced MCCI modelling based on stringent coupling of thermal hydraulics and real solution thermochemistry in COSACO“*J

U%-E$$&*'/7 1>8F *'8$%'<8*-'<9 E-'6$%$'E$ -'' .E9$<% $'/*'$$%*'/J WZ [D\

1>J ^%9*'/8-'J I^J ^O%*9J 3>>3

k[\ZY >>k W'7*/F87 *'8- 8F$ Z-'8%-9 -6 8F$ P9<7$ -6 W-&*'$J Z$7*.5J V8%-'8*.5 <'&

[8F$% R*77*-' U%-&.E87 *' 8F$ Z-'8<*'5$'8 K_ V$0$%$ ^EE*&$'8

]<'</5'8

[\ZY D.E9$<% \'$%/_ ^/$'E_

D\^kZVDWkP S3>>>X d S]<%EF 3>>>X

kVZc >@k VEF'$*&$%J P:Q]<_*'/$%J R:

P$7.7O$'7*-' 0-' ^$%-7-9$' &.%EF 8%<'7*$'8$ V8%)5.'/$' *5

Z-'8<*'5$'8: ^K7EF9.77K$%*EF8A.5 R-%7EF.'/70-%F<K$' T] TR 1=> 11>3J

M$F%78.F9 6N% GF$%5-&_'<5*LJ G$EF'*7EF$ ''*0$%7*8B8]N'EF$'J

]B%A 3>>@

kVZc >@k VEF-98_77$LJ b:$8: <9:

W'8$/%<9 M<%/$ VE<9$ \eO$%*5$'87 -' c_&%-/$' Z-5K.78*-' 6-% V$0$%$

^EE*&$'8 Z-&$ I<9*&<8*-'

cjZ[ ]qRW(V 2ZG1ddd2>>>>IJ RWV^ 3>>@J M.e$5K.%/J

1>21@ D-0$5K$% 3>>@

kI [V dmk I-,'<EL$J ^:Q (-EFJ]: (:Q ''/$%J c:

\'8#*EL9.'/ $*'$7 P$7.7O$'7*-'7O%-/%<5 5-&.97 A.%

P<&*-'.L9*&%NELF<98.'/ *' b<77$%0-%9</$'

^K7EF9.77K$%*EF8A.5 R-%7EF.'/70-%F<K$' T] TR 1=>>di>J P'T \21mJ

P.F%2''*0$%7*8B8 T-EF.5J Y$A$5K$% 1ddm

8 Querschnittsgebiete

8.1 Unsicherheits- und Sensitivitätsanalyse

8.1.1 Allgemeines zur Unsicherheits- und Sensitivitätsanalyse

RN% 7*EF$%F$*878$EF'*7EF$ R%</$78$99./$' .'& P*7*L-.'8$%7.EF./$' #$%&$' FB.6*/ \%/$K'*77$ 0-' ^'#$'&./$' L-5O9e% PEF'5-&99 K$')8*/8: Y*$ \%/$K'*77$ 7-9EF$%]-&$99$ 7*'& 5*8 ''7*EF$%F$*8$' 0$%K.'&$'J &*$ <.6 $O*78$5*7EF$ *'/<'/7.'7*EF$%F$*8$' A.%NELA.6NF%$' 7*'&J &: F: <.6 ''7*EF$%F$*8$' *5 ($''8'*72 78<'& 0-% <99$5 A. *'/<K$O<%<5$8$%'J A. U<%<5$8$%' 0-']-&$996-%5.9*$%./$' .'& A. U<%<5$8$%' &$% '.5$%*7EF$' M)7./7<9/-%*8F5$':

a*$9 0-' ''7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$' A. ^'#$'&./$' L-5O9$e$% P$EF$'5-&$99$ *78 &*$ T$<'8#-%8./6-9/$'&$% R%</$'C

S1X b*$ /%-, *78 &$% /$5$*'7<5$ *'69.77 <99$% $O*78$5*7EF$' *'/<'/7.'7*EF$%F$*8$' <.6 &*$ \%/$K'*77$ &$7 P$EF$'5-&$997r Sú'7*EF$%F$*87<'<9_7$X

S3X b$9EF$ *'/<'/7.'7*EF$%F$*8$' 8%</$' <5 5$*78$' A.% \%/$K'*72 .'7*EF$%F$*8 K$*rSW/$'7*8*0*8B87<'<9_7$X

''7*EF$%F$*87<'<9_7$' SR%</$ 1X 7*'& 0-' T$&$.8./ .:<: K$*5 I$%/9$*EF 0-'

- PEF'5-&99%/$K'*77$' 5*8 +$'$F5*/.'/7<'6-%&$%./$' KA#: 7*EF$%F$*872 %$9$0<'8$' +%$'A#$%8$'J
- PEF'5-&99%/$K'*77$' 5*8]$77#$%8$' K$* \eO$%*5$'80-%<.72 -&$% D<EF2 %$EF'./J
- K$*5 I$%/9$*EF 0-' \%/$K'*77$' 0$%7EF*$&$'$% P$EF$'5-&$99$ A. &$57$9K$' U%-K9$5:

V$'7*8*0*8B87<'<9_7$' SR%</$ 3X 9*6%' .:<: ^'F<9870.'L8$ &<6N%J <' #$9EF$' V8$99$' &.%EF /$'<.$%$]-&$99*$%./ $*'$ \%F)F./ &$% ^.77</$7*EF$%F$*8 SuP$&.A*$%./ &$% +$7<58.'7*EF$%F$*8X &$% P$EF'./ $%A*$98 #$%&$' L)''8$J &: F: #- &$% ($''8'*778<'& &.%EF #$*8$%$ 8F$-%$8*7EF$ ''8$%7.EF./$'J \eO$%*5$'8$J \eO$%8$'2

K$6%</.'/$'J Y<8$'7<5 59.'/$' $8E: 0$%K77%8 #$%&$' 7-998$J .5 &*$ ''7*EF$%F$*8 &$% \%/$K'*77$ &$7 P$EF$'5-&$997*' 5)/9*EF78 $66*A*$'8$% b$*7$ A.%$&.A*$%$':

Y<5*8 9<77$' 7*EF <'<9_8*7EF$.'& eO%*5$'8$99$ R-%7EF.'/7<L8*O*8B8$' F*'7*EF89*EF $*'$% #*%L.'/70-99$' I$%K77%.'/ &$% ^.77</$7*EF$%F$*8 &$% \%/$K'*77$ 0-' PEF'O%-/%<55$' K$#$%8$': \7 L)''$' 7-#-F9 6.'&*$%8 VEF#$%O.'L8$ 6N% &*$ b$*8$%$'8#*EL9.'/ .'& I$%K77%.'/ &$7 P$EF$'5-&$997 /$7$8A8 #$%&$' <K$% <.EF c*'#$*7$ /$9*$6$%8 #$%&$'J<' #$9EF$' V8$99$' \'8#*EL9.'/7<%K$*8$' .'')8*/ 7*'&J #$*9 &.%EF /$'<.$%$]-&$99*$%.'/ L$*'$ #7'89*EF$ P$&.A*$%.'/ &$% +$7<58.'7*EF$%F$*8 &$% P$EF'.'/ 5$F% A.$%A*9'*78:

Y<%NK$% F*'<.7 8%</$' ''7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$' <.EF A.% o<9*8B877*EF$%.'/ &$% h$#$*9*/$' P$EF$'O%-/%<55$.'& *F%$% ^'#$ '&.'/$' K$*J *'&$5 7*$ F$%6$'J]-&$997EF#BEF$' .'& U%-/%<55*$%6$F9$% <.6A.&$EL$':

8.1.2 Die „GRS-Methode“ zur Unsicherheits- und Sensitivitätsanalyse

W' kc[Rd@kJ k(Padlk #*%& $*'$]$8F-&$ A.% ''7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$ K$7EF%*$K$'J &*$ *'8$%'<8*-'<9 .'8$% &$% T$A$*EF'.'/ !+PV2]$8F-&$; $*'/$6NF%8 *78: c<.O85$%L5<9$ &$% }+PV 2]$8F-&$}7*'&C

S1X Y*$ $O*78$5*7EF$' *'/<'/7.'7*EF$%F$*8$' #$%&$' !O%-K<K*9*78*7EF; .'8$% a./%.'&$9$/.'/ &$% 7.Kh$L8*0*78*7EF$' -&$% T<_$7/EF$' W'8$%O%$8<8*-' &$7 b<F%7EF$*'9*EFL$*87K$/%*667 p<'8 *6*A*$%8 Sb<F%7EF$*'9*EFL$*8 » !+%<& &$7 RN%#<F%2 F<98$'7;J!&$/%$$2-62K$9*$6;X:

S3X Y*$!R-%8O69<'A.'/; &$% *'/<'/7.'7*EF$%F$*8$' &.%EF &<7 PEF'5-&$99 K*7 A.% \%/$K'*7.'7*EF$%F$*8 $%6-9/8 5*8]$8F-&$' &$%]-'8$ Z<%9- V*5.9<8*-'J #-K$* &$% V8*EFO%-K$'.56<'/J &:F: &*$ ^'A<F9 &$% 6N% &*$ ^'<9_7$ &.%EFA.6NF%$'&$']-&$992 P$EF$'9B.6$ 5)/9*EF78 '*$&%*/ 7$*' 7-99:

S@X ^.77</$' A.% %$7.98*$%$'&$' \%/$K'*7.'7*EF$%F$*8 K<7*$%$' <.6 78<8*78*7EF$']$8F-&$' &$% ![%&$% V8<8*78*E7; S!/$-%&'8 V8*EFO%-K$';X .'& #$%&$' *' R-%5 0-' '*EF82O<%<5$8%*7EF$' 78<8*78*7EF$' G-9$%<'A/%$'A$' '<EF b*9L7 6-%5.9*$%8: Y*$!VEFB%6$; &$% ''7*EF$%F$*87<.77</$' #*%& &.%EF &*$ +%),$' b.'&g0-%/$/K'C

b Su !b<F%7EF$*'9*EFL$*87*'F<98;J !HK$%&$EL.'/7#<F%7EF$*'9*EFL$*8;J !O%-K<K*9*8_ E-'8$'8;J !E-0$%</$;X /*K8 <'J #$9EF$% ^'8$*9 &$% +$7<58.'7*EF$%F$*8 0-' &$' A. $%5*88$9'&$' G-9$%<'A/%$'A$' $%6<778 #$%&$' 7-99 SA: T: b u>:d=XJ .'&

g Su!I$%8%<.$'7/%<&;J !(-'6*&$'A D*0$<.;J !E-'6*&$'E$ 9$0$9;X /*K8 <'J 5*8 #$9EF$% V*EF$%F$*8 SI$%8%<.$'J (-'6*&$'AX &*$7 <.6/%.'& &$% T$7EF%B'L8F$*8 &$% V8*EFO%-K$ /98' 7-99 SA: T: g ud=¥v

SIX ^.77</$' A.% !V$'7*8*0*8B8; #$%&$' *5 V*''$ 0-' !.'E$%8<*'8_ *5O-%8<'E$; *'8$%O%$8*$%8: V*$ K<7*$%$' <.6 /$$*/''8' !V$'7*8*0*8B875<,$'; S!.'E$%8<*'8_*5O-%8<'E$ 5$<7.%$7;XJ *' &$%$' T$%$EF'./ 7-#-F9 &*$ *5 PEF'5-&$99 <K/$K*9&8' 6.'L8*-'<9$' a.7<55$'FB'/$ <97 <.EF &*$ K8*9*/8$' I$%8$*9./$' A.% o<'8*6*A*$%./ &$% ‘''7*EF$%F$*8$' $*'/$F$':

Y*$!+PV2]$8F-&$; A.% ‘''7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$ F<8 0-% <99$5 6-9/$'&$ I-%8$*9$C

2 V*$ *78 <99/5*'/N98*/J $%6-%&$%8 L$*'$ #$*8$%$' I-%<.77$8A.'/$' .'& L<'' <.6 h$&$7 K$9*$K*/$ PEF'5-&$99 <'/$#<'&8 #$%&$':

2 V*$ K<7*$%8 '.% <.6 &$% I<%*<8*-' &$% *'/<'/7O<%<5$8$%: T$7-'&$%$ ^'O<72 7.'/$' &$% A. +%.'&$ 9*$/$'&$' Z-&$7 7*'& '*EF8 $%6-%&$%9*EF:

2 Y*$ ^'A<F9 &$% &.%EFA.6NF%$'&$' P$EF$'9B.6$ *78 .'<KFB'/*/ 0-' &$% ^'A<F9 &$% .'7*EF$%$' *'/<'/7O<%<5$8$%: V*$ FB'/8 '.% <K 0-' &$% /$6-%&$%8$' !VEFB%6$; &$% ‘''7*EF$%F$*87<.77</$'J <.7/$&%NEL8 &.%EF &*$ 0-%A./K'&$!HK$%&$EL.'/7#<F%7EF$*'9*EFL$*8; b SA: T: b u>:d=X .'& &$' !I$%8%<.$'7/%<&; g SA: T: g ud=¥v6N% &*$ A.$%5*88$9'&$' G-9$%<'A/%$'A$':

2 RN% /B'/*/$ b$%8$ 0-' b .'& g S>:d> b >:d=J d> v g d=¥v*78 &*$ ^'A<F9 D &$% &.%EFA.6NF%$'&$' P$EF$'9B.6$ %$9<8*0 /$%*'/: V- 7*'& A: T: 6N% &*$ T$%$EF'./ $*'7$*8*/$% Sb u>:d=J g ud=¥v 2G-9$%<'A/%$'A$' 5*'&78'7 D u =d PEF'9B.6$ $%6-%&$%9*EF:

2 Y*$ V$'7*8*0*8B87<'<9_7$ $%6-%&$%8 L$*'$ A.7B8A9*EF$' P$EF$'9B.6$: Y*$ T$%$EF'./ /$$*/''8% V$'7*8*0*8B875<,$ 6N% &*$ V$'7*8*0*8B87<.77</$' $%6-9/8 *' &$% P$/$9 5*8 &$'7$9K$' Y<8$' #*$ &*$ T$%$EF'./ &$% G-9$%<'A/%$'A$' 6N% &*$ ‘''7*EF$%F$*87<.77</$':

Y*$!+PV2]$8F-&$; *78 &<F$% K$7-'&$%7 /$$*/'$8 6N% ''7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$' 0-' ^'#$'&.'/$' L-5O9$e$% .'& 7$F% %EF'A$*8*'8$'7*0$% Z-5O.8$%5-&99J K$* &$'$' &*$ ^'A<F9 &$% A. &*$7$5 a#$EL &.%EFA.6NF%$'&$']-&$99%$EF'.'/$' 5)/9*EF78 '*$&%*/ K9$*K$' 5.77:

8.1.3 Erreichter Stand der „GRS-Methode“

Y*$!+PV2]$8F-&$; A.% ''7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$ #.%&$ K$* A<F9%$*EF$' ''8$%7.EF.'/$' 5*8 \%6-9/ <'/$#$'&$8J .:<:

- K$* &*0$%7$' ^'<9_7$' A.% GF$%5-F_&%<.9*L &$7 (NF9L%$*79<.67 S5*8 &$5 Z-&$ ^GcM\GXJ
- A.5 ^$%-7-90$%F<98$' *5 V*EF$%F$*87K$FB98$% S5*8 &$5 Z[Z[VjV2 I-%9B.6$%E-&$ RWUM[ZXJ
- A.% V8%.L8.%2 .'& T%.EF5$EF<'*L 0-' (-5O-'$'8$' &$7 U%*5B%L%$*7$7 S5*8 &$5 Z-&$ ^YWD^XJ
- A. g92 .'& (<K$9K%<'&2VA$'<%*$'J
- A.% ^K7EFB8A.'/ &$% %<&*-9-/*7EF$' (-'7p'A$' 0-' VO<98O%-&.L8 2 6%$*7$8A.'/$' *' &*$ ^85-7OFB%$ S5*8 &$5 P$EF$'5-&$99 U^P(XJ
- A.% ^.7K%$*8.'/ 0-' VO<98O%-&.L8$' NK$% &*$ D<F%.'/75*88$9L$88$J
- K$* &*0$%7$' ^'<9_7$' A.% M<'/A$*87*EF$%F$*8 0-' \'&9</$%' 6N% %<&*-<L8*0$ ^K6B99$ S5*8 &$5 P$EF$'5-&$99]^PDW\X:

Y*$!+PV2]$8F-&$; #.%&$ O%-/%<558$EF'*7EF *5 U%-/%<550<L$8 V'V^ SU%-/%<5 V_78$5 6-% ''E$%8<*'8_ <'& V$'7*8*0*8_ ^'<9_7*7X %$<9*7*$%8: V*$ F<8 7*EF *' &$' K*7F$%*/$' ^'#$'&.'/$' <97 $66*A*$'8$7 .'& B.,$%78 'N8A9*EF$7 b$%LA$./ A.% \%5*889.'/ &$% \%/$K'*7.'7*EF$%F$*8 .'& 27$'7*8*0*B8 $%#*$7$': Y<%NK$% F*'<.7 8%./$' &*$ &.%EF/$6NF%8$' ^'<9_7$' *55$% #*$&$% <.EF A.% o<9*8B 877*EF$%.'/ &$% h$#$*9*/$' P$EF$'O%-/%<55$.'& *F%$% ^'#$'&.'/$' K$*:

W'8$%'<8*-'<9 #$%&$' 6N% ''7*EF$%F$*87<'<9_7$' *5 P<F5$' 0-' V8)%2 .'& ''6<99<'<9_7$' *' ($%'L%<68#$%L$' 0$%7EF*$&$'$]$8F-&$' 0-%/$7EF9</$' .'& <'/$#$'&$8: Y*$!+PV2]$8F-&$; #*%& A.'$F5$'& <.EF *'8$%'<8*-'<9 $*'/$7$8A8J A: T: 0-' R%<5<8-5$2^DU *5 <5$%*L<'*7EF$' +$'$F5*/.'/70$%6<F%$' SkVG[>@kX .'& 0-' b$78*'/F-.7$ *5 P<F5$' *F%$% ^VGP']2]$8F-&$ S^.8-5<8$& V8<8*78*E<9 G%$<85$'8

-6 ‘ ’E$%8<*’8_]$8F-&X SkDWV >@kX: \7*78A. $%#<%8$’J &<77 &.%EF &<7*’ HK$%<%K$*8.’/ K$6*’&9*EF$ &$.87EF$ L$%’8$EF’*7EF$ P$/$9#$%L &$% G%$’& A. ‘ ’7*EF$%F$*87<’<9_7$’ *5 P<F5$’ &$% +$’$F5*/.’/ .’& ^.67*EF8 0-’ ($%’L%<68#$%L$’ &$.89*EF A.’$F5$’ #*%&:W’ &$’ ‘V^ *78 &*$ Y.%EF6NF%.’/ 0-’ ‘ ’7*EF$%F$*87<’<9_7$’ K$* I$%#$’&.’/ 0-’ %$<9*78*7EF$’ PEF’O%-/%<55$’ S!K$78 $78*5<8$;X K$%$*87 0-%/$7EF%*$K$’:

W5 U%-/%<55 ;T$78 \78*5<8$]$8F-&7 2 ‘ ’E$%8<*’8_ <’& V$’7*8*O*8_ \0<9.<8*-’ ST\]‘V\Xq&$7 ZVDW #*%& $*’ I$%/9$*EF 0-’ %$<9*78*7EF$’ P$EF$’5$8F-&$’ 5*8 ‘ ’7*EF$%F$*872 .’& V$’7*8*O*8B87<’<9_7$’ &.%EF/$6NF%8: I-’ &$’ A#)%8$*9’$F5$’&$’ [%/<’*7<8*-’$’ #-99$’ $96 &*$0-’ &$% +PV0-%/$7EF9</$’$]$8F-&$<’#$’&$’:

8.1.4 Weiterer methodischer Entwicklungsbedarf zur „GRS-Methode“

^.6/%.’& &$% \%6<F%.’/ <.7 &$’ K*7F$%*/$’ ^’#$’&.’/$’ 7-998$ &*$]$8F-&*L &$% ‘ ’7*EF$%F$*872 .’& V$’7*8*O*8B87<’<9_7$*’ 6-9/$’&$’ U.’L8$’ #$*8$% $’8#*EL$98 #$%&$’C

Entwicklung von „effektiveren“ Methoden zur approximativen Bestimmung von „Tolerance Limits“ für Unsicherheitsaussagen (Abbau der Konservativität)

Y*$ ‘ ’7*EF$%F$*87<.77</$’ &$% !+PV2]$8F-&$;*’ R-%5 78<8*78*7EF$% G-9$%<’E$ M*5*87 L)’’$’ K$* L9$*’$’ V8*EFO%-K$’.56B’/$’ SA:T: D u=dX 7$F% L-’7$%O<8*0 7$*’: W’ &*$7$5 R<99 SD u=dX /*98 ’B59*EF ’*EF8 ’.%J #*$ /$6-%&$%8J $*’$ >:d=kd= v ‘ ’7*EF$%F$*87<.77</$ 7-’&$%’ A./9$*EF A:T: $*’$ >:dkd1 v-&$% >:dhi@ v-&$% >:dikn v-&$% >:ddkl= v^.77</$:Y<5*8 9*$/$’ .’8$%F<9K &$7 $%%$EF’8’ M*5*87 ’*EF8 ’.%J #*$ /$6-%&$%8J d=v&$% \%/$K’*7.’7*EF$%F$*8 5*8 $*’$5 I$%8%<.$’7/%<& 0-’ d=ỳv 7-’&$%’ 7-/<% di v&$% \ %/$K’*7.’7*EF$%F$*8 5*8 *55$%F*’ ’-EF n v I$%8%<.$’7/%<& -&$% dn v&$% \%/$K’*7.’7*EF$%F$*8 5*8 i@ vI$%8%<.$’7/%<&J $8E: S7*$F$ T*9& i21X:

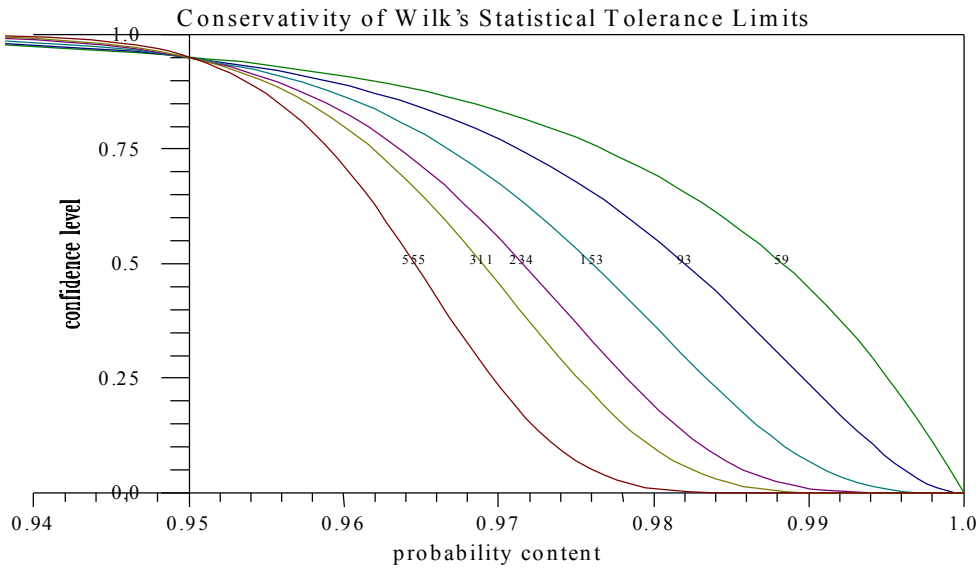


Bild 8-10 */$'7EF<68$' S!(-'7$%0<8*0*8B8;X 0-' >:d=kd= v 2G-9$%<'E$ M*5*87 K$*.'8$%7EF*$&9*EF$' V8*EFO%-K$'.56B'/$':

G-9$%<'E$ M*5*87 <.7 L9$*'$' V8*EFO%-K$' $%6<77$' <97- 5*8 $*'$5 '-EF %$9<8*0 F-F$' I$%8%<.$'7/%<& $*'$' &$.89*EF F)F$%$' ^'8$*9 &$% ''7*EF$%F$*8 <97 .%7O%N'/9*EF /$6-%&$%8J &: F: 7*$ 7*'& L-'7$%0<8*0: Y*$7 #.%&$ K$%$*87 <97 .'K$6%*$&*/$'& $%L<''8: Y$%A$*8 #$%&$' 0$%7EF*$&$'$]$8F-&$' *'8$%'<8*-'<9 &*7L.8*$%8J 5*8 &$'$' &*7 (-'7$%0<8*0*8B8$' /$5*9&$%8 #$%&$' L)''8$'J -F'$ &*$ a<F9 &$% P$EF$'9B.6$ &$.89*EF $%F)F$' A. 5N77$': I-%/$7EF9</$' #$%&$' 0$%6$*'$%8$.'& 66L8*0$%$ S!0<%*<'A%$&.A*$%$'&$;X I$%6<F%$' &$% a.6<997<.77O*$9.'/0-' U<%<5$8$%#$%8$' S]-'8$ Z<%9- V<5O9*'/X .'8$% I$%#$'&.'/ $O89: 0$%6N/K<%$%J /$$*/'8% W'6-%5<8*-'$' A.5 P$EF$'5-&$99: V8*EF#-%8$ &<A. 7*'& !W5O-%8<'E$ V<5O9*'/;J !V8%<8*6*$& V<5O9*'/;J !P$7<5O9*'/]$8F-&7 ST--878%<OX; Sk^PY >IkX: \7 *78 L9<%J &<77 O<%<99$9 &<A. &*$]$8F-&$' A.% V$'7*8*0*8B87<'<9_7$ <' &*$ '$.$' V<5O9*'/ I$%6<F%$' <'/$O<778 #$%&$' 5N77$'J.5 A.7B8A9*EF$' P$EF$'<.6#<'&A. 0$%5$*&$':

Y*$ \'8#*EL9.'/ .'& W5O9$5$'8*$%.'/ $'87O%$EF$'&$% I$%6<F%$' #B%$ <.EF 6N% &*$!+PV2]$8F-&$; .'& &<7 U%-/%<5 5O<L$8 V'V^ 7*''0-99 .'& 0-%8$*9F<68:

Erweiterung der „GRS-Methode“ auf „mehrdimensionale“ Unsicherheitsaussagen

Y*$ ‘ ’7*EF$%F$*87<.77</$’ &$% !+PV2] $8F-&$; *’ R-%5 78<8*78*7EF$% G-9$%<’E$ M*5*87 K$A*$F$’ 7*EF <.6 $*’&*5$’7*-’<9$k7L<9<%$ \%/$K’*7/%),$’: I$%/9$*EF$ 5*8 +$’$F5*/.’/7<’6-%&$%.’/$’ .’& 7*EF$%F$*87%$9$0<’8$’ +%$’A#$%8$’ <.6 &$% T<7*7 &*$7$% ‘ ’7*EF$%F$*87<.77</$’ SG-9$%<’E$ M*5*87X 7*’& &<F$% h$#$*97 ’.% $*’A$9’ 6N% *’&*0*&.99 7L<9<%$ +%),$’ $%9<.K8: T$*5 *’7<8A &$% ‘ ’7*EF$%F$*87<’<9_7$J A: T: *’ +$’$F5*/.’/70$%6<F%$’J L)’’$’ <K$% <.EF 7*5.98<’$ I$%/9$*EF$ 5$F%$%$% \%/$K’*7/%),$’ 5*8 &$’ h$#$*9*/$’ +%$’A#$%8$’ $%6-%&$%9*EF 7$*’ SA: T: 7*5.98<’$% I$%/9$*EF 0-’ UZG u!O$<L E9<& 8$5O$%<8.%$; .’&]M[u!5<e*5.5 9-E<9 E9<&&*’/ -e*&<8*-’; 5*8 &$’ h$#$*9*/$’ +%$’A#$%8$’X: c*$%6N% L<’’ &*$ 8%<&*8*-’99 7L<9<%$ ‘ ’7*EF$%F$*87<’<9_7$ ’*EF8 &*%$L8 0$%#$’&$8 #$%&$’J &$’’ $7 *78 O%*’A*O*$99 ’*EF8 -F’$ #$*8$%$7 5)/9*EFJ <99$*’ <.7 !*’&*0*&.99’; ‘ ’7*EF$%F$*8$’ *’ $*’A$9’$’ 7L<9<%$’ \%/$K’*7/%),$’ <.6 &*$!/5*’7<5$; ‘ ’7*EF$%F$*8 A. 5$F%$%$’ &*7% +%),$’ A. 7EF9*$,$’: Y*7 T$7EF%B’L.’/ &$% ‘ ’7*EF$%F$*87<’<9_7$ <.6 !*’&*0*&.99; 7L<9<%$ +%),$’ #*%& <.EF *’8$%’<8*-’<9 <97 .’K$6%*$&*/$’& K$.%8$*98:]$F%$%$ I$%6<F%$’ A.% $’87O%$EF$’&$’ \%#$*8$%.’/ &$%]$8F-&*L &$% ‘ ’7*EF$%F$*87<’<9_7$ *’ &*7 P*EF8.’/ #.%&$’ 0-%/$7EF9</$’ .’& #$%&$’ /$/$’#B%8*/J 8$*9#$*7$ 7$F% L-’8%-0$%7J &*7L.8*$%8 k+‘T >@kJ k b ^M >@kJ k] ^(>@kJ kD‘G >I k:

\7 #B%$ 7*’’0-99 .’& ’-8#$’&*/J 7*EF <’ &$% \’8#*EL9.’/ .’& Y*7L.77*-’ &*7%]$8F-&$’ A. K8*9*/$’ .’& &*$h$’*/$]$8F-&$J &*$ 0-5 ^’7<8A .’& 0-5 PEF’<.6#<’& F$% /$$*/’$8 O%<L8*L<K$9 $%7EF$*’8J *’ &*$!+PV2] $8F-&$; &$% ‘ ’7*EF$%F$*87<’<9_7$.’& &<7 A./$F)%*/$ U%-/%<5 5O<L$8 V‘V^ <.6A.’$F5$’:

Ergänzungen zur Sensitivitätsanalyse (Sensitivitätsmaße für Parametergruppen)

Y*$ V$’7*8*0*8B87<’<9_7$J #*$ 7*$ &*$ +PV2] $8F-&$.’& &<7 U%-/%<5 57_78$5 V‘V^ &$%A$*8 <’K*$8$’J K$7EF%B’L8 7*EF <.6 &*$ o<’8*6*A*$%.’/ &$7 *’69.77$7 &$% ‘ ’7*EF$%F$*8 *’ &$’ $*’A$9’$’ *’&*0*&.$99$’ *’/<’/7O<%<5$8$%’ <.6 &*$ %$7.98*$%$’&$ ‘ ’7*EF$%F$*8 *5]-&99%/$K’*7: Y*$7 9*6%8 K$L<’’89*EF ^’F<987O.’L8$ &<6N%J K$* #$9EF$’!*’&*0*&.$99$’; *’/<’/7O<%<5$8$%’ $*’$ I$%K$77$%.’/ &$7 ($’’8’*778<’&$7 &*$ &$.89*EF78$ P$&.A*$%.’/ &$% \%/$K’*7.’7*EF$%F$*8 $%#<%8$’ 9B778: HK$%8%B/8 5<’ &*$7$ T$8%<EF8.’/7#$*7$ <.6 G$*95-&$99$ 5*8 5$F%$%$’ *’/<’/7O<%<5$8$%’J L<’’ <.EF &*$ 6-9/$’&$ R%</$ 0-’ T$&$.8.’/ 7$*’C #*$ /%-,*78 &$% /$5$*’7<5$ *’69.77

<99$% .'7*EF$%$' *'/<'/7O<%<5$8$% A. &*$7$5 G$*95-&$99 <.6 &*$ +$7<58.'7*EF$%F$*8 *5 \%/$K'*7rY*7 W'6-%5<8*-' #N%&$ ^'F<987O.'L8$ &<6N% 9*6%'J -K &.%EF /$'<.$%$]-&$99*$%.'/ $*'$ #7'89*EF$ P$&.A*$%.'/ &$% +$7<58.'7*EF$%F$*8 $%A*$98 #$%&$' L)''8$: c*$%6N% L<'' &*$ V$'7*8*0*8B87<'<9_7$ *5 P<F5$' &$% +PV2]$8F-&$ /$/$'#B%8*/ L$*'$ K$6%*$&*/$'&$' ^'8#-%8$' 9*$6$%'J &$'' $7 *78 <.EF F*$% O%*'A*O*$99 '*EF8 -F'$ #$*8$%$7 5)/9*EFJ <.7 &$' !*'&*0*&.99'; ''7*EF$%F$*87K$*8%B/$' &$% $*'A$9'$' *'/<'/7O<%<5$8$% <.6 &$' !/5*'7<5$'; ''7*EF$%F$*87K$*8%</ 5$F%$%$% &*$7$% U<%<5$8$% A. 7EF9*$,$': Y*$7 #B%$ '.% &<'' 5)/9*EFJ #$'' &*$ 6-9/$'&$' T$&*'/.'/$' <99$ $%6N998 7*'&C S1X &*$ U<%<5$8$% 5N77$' .'<KFB'/*/ 7$*'J S3X &*$ \%/$K'*7/%),$ 5.77*' &$' U<%<5$8$%' 9*'$<% 7$*'J S@X &$% V8*EFO%-K$'.56<'/ 5.77 /%-, 7$*': Y*7 T$&*'/.'/$' #$%&$' '.% 7$98$' $%6N998: a#<% /*K8 $7 7$*8 /$%<.5$% a$*8]$8F-&$' A.% V$'7*8*0*8B87<'<9_7$ <.EF K$AN/9*EF U<%<5$8$%/%.OO$' Sk]E(d=kJ kc[] dkhkV^M >>kX: Y< h$&-EF <99$ &*7]$8F-&$' A.7B8A9*EF$]-&$99%$EF'.'/$' *' $%F$K9*EF$5 '56<'/ $%6-%&$%'J 7*'& 7*$ 6N% ^'#$'&.'/$' 5*8 %EF'A$*8*'8$'7*0$' Z-&$7 #*$ ^GcM\G '*EF8 O%<L8*L<K$9:

Y*$ \'8#*EL9.'/ $*'$% /$$*/'8']$8F-&$ A.% V$'7*8*0*8B87<'<9_7$J &: F: 0-' /$$*/'8' V$'7*8*0*8B875<,$' 6N% U<%<5$8$%/%.OO$' 78<88 6N% *'A$9O<%<5$8$%J #$9EF$ -F'$ A.7B8A9*EF$' P$EF$'<.6#<'& .'& '.% 5*8 &$' #$'*/$'J <.7 &$% ''7*EF$%F$*87<'<9_7$ K$%$*87 0-%F<'&$'$' PEF'9B.6$' <.7L-55 8J #B%$ &<F$% 7*''0-99 .'& '-8#$'&*/:

Entwicklung einer praktikablen Methodik zur (approximativen) Unsicherheits- und Sensitivitätsanalyse bei rechenzeitintensiven Modellanwendungen, in denen epistemische <u>und</u> aleatorische Unsicherheiten per Monte Carlo Simulation zu berücksichtigen sind

^'#$'&.'/$' 0-' PEF'5-&99' L)''$' 5*8 K$*&$' G_O$' &$% ''7*EF$%F$*8 K$F<68$8 7$*'C 5*8 *epistemischer* ''7*EF$%F$*8 Su''7*EF$%F$*8 <.6/%.'& .'0-9978B'&*/$% ($''8'*7 &8%5*'*78*7EF$% +%),$'X .'& *aleatorischer* ''7*EF$%F$*8 Su''7*EF$%F$*8k ''/$#*77F$*8 <.6/%.'& 0-' a.6<997$*'69N77$'X: Y*$ K$*&$' G_O$' &$% ''7*EF$%F$*8 5N77$' /$8%$''8 K$F<'&$98 .'& *' &$' \%/$K'*77$' $'87O%$EF$'& <.7/$#*7' #$%&$': b*EF8*/$ T$*7O*$9$ 7-9EF$% ^'#$'&.'/$' 7*'& .:<:

- .56<77$'&$k&_'<5*7EF$ UV^ 5*8 &$5 G--9]ZY\G S]-'8$ Z<%9- Y_'<5*E \0$'8 G%$$XJ K<7*$%$'& <.6 &$% (-5K*'<8*-' 0-']-'8$ Z<%9- V*5.9<8*-' 5*8 $*'$% \%$*/'*72^K9<.62^'<9_7$ c[R>1:.'&

- ^'<9_7$ &$% M<'/A$*87*EF$%F$*8 0-' \'&9</$%' c\Mdi:

c*$%K$* 5N77$' '*EF8 '.%J #*$ *' &$% h$8A8 <'/$#<'&8$']$8F-&$J &*$ $O*78$5*7EF$' ''7*EF$%F$*8$'J 7-'&$%' <.EF &*$ <9$<8-%*7EF$' ''7*EF$%F$*8$' 8$*9#$*7$ -&$% /<'A 5*8 c*96$ &$%]-'8$ Z<%9- V*5.9<8*-' K$F<'&$98 #$%&$':

Y*$!'<8N%9*EF$; ^%8 .'& b$*7$ &$% T$F<'&9.'/ &$% K$*&$' G_O$' &$% ''7*EF$%F$*8 5*8]-'8$ Z<%9- V*5.9<8*-' #B%$ *' 7-9EF$' RB99$' $*'$!A#$*78.6*/$; a.6<997<.7#<F9J K78F$'& <.7 S1X $*'$% !B.,$%$'; V*5.9<8*-'77EF9$*6$J*' &$%J*' /$#-F'8$% b$*7$J &*$ b$%8$ &$% $O*78$5*7EF$' +%),$' Su.'7*EF$%$ U<%<5$8$%X /$'$%*$%8 #$%&$' .'& S3X $*'$% !*''$%$'; V*5.9<8*-'77EF9$*6$J*' &$%J*' ^KFB'/*/L$*8 0-' &$' h$#$*9*/$' b$%8$' &$% $O*78$5*7EF$' +%),$'J &*$ b$%8$ &$% K$8%66'&$' <9$<8-%*7EF$' +%),$' /$'$%*$%8 #$%&$':

\7 *78 L9<%J &<77 K$* %$EF$'A$*8*'8$'7*0$' Z-5O.8$%5-&$99$'J #*$ 7*$ A:T:*' $*'$% .56<77$'&$'k&_'<5*7EF$' UV^ 5*8 &$5]ZY\G2G--9 -&$% K$* &$% ^'<9_7$ &$% M<'/A$*87*EF$%F$*8 0-' \'&9</$%' 0$%#$'&$8 #$%&$'J &$% P$EF$'<.6#<'& A.% Y.%EF6NF%.'/ <99$% 6N% &*$!A#$*78.6*/$;]-'8$ Z<%9- V*5.9<8*-' $%6-%&$%9*EF$']-&$99%EF'9B.6$ '*EF8 O%<L8*L<K$9*78:

Y$7F<9K 7-998$']$8F-&$' $'8#*EL$98 #$%&$'J 5*8 &$'$' 5<' 2 .'8$% I$%5$*&.'/ &$% 0-99$' !A#$*78.6*/$';]-'8$ Z<%9- V*5.9<8*-' 2 5*8 $*'$5 &$.89*EF /$%*'/$%$' PEF'<.6#<'& A. K%<.EFK<%$'J A.5*'&$78 <OO%-e*5<8*0$'J $O*78$5*7EF$' ''7*EF$%F$*872 .'& V$'7*8*0*8B87<.77</$' /$9<'/$' L<'': \%78$ ^'7B8A$ *' &*7 P*EF8.'/ #$%&$' *' kc[R>1kJ kc[R>3k .'& k(Pa>lk K$7EF%*$K$': c*$% #$%&$' &*$ K$*&$' G_O$' &$% ''7*EF$%F$*8 *5 a./$ $*'$% 7O$A*$99$' !$*'78.6*/$';]-'8$ Z<%9- V*5.9<8*-' A.'BEF78 5*8$*'<'&$% !0$%5*7EF8; .'& &<'' <K$% <.7 &$' \%/$K'*77$' &$% $'87O%$EF$'&$' PEF'9B.6$ #*$&$% !7$O<%*$%8;: Y<%<.7 L)''$' &<'' K$78*5 58$ <OO%-e*5<8*0$ ''7*EF$%F$*872 .'& V$'7*8*0*8B87<.77</$' F$%/$9$*8$8 #$%&$':

Y*$ \'8#*EL9.'/ $*'$% &$%<%8*/$']$8F-&*L *78 7*''0-99 .'& '-8#$'&*/: ^'&$%'6<997 #B%$ &*$ (-'7p'A $*' 0)99*/$% I$%A*EF8 <.6 $O*78$5*7EF$ ''7*EF$%F$*87 2 .'& V$'7*8*0*8B87<'<9_7$' K$* 7- #*EF8*/$' ^'#$'&.'/$' #*$ .56<77$'&$' .'& &_'<5*7EF$' UV^ .'&M<'/A$*87*EF$%F$*8<'<9_7$' 6N% \'&9</$%:

8.1.5 Literatur zum Forschungsbereich "Unsicherheits- und Sensitivitätsanalyse"

k^PY >lk ^%&*99-' \:C V8%<8*6*$& V<5O9*'/6-% \78*5<8*'/P$9*<K*9*8_ o<'8*9$7 6-% <
GF$%5-F_&%<.9*E G%<'7*$'8: UV^]n2\VP\M>l Z-'6$%$'E$J
f.'$ 1l21iJ 3>>lJ T$%9*'

k+'T >@k +.K< ^:J]<L<*]:J U<9 M:C V8<8*78*E<9 <7O$E87 -6 K$78 $78*5<8$ 5$8F-&2WJ
P$9*<K*9*8_ \'/*'$$%*'/<'& V_78$5 V<6$8_ i>S3>>@X 31n23@3

kc\Mdik c$98-' f:Z:$8<9:J 1ddi:''E$%8<*'8_<'& 7$'7*8*O*8_ %$7.987 -K8<*'$&*' 8F$
1ddm0$%6-%5<'E$ <77$775$'8 6-%8F$ #<78$ *7-9<8*-' O*9-8 O9<'8:
V^DYdi2@mJ ^9K.p$%p$C V<'&*< D<8*-'<9 M<K-%<8-%*$7Q 1ddi

kc[Rd@k c-6$% \:J U%-K<K*9*78*7EF$ ''7*EF$%F$*87<'<9_7$'0-' \%/$K'*77$'
.56<'/%$*EF$% PEF'5-&99: G$EF'*E<9 %$O-%8 +PV2^23>>3J
+$7$997EF<68 6N% ^'9</$'2 .'& P$<L8-%7*EF$%F$*8J 1dd@

kc[R>1k c-6$% \J (9--7]J (%A_L<EA2c<.75<'' TJ U$7EFL$ fJ V-''$'L<9K]C
]$8F-&$'$'8#*EL9.'/A. 7*5.9<8*0$' T$F<'&9.'/&$% V8-EF<78*L*'
O%-K<K*9*78*7EF$' V*EF$%F$*87<'<9_7$' &$% V8.6$ 3: G$EF'*E<9 %$O-%8
+PV2^2ddJn+$7$997EF<68 6N% ^'9</$' 2 .'& P$<L8-%7*EF$%F$*8J 3>>1

kc[R>3k c-6$% \J (9--7]J (%A_L<EA2c<.75<'' TJ U$7EFL$ fJ b-98$%$EL]C
^'<OO%-e*5<8$ $O*78$5*E .'E$%8<*'8_<'<9_7*7 <OO%-<EF*' 8F$ O%7'E$ -6
$O*78$5*E <'& <9$<8-%_ .'E$%8<*'8*$7: P$9*<K*9*8_ \'/*'$$%*'/<'& V_78$5
V<6$8_ n33>>3XJ 33d 23@i

kc[]dkm c-55< G:J V<98$99* ^:J W5O-%8<'E$ 5$<7.%$7*' /9-K<9 7$'7*8*0*8_<'<9_7*7 -6
5-&$9 -.8O.8: P$9*<K*9*8_ \'/*'$$%*'/<'& V_78$5 V<6$8_ =3S1ddXm1 21n

k(Padlk (%A_L<EA T:J c-6$% \:J (9--7]:J ^ 7-68#<%$ 7_78$5 6-% O%-K<K*9*78*E
.'E$%8<*'8_<'& 7$'7*8*0*8_<'<9_7*7 -6 %$7.987 6%-5 E-5O.8$% 5-&$97J
U%-E$$&*'/7 -6 UV^]WJ V<' Y*$/-J Z<9:J 'V^J]<%EF 3>23=J 1ddl

k(Pa>lk (%A_L<EA2c<.75<'' T:C V$'7*8*0*8_ ^'<9_7*7 -6]-'8$ Z<%9- \78*5<8$7 6%-5
Z-5O.8$%]-&$97*' 8F$ U%7'E$ -6 \O*78$5*E <'& ^9$<8-%_ ''E$%8<*'8*$7:
V^][3>>lJ R-.%8F W'8$%'<8*-'<9 Z-'6$%$'E$ -' V$'7*8*0*8_ ^'<9_7*7 -6
]-&$9*'/ [.8O.8J]<%EF i211J 3>>lJ V<'8< R$ SD]X

k]^(>@k]<L<*]:J U<9 M:C P$O9_8-8F$ E-'8%*K.8*-' -6 +%<F<5 T: b<99*7J P$9*<K*9*8_
\'/*'$$%*'/<'& V_78$5 V<6$8_ i>S3>>@X @1@2@1n

k]E(d=k]E(<_]:Y: \0<9.<8*'/O%$&*E8*-' .'E$%8<*'8_: G$EF'*E<9 P$O-%8
D'P\+kZP2@11J 'VDPZ<'& M^DMJ 1dd=

DWV >@k]:\:D*779$_ $8 <9:C P$<9*78*E M<%/$2T%$<L \0<9.<8*-']$8F-&-9-/_ '7*'/
8F$ ^.8-5<8$& V8<8*78*E<9 G%$<85$'8 -6 ''E$%8<*'8_]$8F-&:
bZ^U21mmd 2DUJ P$0*7*-'>J]<_ 3>>@

kD'G>Ik D.88 b:G:J b<99*7 +:T:C \0<9.<8*-' -6 '.E9$<% 7<6$8_ 6%-5 8F$ -.8O.87 -6
E-5O.8$% E-&$7*' 8F$ O%7'E$ -6 .'E$%8<*'8*$7J P$9*<K*9*8_ \'/*'$$%*'/
<'&V_78$5 V<6$8_ i@S3>>IX=n2n

kV^M >>k V<98$99* ^:J ZF<'J (:J VE-88 \:]:S$&7XC V$'7*8*0*8_ ^'<9_7*7J b*9$_ 3>>>

kVG[>@k ':V8-99C ^'#$'&.'/ %$<9*78*7EF$%]$8F-&$' 6N% V8)%6<99<'<9_7$'
R%<5<8-5$ ^DUJ 3@:V*8A.'/ &$7 PV(2^.77EF.77$7 ^'9</$'2 .'&
V_78$58$EF'*LJ 1i:13:3>>@

kb^M >@k b<99*7 +:T:C Z-'8%*K.8*-' 8- 8F$ O<O$% !V8<8*78*E<9 <7O$E87 -6 K$78 $78*5<8$
5$8F-&2W;J P$9*<K*9*8_ \'/*'$$%*'/ <'&V_78$5 V<6$8_ i>S3>>@X @>d2@11

8.2 Probabilistische Sicherheitsanalysen

Y*$ O%-K<K*9*78*7EF$ V*EF$%F$*87<'<9_7$ SUV^X*78 F$.8$ 2*' \%/B'A.'/ A.% &8%5*'*78*2
7EF$' I-%/$F$'7#$*7$ 2 $*' .'0$%A*EF8K<%$7 W'78%.5$'8 &$% V*EF$%F$*87K$#$%8.'/ 0-'
($%'L%<68#$%L$': W' &$% UV^ #$%&$' &*$ ($''8'*77$ NK$% &*$ ^.79$/.'/ .'&
T$8%*$K7#$*7$ &$% ^'9</$J &*$ T$8%*$K7$%6<F%.'/ 5*8 &$% .'8$%7.EF8$' .'& 5*8
BF'9*EF$' ^'9</$'J \%L$''8'*77$ &$% P$<L8-%7*EF$%F$*876-%7EF.'/ .'& &$% <99/$5$*'$
#*77$'7EF<689*EF28$EF'*7EF$ V<EF0$%78<'& A. $*'$% +$7<58K$#$%8.'/ &$7
V*EF$%F$*87A.78<'&$7 &$7 .'8$%7.EF8$' ($%'L%<68#$%L7A.7<55$'/$6NF%8:]*8 c*96$ &$%
UV^ *78 $7 5)/9*EFJ &*$ ^.7/$#-/$'F$*8 &$% 7*EF$%F$*878$EF'*7EF$' ^.79$/.'/ &$%
^'9</$ A. K$#$%8$'J &*$ ^.7#*%L.'/ 0-' D-86<995<,'<F5$' K$* 7EF#$%$' V8)%6B99$'
A. K$.%8$*9$' .'& 7*EF$%F$*87%$9$0<'8$ VEF#<EF78$99$' *' &$% ^.79$/.'/ .'& &$%
T$8%*$K7#$*7$ &$% .'8$%7.EF8$' ^'9</$ A. *&$'8*6*A*$%$': Y*$]$8F-&$' &$% UV^
$%9<.K$' $7 <.EFJ ''7*EF$%F$*8$' *5 ($''8'*778<'& .'& b*77$'79NEL$' A. K$F<'&$9'
.'& *F%$' *'69.77 <.6 &<7 \%/$K'*7 2 A.5*'&$78*' #*EF8*/$' G$*9K$%$*EF$' 2*' R-%5
0-' \%/$K'*7.'7*EF$%F$*8$' A. p<'8*6*A*$%$': Y*$ UV^ 9*6%8 &<5*8 K$9<78K<%$
+%.'&9</$' 6N% \'87EF$*&.'/$' NK$% &*$ D-8#$'&*/L$*8 .'& &$' D.8A$'
7*EF$%F$*878$EF'*7EF$% I$%K$77$%.'/$' *' $*'$5 ($%'L%<68#$%L: Y*$ UV^ #*%& F$.8$*'
<99$' &*$ ($%'$'$%/*$ '.8A$'&$' MB'&$%' *' I$%K*'&.'/ 5*8 &$% &$8$%5*'*78*7EF$'
V*EF$%F$*87<'<9_7$ 6N% $*'$ .56<77$'&$ V*EF$%F$*87K$#$%8.'/ .'& A.% [O8*5*$%.'/
0-' ^.79$/.'/ .'& T$8%*$K7#$*7$ *5 c*'K9*EL <.6 &*$ V*EF$%F$*8 0-' ($%'L%<68#$%L$'
<'/$#<'&8:

T$* &$% UV^ #$%&$' &%$* V8.6$' .'8$%7EF*$&$': *'$ UV^ &$% V8.6$ 1 $%5*88$98 &*$ SA. $%#<%8$'&$X cB.6*/L$*8 0-' '*EF8 KF%%7EF8$' V8)%6<99<K9B.6$'J &*$ A.5 ($%'7EF5$9A$' 6NF%$': Y*$ UV^ &$% V8.6$ 3 .'8$%7.EF8 2 <.6K<.$'& <.6 V8.6$ 1 2 &*$ T$9<78.'/$' &$7 V*EF$%F$*87$*'7EF9.77$7 K$* $*'$5 ($%'7EF5$9A.'6<99 .'& $%5*88$98 &*$ cB.6*/L$*8 .'8$%7EF*$&9*EF$% I$%7</$'7<%8$' &$7 V*EF$%F$*87K$FB98$%7 7-#*$ &<7 ^.75<, .'& &*$ 'BF$%$' '578B'&$ &$% R%$*7$8A.'/ 0-' P<&*-'.L9*&$': Y*$ V8.6$ @ $%5*88$98 2 <.7/F'& 0-' &$' \%/$K'*77$' &$% V8.6$ 3 2 ^.75<, .'& cB.6*/L$*8 &$% &.%EF &*$ 6%$*/$7$8A8$' P<&*-'.L9*&$ 0$%.%7<EF8$' VEFB&$':

RN% 0*9 ($%'L%<68#$%L$ 9*$/$' *'A#*7EF$' UV^ K*7 A.% V8.6$ 3 0-%: ^.EF *' Y$.87EF9<'& #.%&$' 2 <.6K<.$'& <.6 &$' \%6<F%.'/$' 5*8 &$% }Y$.87EF$' P*7*L-78.&*$ ($%'L%<68#$%L$ 2 UF<7$ T} 2 &*$]$8F-&$' &$% UV^ &$% V8.6$' 1 .'& 3 6N% &$' M$*78.'/7K$8%*$K .'& 6N% &$' D*EF89$*78.'/7K$8%*$K *' 5$F%$%$' U%-h$L8$' #$*8$%$'8#*EL$98J .:<: 5*8 &$' }V*EF$%F$*878$EF'*7EF$' ''8$%7.EF.'/$' A.7EF#$%$' V8)%6B99$' *' VbP} &$% }T$#$%8.'/ &$7 ''6<99%*7*L-7 6-%87EF%*889*EF$% Y%.EL#<77$% 2 %$<L8-%$' *' Y$.87EF9<'&}.'& &$% }] $8F-&$'$'8#*EL9.'/ A.% 7*5.9<8*0$' T$F<'&9.'/ &$% V8-EF<78*L*' O%-K<K*9*78*7EF$' V*EF$%F$*87<'<9_7$' &$% V8.6$ 3}

W' 0$%7EF*$&$'$' MB'&$%' S#*$ (<'<&<J D*$&$%9<'&$J 'V^X #.%&$' <.EF UV^ &$% V8.6$ @ &.%EF/$6NF%8:

''<KFB'/*/ 0-5 \'8#*EL9.'/778<'& &$%]$8F-&$' &$% UV^J *78 *' Y$.87EF9<'& &*$ ^'#$'&.'/ &$% UV^ *5 %$/.9<8-%*7EF$' T$%$*EF #$'*/$% $'8#*EL$98 <97 *' <'&$%$' MB'&$%': W' 0*$9$' MB'&$%' #$%&$' 6N% V*EF$%F$*87K$#$%8.'/$' 0-' ($%'L%<68#$%L$' K$%$*87 7$*8 f<F%$' UV^ K*7 A.% V8.6$ 3 /$'.8A8: W' Y$.87EF9<'& *78 7$*8 &$% D$.6<77.'/ &$7 ^8-5/$7$8A$7 0-5 ^O%*9 3>>3 &*$ UV^ -K9*/<8-%*7EF$% T$78<'&8$*9 &$% A.6$78/$9$/8$' G$%5*'$' &.%EFA.6NF%$'&$' V*EF$%F$*87NK$%O%N6.'/ SVHX 6N% ($%'L%<682 #$%L$: W5 R<EF<%K$*87L%$*7 UV^ #.%&$ &$% &*$7K$AN/9*EF$ UV^2M$*86<&$' 5*8 7$*'$' A./$F)%*/$' R<EFKB'&$' S]$8F-&$'2 .'& Y<8$'K<'&X <L8.<9*7*$%8 .'& $%#$*8$%8 S.:<: .5 ^'<9_7$' &$% V8.6$ 1 6N% &$' D*EF89$*78.'/7K$8%*$KX:

RN% &*$ A.LN'68*/ &.%EFA.6NF%$'&$' UV^ 6N% &*$ ($%'L%<68#$%L$ *' Y$.87EF9<'& *78 $7 '-8#$'&*/J]$8F-&$' .'& PEF'#$%LA$./$ 6N% &*$ UV^ #$*8$% A. $'8#*EL$9'J .5 %*7*L-%$9$0<'8$ \%$*/''*77$ 5)/9*EF78 .56<77$'& K$%NEL7*EF8*/$' A. L)''$' .'& \%$*/''*72 7-#*$ ''6<99<K9B.6$ 5)/9*EF78 %$<9*78*7EF A.5-&$99*$%$': T$*5 *'7<8A &$% UV^ *5 <8-5%$EF89*EF$' I$%6<F%$' 7*'&]$8F-&$' A. 0$%#$'&$'J &*$ &$5 *'8$%'<8*-'<9$' V8<'& 0-' b*77$'7EF<68 .'& G$EF'*L $'87O%$EF$': b*$ *' <99$'

T$%$*EF$' &$% P$<L8-%7*EF$%F$*876-%7EF.'/ 7*'& <.EF A.5 GF5'K$%$*EF O%-K<K*9*78*7EF$ V*EF$%F$*87<'<9_7$' SUV^X &*$ %$9$0<'8$' <.79B'&*7EF$' ^%K$*8$' A. K$%NEL7*EF8*/$' S0/9: A: T: kVUW >IkX: Y<K$* *78 A. O%N6$'J #$9EF$ 5$8F-&*7EF$' ^'7B8A$ -&$% \%/$K'*77$ *' <'&$%$' MB'&$%' -&$% *' 5.98*9<8$%<9$' +%$5*$' $%<%K$*8$8 #.%&$' .'& -K &*7 <.6 &$.87EF$ P<'&K$&*'/./$' NK$%8%</K<% .'& 2 *F%$ I$%6N/K<%L$*8 0-%<.7/$7$8A8 2 <.6 &$.87EF$ ^'9</$' <'#$'&K<% 7*'&: \7 *78 &<'' *5 h$#$*9*/$' *'A$%<99 A. &*7L.8*$%$'J -K $*/$'$ &$.87EF$ b$*8$%$'8#*EL9./$' $%6-%&$%9*EF 7*'&:

8.2.1 Weiterentwicklung von Methoden

- **Methoden zur Abschätzung des Risikobeitrags redundanzübergreifender Brandschäden**

T%<'&<'<9_7$' <97 G$*9 $*'$% UV^ #$%&$' NK9*EF$%#$*7$ *' A#$* VEF%*88$' &.%EF/$6NF%8C

1: R$7878$99./ L%*8*7EF$% T%<'&K$%$*EF$ SVE%$$'*'/X .'&

3: &$8<*99*$%8$ ‘'8$%7.EF./ &$% L%*8*7EF$' T$%$*EF$:

Die bisher eingesetzten Ausleseverfahren verwenden nur qualitative Kriterien oder liefern aufgrund pessimistischer Annahmen eine zu hohe Anzahl von kritischen Brandbereichen (hoher Folgeaufwand). Daher soll das entwickelte qualitativ-quantitative Ausleseverfahren durch ergänzende Programmmodule so verbessert werden, dass bereits beim Screening Auswirkungen brandbedingter auslösender Ereignisse auf die Beherrschung dieser Ereignisse abgeschätzt werden können. Durch dieses Vorgehen kann der Aufwand für Detailanalysen erheblich verringert werden.

RN% &*$ Y$8<*9<'<9_7$' 6$F98 K*7F$% $*'$]$8F-&$J &*$ &$' A$*89*EF$' T%<'&0$%9<.6 *5 c*'K9*EL <.6 &*$ TF%%7EFK<%L$*8 <.79)7$'&$% \%$*/'*77$ K$%NEL7*EF8*/: a.&$5 L)''$' &*$ ^.7#*%L./$' 0-' T%B'&$' <.6 &*$ 7*EF$%F$*87%$9$0<'8$ \9$L8%-2 .'& M$*88$EF'*L &$%A$*8 '*EF8 *' <'/$5$77$'$% b$*7$ <'<9_7*$%8 #$%&$': \7 *78 &<F$% $*' U%-/%<555-&.9 A.% \%5*889./ &$% cB.6*/L$*8$' K%<'&K$&*'/8$% ($%'7EF<&$'72 A.78B'&$ <97 R-9/$ 0-' (<K$97EFB&$' A. $'8#*EL$9'J &<7 &$' A$*89*EF$' ^7O$L8 &$% T%<'&0$%9B.6$.'8$% T$%NEL7*EF8*/.'/ &$% ‘'7*EF$%F$*8$' 0-' *'/<'/7&<8$' .'&]-&$99*$%.'/$' .'& &$% 7*EF $%/$K$'&$' o<'8*6*A*$%.'/ &$% ‘'7*EF$%F$*8$' &$% ^'<9_7$$%/$K'*77$ $*'K$A*$F8:

- **Entwicklung eines Verfahrensschemas zur systematischen Bewertung der Übertragbarkeit von Ereignissen infolge gemeinsam verursachter Ausfälle (GVA)**

Y*$ 5*8 &$% UV^ $%5*88$98$' cB.6*/L$*8$' 0-' ($%'7EF<&$'7A.78B'&$' #$%&$' &-5*'*$%8 0-' /$5$*'7<5 0$%.%7<EF8$' ^.76B99$' S+I^X 5$F%$%$% S<L8*0$%X (-5O-'$'8$': V- A$*/8$ A: T: $*'$ UV^ $*'$' ^'8$*9 &$% +I^ <' &$% cB.6*/L$*8 &$% ($%'7EF<&$'7A.78B'&$ 0-' @ v^'&$%$ V8.&*$' L-55$' <.6 '-EF F)F$%$ +I^ 2 ^'8$*9$: Y5'87O%EF'& FB'/8 <.EF &*$ \%/$K'*7.'7*EF$%F$*8 0-' UV^ 78<%L 0-' &$' ''7*EF$%F$*8$' K$* &$% o<'8*6*A*$%.'/ &$% b<F %7EF$*'9*EFL$*8 0-' +I^<K:

Y*$ I$%5$*&.'/ 0-' +I^ *78 0-' /%-,$% T$&$.8.'/ 6N% &*$ a.0$%9B77*/L$*8 0-' V*EF$%F$*877_78$5$': Y<F$% #$%&$' *' <99$' ($%'L%<68#$%L$' #$*8 %$*EF$'&$ I-%L$F%.'/$' /$/$' +I^ /$8%-66$': Y*$7 6NF%8 &<A.J &<77 +I^ 7$F% 7$98$' <.68%8' .'& &*$ <'9</$'7O$A*6*7EF$' \%6<F%.'/$' L$*'$ K$9<78K<%$ o<'8*6*A*$%.'/ *F%$% *'8%*887#<F%7EF$*'9*EFL$*8 $%9<.K$': Y*$7 5<EF8 7*EF K$7-'&$%7 K$* 7$F% F-F$5 P$&.'&<'A/%<& K$55$%LK<%: Y$7F<9K 5.77 <.6 /$'$%*7EF$ Y<8$' A.%NEL/$/%*66$' #$%&$'J K$* &$'$' 7*EF <K$% #*$&$%.5 &<7 U%-K9$5 &$% HK$%8%</K<%L$*8 $%/*K8:

Y.%EF &<7 W'8$%'<8*-'<9$ +I^2Y<8$'<.78<.7EFO%-h$L8 !W'8$%'<8*-'<9 Z-55-' Z<.7$ R<*9.%$ Y<8< \eEF<'/$; SWZY\X &$% [\ZYkD\^ #.%&$' *' &$' 9$8A8$' f<F%$' K$* &$% 7_78$5<8*7EF$' \%6<77.'/ .'& T$#$%8.'/ &$% #$98#$*8$' T$8%*$K7$%6<F%.'/ 5*8 +I^ '<EF $*'F$*89*EF$' (%*8$%*$' .'& T$#$%8.'/7%*EF89*'*$' #7'89*EF$ R-%87EF%*88$ /$5<EF8: Y$% \%6<F%.'/7.56<'/ 0-' NK$% ₥ \%$*/'*77$'J &<0-' ₥ 5*8 0-9978B'&*/$5 ^.76<99 <99$% %$&.'&<'8$' (-5O-'$'8$' &$% h$#$*97 K$8%-66$'$' (-5O-'$'8$'/%.OO$J 7-998$ /$'.8A8 #$%&$' 6N% $*'$ b$*8$%$'8#*EL9.'/ &$%]$8F-&*L A.% T$#$%8.'/ &$% HK$%8%</K<%L$*8 0-' +I^2\%$*/'*77$': ^.6 &*7 b$*7$ L)''8$' &*$ ''7*EF$%F$*8$' K$* &$% o<'8*6*A*$%.'/ 0-' +I^ 0$%%* '/$%8 #$%&$':

Y<K$* L<'' <.6 $*'$' T$#$%8.'/7<'7<8A <.6/$K<.8 #$%&$'J &$% *' hN'/78$% a$*8 *' $*'$5 &$.87EF$' U%-h$L8 A.% b$*8$%$'8#*EL9.'/ &$% Y<8$'K<7*7 6N% +I^ $'8#*EL$98 #.%&$: Y*$7$% ^'7<8A /$F8 &<0-' <.7J /$'$%*7EF$ +I^2UFB'-5$'$ K$* K$-K<EF8$8$' +I^2\%$*/'*77$' A. <K78%<F*$%$' .'& <'9</$'7O$A*6*7EF$]<,'<F5$' A.% I$%F*'&$%.'/ -&$% %$EF8A$*8*/$' \'8&$EL.'/ 7-9EF$% UFB'-5$'$ A. *&$'8*6*A*$%$': Y.%EF \eO$%8$'7EFB8A.'/ L<'' &<'' &*$ HK$%8%</K<%L$*8 $*'$7 K$-K<EF8$8$' +I^2 \%$*/'*77$7 <.6 $*'$ <'&$%$ ^'9</$ &.%EF $*'$ T$#$%8.'/ &$% .'8$%7EF*$&9*EF$' b*%L7<5L$*8 &$% OFB'-5$'7O$A*6*7EF$' I$%F*'&$%.'/75<,'<F5$' *' &$' K$*&$' ^'9</$' p<'8*6*A*$%8 #$%&$':

Y$% 0-%9*$/$'&$ T$#$%8.'/7<'7<8A 7-998$ #$*8$%$'8#*EL$98 .'& 7_78$5<8*7*$%8 #$%&$'J *'&$5 $7 <.6 &*$ <.79B'&*7EF$' \%$*/''*77$ <'/$#$'&$8 #*%&J &*$ NK$% &<7 WZY\2 U%-h$L8A./B'/9*EF 7*'&: Y<K$* 7-998$ $*' (-'A$O8 $'8#*EL$98 #$%&$'

- A.% p<'8*8<8*0$' W&$'8*6*A*$%.'/ 0-' I$%F*'&$%.'/75<,'<F5$'J &*$ $7 %$EF86$%8*/$'J 0-' $*'$% *'72A.2$*'72HK$%8%</.'/ 0-' +I^2\%$*/''*77$' <KA.#$*EF$'J
- A.% p<'8*8<8*0$' T$#$%8.'/ &$% HK$%8%</K<%L$*8 K$* I-%9*$/$' K$78*5 58$% I$%F*'&$%.'/75<,'<F5$'
- .'&A.% \e8%<O-9<8*-'<.6 F-F$ P$&.'&<'A/%<&$:

Y<5*8 L<'' $*'$ (9<77$'$*'8$*9.'/ 0-' +I^2'%7<EF$' $'8#*EL$98 #$%&$'J .5 K$*7O*$97#$*7$ A. .'8$%7EF$*&$' A#*7EF$' ^.79$/.'/72 -&$% (-'78%.L8*-'76$F9$%'J K$* &$'$' <99$ (-5O-'$'8$' $*'$% (-5O-'$'8$'/%.OO$.'8$% K$78*5 58$'J .'0-%F$%/7F$'$' V_78$5%<'&K$&*''/.'/$' 0$%7</$' S.'& 6-9/9*EF .'<KFB'/*/ 0-5 P$&.'&<'A/%<& $*'$ F-F$ (-OO9.'/ 0-%9*$/8XJ .'& R$F9$%'J &*$ 7*EF A$*89*EF $'8#*EL$9' .'& &*$ 2 K$* $*'$5 $'87O%$EF$'&$' T$8%*$K76NF%.'/72 .'& U%N6L-'A$O8 2 $%#<%8$' 9<77$'J &<77 K*7 A.% \'8&$EL.'/ $*'$7 7-9EF$' R$F9$%7 *' F)F$% %$&.'&<'8$' (-5O-'$'8$'/%.OO$' '-EF '*EF8 <99$ (-5O-'$'8$' <.7/$6<99$' 7*'&:

a*$9 *78 $7J &*$ *'/$'*$.%8$EF'*7EF$' *'7EFB8A.'/$' A. 7_78$5<8*7*$%$' .'& K$* &$% T$#$%8.'/ &.%EF .'8$%7EF*$&9*EF$ \eO$%8$' &*$ V8%$.K%$*8$' &$% VEFB8A.'/ A. 5*'*5*$%$':

- **Berücksichtigung von Ergebnisunsicherheiten der Störfallsimulation in der Unsicherheitsanalyse der PSA Stufe 1**

*' #*EF8*/$% T$78<'&8$*9 &$% UV^ *78 &*$ o<'8*6*A*$%.'/ &$% &.%EF .'0-9978B'&*/$ ($''8'*7 &$8$%5*''*78*7EF$% +%),$' 0$%.%7<EF8$' \%/$K'*7.'7*EF$%F$*8$' S;$O*78$5*2 7EF$; ''7*EF$%F$*8$'X: '%7<EF$0-' \%/$K'*7.'7*EF$%F$*8$' 7*'&C

- U<%<5$8$%.'7*EF$%F$*8$'J
-]-&$99.'7*EF$%F$*8$'J
- ''7*EF$%F$*8$' K$AN/9*EF &$% I-9978B'&*/L$*8:

T*7F$% #$%&$' *' &$% UV^ '.% &*$ &.%EF ‘ ’7*EF$%F$*8$’ &$% O%-K<K*9*78*7EF$’ *’/<’/7/%),$’ 0$%.%7<EF8$’ \%/$K’*7.’7*EF$%F$*8$’ p<’8*6*A*$%8: Y*$ o<’8*6*A*$%.’/ 0-’ ‘ ’7*EF$%F$*8$’ <.6/%.’& 5)/9*EF$% ‘ ’0-9978B’&*/L$*8 *78 O%<L8*7EF ’*EF8 5)/9*EF:

T$*]-&$99.’7*EF$%F$*8$’ *78 A. .’8$%7EF$*&$’ A#*7EF$’ ‘ ’7*EF$%F$*8$’ <.7 &$5 O%-K<K*9*78*7EF$’]-&$99 SA: T: K*’B%$ M-/*L *’ &$% R$F9$%K<.5<’<9_7$J &*7L%8 I$%A#$*/.’/7O.’L8$ *’ &$% \%$*/’*7<K9<.6<’<9_7$X .’& ‘ ’7*EF$%F$*8$’ <.7 &$% S&$8$%5*’*78*7EF$’X V*5.9<8*-’ 0-’ \%$*/’*7<K9B.6$’ .:<: A.% R789/./ 0-’ b*%L7<5L$*87<’6-%&$%.’/$’ .’& 0-’ 0$%6N/K<%$’ a$*8$’ 6N% c<’&5<,’<F5$’:

[K#-F9 ‘ ’7*EF$%F$*8$’ <.7 &$% V*5.9<8*-’ 0-’ \%$*/’*7<K9B.6$’ *5 U%*’A*O p<’8*6*A*$%8 #$%&$’ L)’’$’J #*%& &*7])/9*EFL$*8 *’ K*7F$% &.%EF/$6NF%8$’ UV^ ’*EF8 /$’.8A8: Y*$ ‘ ’7*EF$%F$*8$’ L)’’$’ 7*EF <.7#*%L$’ 0-% <99$5 K$* &$% R789/./ 0-’]*’&$78<’6-%&$%.’/$’J K$* &$% ^’<9_7$ 5$’7EF9*EF$% a.0$%9B77*/L$*8 S0$%6N/K<%$ a$*8$’X 7-#*$ K$* &$% R$7878$99.’/ %$9$0<’8$% \%$*/’*7<K9B.6$ SA: T: g66’$’ -&$% D*EF8)66’$’ 0-’ Y%.ELF<98$%0$’8*9$’ K$* G%<’7*$’8$’X:

‘5 &$’ *’69.77 0-’ ‘ ’7*EF$%F$*8$’ <.7 &$% V*5.9<8*-’ 0-’ \%$*/’*7<K9B.6$’ <.6 &*$ \%/$K’*7.’7*EF$%F$*8$’ &$% UV^ <KA.7EFB8A$’J 7*’& 6-9/$’&$ b$*8$%$’8#*EL9.’/$’ ’-8#$’&*/C

- W&$’8*6*L<8*-’ &$% \%$*/’*7<K9B.6$J K$* &$’$’ 7*/’*6*L<’8$ *’69N77$ <.7 &$’ ‘ ’7*EF$%F$*8$’ &$% V8)%6<997*5.9<8*-’ <.6 &<7 UV^2\%/$K’*7 A. $%#<%8$’ 7*’&J 5*8 c*%6$ 0-’ VE%$$’*’/2]$8F-&$’J
- o<’8*6*A*$%.’/ &$% \%/$K’*7.’7*EF$%F$*8$’ &$% <.7/$#BF98$’ V*5.9<8*-’7 2 %$EF’.’/$’ 5*8 0-%F<’&$’$’]$8F-&$’J
- HK$%8%</.’/ &$% ‘ ’7*EF$%F$*8$’ <.7 &$’ V8)%6<997*5.9<8*-’$’ <.6 &*$ ’<EF6-9/$’&$ UV^2^’<9_7L88$.’& o<’8*6*A*$%.’/ &$7 *’69.77$7 &*7% ‘ ’7*EF$%F$*8$’ <.6 &*$ \%/$K’*7.’7*EF$%F$*8$’ &$% UV^:

Y<’K’ 7-998$’ &*$ \’8#*EL9.’/$’ A.% L-’L%$8$’ T$F<’&9.’/ 0-’ ‘ ’7*EF$%F$*8$’J &*$ *5 P<F5$’ &$% ^%K$*8$’ 6N% &*$ ^L8.<9*7*$%.’/ .’& \%#$*8$%.’/ &$7 UV^2M$*86<&$’7 5*8 7$*’$’ A./$F)%*/$’ R<EFKB’&$’ S]$8F-&$’2 .’& Y<8$’K<’&X &.%EF/$6NF%8 #-%&$’ 7*’&J $*’$% b$*8$%$’8#*EL9.’/ .’& O%<L8*7EF$’ \%O%-K.’/ .’8$%A-/$’ #$%&$’J 5*8 &$% a*$97$8A.’/ $*’$% K%$*8$%$’ T$%NEL7*EF8*/.’/ 0-’ ‘ ’7*EF$%F$*8$’ *’ UV^:

- **Untersuchungen zu extremen Wetter- und Witterungsbedingungen**

T$* &$% ^.7$/.'/ L$%'8$EF'*7EF$% ^'<$' #$%&$' <.EF '<8.%K$&*'/8$ B.,$%$ *'#%L.'/$' K$%NEL7*EF8*/8: Y*$ ^.7$/.'/J #*$ <.EF 7OB8$%$ ''8$%7.EF.'/$'J 78N8A$' 7*EF K*7F$% h$&-EF '.% <.6 &$8$% 5*'*78*7EF$]$8F-&$' S^.7'<F5$C \%&K$K$'X: *'$ .56<77$'&$ D$.K$#$%8.'/ &$7 +$6BF%&.'/7O-8$'A*<97 7-9EF$% *'#*%L.'/$' <.6 &$% T<7*7 &$7 <L8.99' V8<'&$7 0-' b*77$'7EF<68 .'& G$EF'*L SA: T: <.EF .'8$% T$%NEL7*EF8*/.'/ &$% 5)/9*EF$' ^.7#*%L.'/$' $*'$7 5)/9*EF$' (9*5<#<'&$97X 7-#*$ $*'$ 0-9978B'&*/$ O%-K<K*9*78*7EF$ T$F<'&9.'/ 0-' #$88$%2 .'& #*88$%.'/7K$&*'/8$' *'#*%L.'/$' 78$F$' '-EF <.7:W'7K$7-'&$%$ 78F']$8F-&$' 6N% &*$ O%-K<K*9*78*7EF$ T$F<'&9.'/J &:F: 6N% &*$ *'K*'&.'/ 7-9EF$% \%$*/''*77$ *' &*$ UV^J K*7F$% *' Y$.87EF9<'& '*EF8A.% I$%6N/.'/:

'5 F*$% ^KF*96$ A. 7EF<66$'J 7-99$' A.'BEF78 0-%F<'&$'$ W'6-%5<8*-'$' .'& T<7*7<%K$*8$'J #*$ 7*$ K$*7O*$97#$*7$ 5*8 k(D[>Ik -&$% kfD >Ik 0-%9*$/$'J 7_78$5<8*7EF $%6<778 .'&<.7/$#$%8$8 #$%&$':

- **Methoden der probabilistischen Dynamik**

a.6B99*/ <.68%8'&$ \%$*/''*77$ SA: T: ^.76<99 0-' V_78$5L-5O-'$'8$'J a$*8&<.$% $*'$% 0-' &$% T$8%*$K75<''7EF<68 &.%EFA.6NF%$'&$' ^L8*-'J $e8$%'$ \%$*/''*77$X L)''$' ''6<99<K9B.6$ $%F$K9*EF K$$*'69.77$': Y*$ I*$96<98 5)/9*EF$% (-5K*'<8*-'$' 0-' a$*8O.'L8 .'& P$*F$'6-9/$ 7-9EF$% 78-EF<78*7EF$' \%$*/''*77$ F<8 A.% R-9/$J &<77 <.EF &*$ ''6<99<K9B.6$ $*'$ $%F$K9*EF$ I<%*<K*9*8B8 <.6#$*7$' L)''$':

]*8 &$']$8F-&$' &$% O%-K<K*9*78*7EF$' Y_'<5*L #$%&$' 78-EF<78*7EF$ \%$*/''*77$J &*$ $*'$' ''6<99<K9<.6 K$$*'69.77$' L)''$'J *' &*$ $'87O%$EF$'&$' Y_'<5*L2P$EF'.'/$' *'8$/%*$%8J .5 &*$ Y_'<5*L2V8-EF<78*L2b$EF7$9#*%L.'/$' *' $*'$5 U%-A$77<K9<.6 5)/29*EF78 %$<9*8B87/$8%$. .'& .56<77$'&7*5.9*$%$' A.L)''$':

a. &*$7$5 a#$EL #.%&$ &<7 ^'<9_7$#$%LA$./]ZY\G S**M**-'8$ **C**<%9- **D**_'<5*E **E**0$'8 **T**%$$X $'8#*EL$98J &<7 &*$ T$%NEL7*EF8*/.'/ &$% b$EF7$9#*%L.'/ A#*7EF$' &$% Y_'<5*L $*'$7 \%$*/''*7<K9<.6$7 .'& &$' V8-EF<78*L$*'69N77$' *5 P<F5$' $*'$% UV^ $%5)/9*EF8 .'& <97 \%/$K'*7 &_'<5*7EF$ \%$*/''*7KB.5$ 9*6%8J &*$ 7*EF $'89<'/ &$% a$*8<EF7$ *' ^KFB'/*/L$*8 0-' &$' <.68%8'&$' 78-EF<78*7EF$' \%$*/''*77$ $'8#*EL$9':

a.%A$*8 #*%& $*' b$%LA$./ $'8#*EL$98J 5*8 &$5 &$% *'69.77 0-' *'/%*66$' &$7 T$8%*$K7O$%7-'<97 $%6<778J 5-&$99*$%8 .'& *' &*$ &_'<5*7EF$' \%$*/''*7KB.5$ *'8$/%*$%8

#$%&$' L<'': Y*$ K*7F$% *' &$% UV^ 0$%#$'&8']$8F-&$' A.% ^'<9_7$ &$% 5$'7EF9*EF$' a.0$%9B77*/L$*8 L)''$' &*7' ^'7O%.EF '*EF8 $%6N99$':

Y.%EF &*$ *'K$A*$F.'/ &$% Y_'<5*L2V8-EF<78*L2b$EF7$9#*%L.'/$' *' &$' Y_'<5*L2 Z-&$ K<7*$%8 &*$ O%-K<K*9*78*7EF$ T$#$%8.'/ &$% <.7 &$' ''6<99<K9B.6$' 6-9/$'&$' VEF<&$'7A.78B'&$ <.6 $*'$% &$8<*99*$%8$' .'& %$<9*78*7EF$']-&$99*$%.'/: a.7B8A9*EF A. $*'$% 5)/9*EF78 /$'<.$' V*5.9<8*-' &$% OF_7*L<9*7EF$' UFB'-5$'$ L)''$' &*$ ^.7#*%L.'/$' 78-EF<78*7EF$% I<%*<8*-'$' 0-' *'69.77/%),$' <.6 &$' U%-A$77<K9<.6 K$%NEL7*EF8*/8 #$%&$':

W'7K$7-'&$%$ K$* &$% UV^ &$% V8.6$ 3 L)''$' '$K$' &$' $O*78$5*7EF$' S($''82 '*778<'&X ''7*EF$%F$*8$' <.EF &*$ <9$<8-%*7EF$' S78-EF<78*7EF$'X ''7*EF$%F$*8$' &*$ I<%*<K*9*8B8 &$% ''6<99<K9B.6$ $%F$K9*EF K$$*'69.77$': ^9$<8-%*7EF$ ''7*EF$%F$*8$' L)''$' 2 *5 +$/$'7<8A A. $O*78$5*7EF$' ''7*EF$%F$*8$' 2 *' &$% L-'0$'8*-'99' \%$*/'*7K<.5<'<9_7$ '.% .'A.%$*EF$'& K$%NEL7*EF8*/8 #$%&$':

'5 &$' *'69.77 78-EF<78*7EF$% +%),$' <.6 &$' &_'<5*7EF$' U%-A$77 K77% 5-&$99*$%$' .'& &.%EF &$' I$%/9$*EF 5*8 &$' \%/$K'*77$' <.7 &$% L-'0$'8*-'$99$' \%$*/'*7K<.5<'<9_7$ K$#$%8$' A. L)''$'J 7-99$' *' LN'68*/$' UV^2^'#$'&.'/$' 6N% <.7/$#BF98$ U%-K9$5$ O%-K<K*9*78*7EF$ Y_'<5*L%$EF'.'/$' O<%<99$9 A.% L-'0$'8*-'99' \%$*/'*7K<.5<'<9_7$ &.%EF/$6NF%8 #$%&$' SA:T: 6N% ''6<99<K9B.6$ K$*5 c-EF&%.EL2($%'7EF5$9A$'X:

Y<A. 7-998$' <.EF &*$ *5 *'8$%'<8*-'<9$' T$%$*EF 0-%9*$/$'&$' \'8#*EL9.'/$' .'& \%6<F%.'/$' S.:<: T$9/*$'J VO<'*$'J 'V^J \'Q A:T: kZ^Z dikX <.6 *F%$ D.8AK<%L$*8 6N% &$.87EF$ ($%'L%<68#$%L$ /$O%N68 #$%&$':

- **Unfallanalysen für den Nichtleistungsbetrieb bei offenem Reaktordruckbehälter (RDB)**

T$*5 ($%'7EF5$9A$' *' $*'$5 -66$'$' PYT L<'' *5 +$/$'7<8A A.5 ($%'7EF5$9A$' K$* /$7EF9-77$'$5 PYT M.68 $*'&%*'/$' .'& &$' ($%'A$%78)%.'/7O%-A$77 K$$*'69.77$': Y<&.%EF B'&$%8 7*EF &*$ 8F$%5*7EF$ \'$%/*$6%$*7$8A.'/ S[e*&<8*-' &$7 a*%L-'*.57 &.%EF M.687<.$%78-66 78<88 &.%EF V<.$%78-66 <.7 &$% c_&%-9_7$X .'& $7 $'878$F$' <'&$%$ P$<L8*-'7O%-&.L8$ <97 K$* /$7EF9-77$'$5 PYTJ 7-&<77 <.EF &*$ P<&*-'.L9*&6%$*7$8A.'/ K$$*'69.778 #*%&: T78F$'&$ PEF'O%-/%<55$ $'8F<98$' 0$%$*'A$98]-&$99$J &*$ &$%<%8*/$ U%-A77 K$%NEL7*EF8*/$' L)''$': Y*$7$]-&99 7*'&

<K$% 78<%L 0$%$*'6<EF8 .'& '*EF8 0<9*&*$%8: RN% &*$ UV^ &$% V8.6$ 3 6N% &$' D*EF89$*78.'/7K$8%*$K 7-99$' &*$7$]-&99 #$*8$% $'8#*EL$98 .'& 0<9*&*$%8 #$%&$':

- **Methoden zur Generierung und Validierung von Daten zur Zuverlässigkeit von Personalhandlungen**

RN% &*$ T$#$%8.'/ &$% a.0$%9B77*/L$*8 0-' U$%7-'<9F<'&9.'/$' #*%& &$%A$*8 *: b:&*$]$8F-&$ Gc\PU $5O6-F9$' k+PV >3k .'& kTRV dn< .'& Kk :Y*$ *'/<K$&<8$' 6N% &*$ Gc\PU2]$8F-&$ 5N77$' K*7F$% NK$%#*$/$'& &$5 c<'&K.EF 0-' V#<*' .'& +.885<'' kVb^ i@k $'8'-55$' #$%&$'J-K#-F9 &*$ &-%8 $'8F<98$'$' Y<8$' %$9<8*0 <98 7*'& .'& A.5 /%-,$' G$*9 '*EF8 <.7 &$% ($%'8$EF'*L 78<55$': *'$ I<9*&*$%.'/ &$% Y<8$' 6N% &*$ T$&*'/.'/$' *' &$% ($%'8$EF'*L -&$% 7O$A*6*7EF$ Y<8$' 6N% &*$ ($%'8$EF'*L /*K8 $7 '.% O.'L8.$99: a.&$5 *78 &*$ Y<8$'K<7*7 kVb^ i@k '*EF8 -F'$ #$*8$%$7 <.6 <'&$%$ L.98.%99 c*'8$%/%N'&$ 7-#*$.'8$%7EF*$&9*EF$ ^.7K*9&.'/72 .'& T$8%*$K70$%FB98'*77$ NK$%8%</K<%: ^'/$7*EF87 &$% T$&$.8.'/ &$% a.0$%9B77*/L$*8 0-' U$%7-'<9F<'&9.'/$' 6N% &*$ UV^2\%/$K'*77$ *78 $*'$ I<9*&*$%.'/ &$% F$%<'A.2 A*$F$'&$' Y<8$'J $*'$ I$%K%$*8$%.'/ &$% Y<8$'/%.'&9</$.'& &*$ b$*8$%$'8#*EL9.'/ &$%]$8F-&$' A.% +$#*''.'/ &$% Y<8$' $%6-%&$%9*EF:

W' &$% I$%/<'/$'F$*8 #.%&$ 7-#-F9 '<8*-'<9 <97 <.EF *'8$%'<8*-'<9 *55$% #*$&$% 0$%7.EF8J &$']<'/$9 <' K$9<78K<%$' Y<8$' A. KFK$': b$7$'89*EF$ R-%87EF%*88$ #.%&$' <99$%&*'/7 $%78 *' &$' 9$8A8$' f<F%$' $%A*$98: Y*$ *' &-L.5$'8*$%8$' R-%7EF.'/7<%K$*8$' k+PV >1k 9*$6$%8$']$8F-&$'J 5*8 &$'$' ^.76<99#<F%7EF$*'2 9*EFL$*8$' 0-' U$%7-'<9F<'&9.'/$' <.7 &$% T$8%*$K7$%6<F%.'/ 5*8 &$.87EF$' ($%'L%<68#$%L$' $%5*88$98 #$%&$' L)''$': Y*$]$8F-&$' #.%&$' <' T$*7O*9' $%O%-K8 .'& 6NF%8$' A. $%78$' \%L$''8'*77$' NK$% &*$ I<9*&*8B8 &$% Gc\PU2Y<8$'J.5 &*$ '<EF #*$ 0-% 0-%F<'&$'$' MNEL$' A. 7EF9*$,$': Y<K$* 7*'& 5$8F-&*7EF$ b$*8$%$'82 #*EL9.'/$' A.6-9/$'&$' ^7O$L8$' &.%EFA.6NF%$'C

- D.8A.'/ 0-' I-%$%6<F%.'/ A. 0$%/9$*EFK<%$' c<'&9.'/$' <.7 <'&$%$' ^'9</$'J <.7 V*5.9<8-%NK.'/$' .'& <.7 &$% T$6%</.'/ 0-' ^'9</$'O$%7-'<9 SO/9: k+PV >1kXJ

- T$#$%8.'/ &$% b*%L.'/ 0-' R<L8-%$'J &*$ &*$ a.0$%9B77*/L$*8 0-' U$%7-'<92 F<'&9.'/$' K$$*'69.77$': c*$%K$* 7*'& <.EF *'69N77$ &$% T$8%*$K7-%/<'*7<8*-' $*'A.K$A*F'J

- +$'$%*$%.'/ 0-' Y<8$' A. U$%7-'<9F<'&9.'/$' <.,$%F<9K &$% b<%8$J A. c<'&9.'/$' K$*<K/$7EF<98$8$% ^'9</$7-#*$A. P$O<%<8.%F<'&9.'/$':

Y*$ R%</$78$99.'/ &$% F$%<'A.A*F'&$' Y<8$' 6N% &*$ T$#$%8.'/ &$% a.0$%9B77*/L$*8 0-' U$%7-'<9F<'&9.'/$' *78 $'/ 0$%K.'&$' 5*8 &$5 A./%.'&$ A. 9$/$'&$' 5$8F-&*7EF$' P<F5$'J*''$%F<9K &$%$% 9$8A8$%$ $%5*88$98 #$%&$': Y$7F<9K 7-998$' <.EF &*$ *5 *'8$%'<8*-'<9$' T$%$*EF 0-%9*$/$'&$' b$*8$%$'8#*EL9.'/$' .'& \%6<F%.'/$' A.% L-'7*78$'8$' \%5*889.'/ 0-' Y<8$' .'8$% c$%<'A*$F.'/ $*'$% 6-%87EF%*889*EF$']$8F-&*L SO/9: A: T: kP\ >IkX A. &*$7$5 GF5'K$%$*EF 5*8 K$%NEL7*EF8*/8 #$%&$':

8.2.2 Neuentwicklung von Methoden

- **Bewertung der Zuverlässigkeit softwarebasierter Leittechnik**

G%-8A *'8$'7*0$% T$5NF.'/$' $e*78*$%$' K*7F$% #$98#$*8 L$*'$ <'$%L<''8$']$8F-&$' A.% p<'8*8<8*0$' \%5*889.'/ &$% a.0$%9B77*/L$*8 7-68#<%$K <7*$%8$% M$*88$EF'*L7_78$5$:

]*8 $e*78*$%$'&$' 5$8F-&*7EF$' ^'7B8A$' 7*'& A#<% %$9<8*0$ a.0$%9B77*/L$*872 K$#$%8.'/$' A. <98$%'<8*0$' ^.76NF%.'/$' 7-68#<%$K<7*$%8$% V_78$5$' 5)/9*EF: \7*78 <K$% '-EF '*EF8 5)/9*EFJ &*$ a.0$%9B77*/L$*8 7- A. p<'8*6*A*$%$'J &<77 $*'$ K$9<78K<%$ P$9<8*-' &$% a.0$%9B77*/L$*8 7-68#<%$K<7*$%8$% M$*88$EF'*L7_78$5$ A.% a.0$%9B77*/L$*8 0$%6<F%$'78$EF'*7EF$% (-5O-'$'8$' -&$% 9$*88$EF'*7EF$% *'%*EF8.'/$' *' <'<9-/$% G$EF'*L <'/$/K' #$%&$' L<'': T*7F$% *78 $7 <.EF '*EF8 5)/9*EFJ &$' O%-K<K*9*78*7EF$' D<EF#$*7 A. 6NF%$'J &<77 $*' '$.$7 7-68#<%$K<7*$%8$7 M$*88$EF'*L7_78$5 5*'&$78$'7 &*$ /9$*EF$ a.0$%9B77*/L$*8 $%%$*EF8 #*$ &<7 A. $%7$8A$'&$ M$*88$EF'*L7_78$5*' <'<9-/$% G$EF'*L:

T$&*'/8 &.%EF &$' 8$EF'*7EF$' R-%87EF%*88 F<8 $7*' &$' 9$8A8$' E<: 1= f<F%$' K$* &$% M$*88$EF'*L .'& <.EF K$* (-5O-'$'8$' &$% \9$L8%-8$EF'*LJ #*$ K$* VEF.8A%$9<*7*' &$' VEF<98<'9</$' -&$% K$* *'8$99*/$'8$' ^'8%*$K7NK$%#<EF.'/75-&.9$'J $*'$' +$'$%<8*-'7#$EF7$9 0-' 6$780$%&%<F8$8$' <'<9-/$' A. 7-68#<%$K<7*$%8$' V_78$5$' .'& +$%B8$' /$/$K$': Y*$7$ \'8#*EL9.'/ *78*''A#*7EF$' 7- #$*8 6-%8/$7EF%*88$'J &<77 K$* &$% \%7<8AK$7EF<66.'/ -68 '.%''-EF 7-68#<%$K<7*$%8$ +$%B8$ <'/$K-8$' #$%&$':

W' &$' &$.87EF$' ($%'L%<68#$%L$' #$%&$' <.EF *' 7*EF$%F$*87%$9$0<'8$' T$%$*EF$' A.'$F5$'& 7-68#<%$K<7*$%8$ M$*88$EF'*L7_78$5$' $*'/$7$8A8: Y*$ $%78$' ^'9</$' F<K$' <'<9-/$ &.%EF 7-68#<%$K<7*$%8$ T$/%$'A.'/77_78$5$ $%7$8A8: T$&*'/8 &.%EF &<7 T$8%*$K7<98$% &$% &$.87EF$' ^'9</$' *78*' &$% 'BEF78$' a$*8 &<5*8 A. %$EF'$'J &<77 7*EF &*$7$% G%$'& '-EF 0$%78B%L8:

^.6 &*$ UV^ 6N% &*$ K$8%-66$'$' ^'9</$' F<88$' &*$7$ ' 578$99.'/$' K*7F$% L$*'$' /%-,$' *'69.77J &< &*$ $%'$.$%8$' T$/%$'A.'/77_78$5$ L$*'$' #7'89*EF$' T$*8%</ A.5 \%/$K'*7 &$% UV^ 9*6%':W' '<F$% a.L.'68 *78 h$&-EF A. $%#<%8$'J &<77 <.EF *5 V*EF$%F$*877_78$5 <.6 7-68#<%$K<7*$%8$ M$*88$EF'*L .5/$78$998 #*%&: Y<'' #*%& &<7 \%/$K'*7 &$% UV^ $%F$K9*EF 0-' &$% o<'8*6*A*$%.'/ &$% 7-68#<%$K<7*$%8$' M$*88$EF'*L &$7 V*EF$%F$*877_78$57 <KFB'/*/: ^.7 &*$7$5 +%.'& *78 $7 $%6-%&$%9*EFJ &*$]$8F-&$'$'8#*EL9.'/ A.% p<'8*8<8* 0$' a.0$%9B77*/L$*87K$#$%8.'/ 7-68#<%$K<7*$%8$% M$*88$EF'*L7_78$5$ #$*8$% 6-%8A.6NF%$':W' &*$7$5 a.7<55$'F<'/ 7-998$' A.'BEF78 &*$ \'8#*EL9.'/$' .'& \%6<F%.'/$'J &*$ A. &*$7$5 GF$5< <.EF <.,$%F<9K &$% ($%'8$EF'*L *' $*'$5 /%),$%$' ' 56<'/ 0-%9*$/$' SO/9: A: T: kVUW>IkXJ *5 c*'K9*EL <.6 $*'$ 5)/9*EF$ D.8AK<%L$*8 .'8$%7.EF8 #$%&$':

- **Berücksichtigung von übergreifenden Einwirkungen durch Fremdspannungseinträge in die Leittechnik**

'$ 5$EF<'*78*7EF$ T$#$%8.'/ &$% R-9/$' 0-' VEFB&$' <' \'$%/$2 .'& M$*88$EF'*L2 (<K$9'J &*$.:<: &.%EF T%<'&J I$%7</$' 0-' (-50-'$'8$'J c<'&F<K.'/76$F9$%J NK$%/%$*6$'&$ *'#*%L.'/$' 0-' <.,$' 0$%.%7<EF8 #$%&$' L)''$'J *78 K$* F$.8*/$5 V8<'& &$% UV^2]$8F-&$' <.EF &<'' '*EF8 5)/9*EFJ #$'' /$'<.$ W'6-%5<8*-'$' NK$% &*$)%89*EF$ I$%9$/.'/ .'& &*$ R.'L8*-' K$8%-66$'$% (<K$9 A.% I$%6N/.'/ 78$F$': W'7K$7-'&$%$ *78 &$%A$*8 '*EF8 /$L9B%8J #*$ &*$ 0$%7EF*$&$'$' I$%7</$'75)/9*EFL$*8$' $*'$7 M$*88$EF'*LL<K$97 S' '8$%K%$EF.'/J (.%A7EF9.77J V*/''<90$%B'&$%.'/J HK$%7O<'2 '.'/7$*'8%</X 5*8 *F%$' .'8$%7EF*$&9*EF$' R-9/$' *' &*$ UV^ $*'/$F$' L)''$': ^'&$%$%7$*87 L<'' '*EF8 <.7/$7EF9-77$' #$%&$'J &<77 *5 \e8%$56<99 &$% VEF<&$'72 <.7K%$*8.'/ <.6 A#$* -&$% 5$F% P$&.'&<'AK$%$*EF$ 6$F9$%F<68$ P$<L8*-'$' &$7 P$<L8-%7EF.8A7_78$57 <.68%$8$' L)''$'J &*$ &*$ TF%%7EF.'/ $*'$% /9$*EFA$*8*/ <.68%8'&$' G%<'7*$'8$ $%7EF#$%$' -&$% 0$%F*'&$%':

'5 &$' *'69.77 7-9EF$% \%$*/''*77$ <.6 &*$ cB.6*/L$*8 0-' VEF<&$'7A.78B'&$' <KA.7EFB8A$'J 7*'&]$8F-&$' A. $'8#*EL9'J 5*8 &$'$' &*$ cB.6*/L$*8 %$&.'&<'ANK$%/%$*6$'&$% VEFB&$' <' 7*EF$%F$*87%$9$0<'8$' \'$%/*$2 .'& M$*88$EF'*L2 L<K$9' $%5*88$98 .'& *F%$ R-9/$' 6N% &*$ ^'9</$ *' T$A./ <.6 &*$ cB.6*/L$*8 0-' VEF<&$'7A.78B'&$' <K/$7EFB8A8 #$%&$' L)''$':

]*8 &*7% a*$97$8A.'/ 7-998$' 6-9/$'&$ ‘ '8$%7.EF.'/$' &.%EF/$6NF%8 #$%&$'C

- W&$'8*6*L<8*-' 0-' P<.5K$%$*EF$' *' $*'$% P6%$'A<'9</$J K$* &$'$' T%B'&$ -&$% <'&$%$ *'#*%L.'/$' *5 \e8%$56<99 %$&.'&<'ANK$%/%$*6$'&$ VEFB&$' <' 7*EF$%F$*87%$9$0<'8$' (<K$9' 0$%.%7<EF$' L)''$'J

- \'8#*EL9.'/ 0-']$8F-&$' A.% \%5*889.'/ &$% cB.6*/L$*8 7-9EF$% VEFB&$'J

- \'8#*EL9.'/ 0-']$8F-&$' A.% ^K7EFB8A.'/ &$% K$&*'/8$' b<F%7EF$*'9*EFL$*8 0-' VEF<&$'7A.78B'&$' K$* %$&.'&<'ANK$%/%$*6$'&$' VEFB&$' SVE%$$'*'/2]$8F-&$X:

· **Entwicklung von Methoden zur Berücksichtigung von wissensbasierten Handlungen mit positivem Einfluss auf die Anlagensicherheit**

^97 #*77$'7K<7*$%8 #$%&$' U$%7-'<9F<'&9.'/$' KA*EF'$8J &*$ 2 <.7/F'& 0-5 0$%6N/K<%$' b*77$'*'7K$7-'&$%$ NK$% &*$ 7_78$58$EF'*7EF$' a.7<55$'FB'/$ 2 <.6 &$% +%.'&9</$ $*'$% Y*</'-7$ 7*8.<8*-'77O$A*6*7EF '$. /$O9<'8 .'& &.%EF/$6NF%8 #$%&$': V*8.<8*-'77O$A*6*7EF$ U9<'.'/ *78 <.EF &<'' $%6-%&$%9*EFJ #$'' A#<% 0-%/$O9<'8$]<,'<F5$' 0$%6N/K<% 7*'&J &*$ 8<87BEF9*EF$' P<'&K$&*'/.'/$' <K$% #7'89*EF 0-' &$' 0-%/$O9<'8$' P<'&K$&*'/.'/$' 6N% &$' *'7<8A &*7%]<,'<F5$' <K#$*EF$': b*77$'7K<7*$%8$ c<'&9.'/$' 7*'& *' ^'9</$'7*8.<8*-'$' $%6-%&$%9*EFJ 6N% &*$ L$*'$<.7%$*EF$'&$ I-%O9<'8*6 K$%$*8/$78$998 #$%&$' L<'': c*$%A./$F)%$'.:<:

- ‘ '$%#<%8$8 $*'8%$8$'&$ \%$*/''*77$ K$* &$% P$0*7*-'J

- L.%A6%*78*/ &.%EF/$6NF%8$ P$O<%<8.%$' '<EF *'8%*88 $*'$7<.79)7$'&$' \%$*/''*77$7J

- L-5O9e V8)%6<99 2 -&$% ‘ '6<997*8.<8*-'$':

^.7 &$% &$.87EF$' .'& <.79B'&*7EF$' T$8%*$K7$%6<F%.'/ 7*'& A<F9%$*EF$ \%$*/''*77$ K$L<''8J *' &$'$' &<7 U$%7-'<9 #*77$'7K<7*$%8 0-%/*'/ .'& &<&.%EF /%),$%$ VEFB&$' 0$%5$*&$' L-''8$: a.5 ‘ '8$%7.EF.'/7.56<'/ 0-' UV^ &$% V8.6$' 1 .'& 3 /$F)%$' <.EF P$0*7*-'7A.78B'&$J P$O<%<8.%5<,'<F5$' *' V8)%6<997*8.<8*-'$'J <.79$/.'/72 NK$%7EF%$*8$'&$ ^K9B.6$.'& ‘ '6<997*8.<8*-'$': a.% T$#$%8.'/ &$% *' &*7' V*8.<8*-'$' A. $%#<%8$'&$' #*77$'7K<7*$%8$' c<'&9.'/$' 78$F$' K*7F$% L$*'$ <'$%L<''8$']$8F-&$' A.% I$%6N/.'/ k+PV >3kJ kTRV dn< .'& K kJ k[\ZY dikJ k[\ZY >lk .:<:: V-9EF$ c<'&9.'/$' #$%&$' &$7F<9K *' &$% UV^ '*EF8 K$%NEL7*EF8*/8J -K#-F9 7*$ $%F$K9*EF$' *'69.77 <.6 &*$ \%/$K'*77$J *'7K$7-'&$%$ K$* &$% UV^ &$% V8.6$ 3J F<K$' L)''$':

‘ 5 &*$ ^.77</$L%<68 0-’ \%/$K’*77$’ O%-K<K*9*78*7EF$% V*EF$%F$*87<’<9_7$’ &$% V8.6$’ 1 .’& 3 A. $%F)F$’J 7*’&]$8F-&$’ A.% T$%NEL7*EF8*/.’/ 0-’ #*77$’7K<7*$%8$’ c<’&9.’/$’ A. $’8#*EL$9’ .’& Y<8$’ A.% a.0$%9B77*/L$*8 7-9EF$% c<’&9.’/$’ K$%$*8A.78$99$’: Y*$7$ 7*’&C

- \’8#*EL9.’/ $*’$7 I$%6<F%$’7 A.% W&$’8*6*L<8*-’ 0-’ A. .’8$%7.EF$’&$’ #*77$’7K<7*$%8$’ c<’&9.’/$’

  ]*8 &$5 I$%6<F%$’ 7-99$’ 5)/9*EF$ #*77$’7K<7*$%8$ c<’&9.’/$’ &$7 U$%7-’<97 .’& &*$ I-%<.77$8A.’/$’ $%5*88$98 #$%&$’J &*$ 6N% &*$ ^.76NF%.’/ 7-9EF$% c<’&9.’/$’ #7’89*EF 7*’&: c*$%K$* *78 <’A.’$F5$’J &<77 &<7 U$%7-’<9 K$* &$% ^.7#<F9J U9<’.’/ .’& Y.%EF6NF%.’/ <.6 \%6<F%.’/$’ A.%NEL/%$*68 .’& &<77 &*$ c<’&9.’/ 7*EF*’ &$5 K$-K<EF8K<%$’ ‘ 56$9& <97 $%9<.K8 .’& A*$96NF%$’& &<%78$998:

- \’8#*EL9.’/ $*’$7]-&$997 A.% T$7EF%$*K.’/ &$% L-/’*8*0$’ U%-A$77$ K$* &$% W&$’8*6*L<8*-’J \’87EF$*&.’/ .’& U9<’.’/ $*’$% #*77$’7K<7*$%8$’ c<’&9.’/

  ^97 (-/’*8*-’ #$%&$’ &*$ O7_EF*7EF$’ ^L8*O*8B8$’ KA*EF’$8J <.6 &$’$’ \%#$%KJ [%/<’*7<8*-’ .’& D.8A.’/ 0-’ b*77$’ K$%.F$’ kD\Wm W’ c<’&9.’/77*8.<8*-’$’J &*$ 0-5 (%<68#$%L7O$%7-’<9 &*$ Y.%EF6NF%.’/ 0-’ ’$.<%8*/$’J ’*EF8 <.7%$*EF$’& 0-%/$O9<’8$’ c<’&9.’/$’ $%6-%&$%’J 7*’& &*$ L-/’*8*0$’ U%-A$77$ K$* &$% W’6-%5<8*-’7<.6’<F5$.’& I$%<%K$*8.’/ 7-#*$ &*$ /N’78*/$ KA#: .’/N’78*/$ +$78<98.’/ &$% &*7 U%-A77 K$$*’69.77$’&$’ R<L8-%$’ 5<,/$K9*EF 6N% &*$ b<F%7EF$*’9*EFL$*8J &<77 7-9EF$ c<’&9.’/$’ *&$’8*6*A*$%8 .’& $%6-9/%$*EF <.7/$6NF%8 #$%&$’: \7 5.77 7-5*8 $*’]-&$99 K$%$*8/$78$998 #$%&$’J &<7 ^.6K<. .’& ^%K$*87#$*7$ 5$’7EF9*EF$% (-/’*8*-’ *’ *F%$’ #$7$’89*EF$’]$%L5<9$’ &<%78$998 .’& $*’$ 7_78$5<8*7EF$ W&$’8*6*L<8*-’ .’& b$%8.’/ &$% &$’ (-/’*8*-’7O%-A$77 K$$*’69.77$’&$’ R<L8-%$’ $%5)/9*EF8:

- +$’$%*$%.’/ 0-’ p<9*8<8*0$’ .’& p<’8*8<8*0$’ Y<8$’ A. #*77$’7K<7*$%8$’ c<’&9.’/$’

  Y$%A$*8 9*$/$’ L$*’$ <.7%$*EF$’& &$8<*99*$%8$’ .’& 0$%*6*A*$%8$’ p<’8*8<8*0$’ Y<8$’ A.% a.0$%9B77*/L$*8 #*77$’7K<7*$%8$% c<’&9.’/$’ 0-%: Y*$ +$’$%*$%.’/ 0-’ Y<8$’ 7-99 5*8 0-%F<’&$’$’]$8F-&$’ k+PV >1kJ k+PV >@k $%6-9/$’J #-K$* \%L$’’8’*77$ <.7 &$% &$.87EF$’ T$8%*$K7$%6<F%.’/ 5*8 \%$*/’*77$’ .’8$%F<9K .’& -K$%F<9K &$%]$9&$7EF#$99$ A. ’.8A$’ 7*’&:

^.EF A.%]-&$99*$%.’/ L-/’*8*0$% U%-A$77$J &: F: &$% 6-%87EF%*889*EF$’ T$%NEL7*EF8*/.’/ &$7 L-/’*8*0$’ ^7O$L8$7 5$’7EF9*EF$’ c<’&$9’7 *’ &$% &_’<5*7EF$’ b$EF7$9#*%L.’/

5*8 &$% 7-A*-28$EF'*7EF$' ‘ 5/$K.'/J 9*$/$' *5 *'8$%'<8*-'<9$' T$%$*EF .56<'/%$*EF$ \'8#*EL9.'/$' .'& \%6<F%.'/$' SA: T: kP\ >IkJ kZ^Z d=kX 0-%J &*$ *' Y$.87EF9<'& K$%$*87 e5O9<%*7EF <'/$#$'&$8 #.%&$' kVUW >>k:

- **Untersuchungen zur Berücksichtigung organisatorischer Einflüsse sowie von Einflüssen des Sicherheitsmanagements**

V*EF$%F$*875<'</5'8 *78 $*' #$7$'89*EF$7 W'78%.5$'8J .5 $*'$ F-F$ a.0$%9B77*/L$*8 &$% 8$EF'*7EF$' *'%*EF8.'/$' .'& -%/<'*7<8-%*7EFk<&5*'*78%<8*0$']<,'<F5$' <.6 <99$' \K$'$' &$7 /$78<66$98$' VEF.8AL-'A$O87 A. /$#BF%9$*78$': V*EF$%F$*872 5<'</$5$'8 *78 $*'$ ^.6/<K$ &$% /$7<58$' [%/<'*7<8*-' .'& <99$% K8*9*/8$' U$%7-'$'J '*EF8 '.% $*'$% 7O$A*$99$' [%/<'*7<8*-'7$*'F$*8:

Y< &<7 V*EF$%F$*875<'</5'8 &*$ P$/$9.'/$' .'&]<,'<F5$' .56<778J 5*8 &$'$' $*'$ F-F$ o<9*8B8 <99$% 6N% &*$ V*EF$%F$*8 K$&$.87<5$' GB8*/L$*8$' /$#BF%9$*78$8 #$%&$' 7-99J #*%& $7 *5 ^99/$5$*'$' <97 G$*9 &$7 o<9*8B875<'</5'87_78$57 K$8%<EF8$8: Y*$7$ V*EF8#$*7$ *78 /%.'&7B8A9*EF A.8%66'&Q 7*$ *5O9*A*$%8 h$&-EF &*$ +$6<F%J &<77 '*EF8 /$A*$98 NK$%O%N68 #*%&J -K &<7 V*EF$%F$*875<'</5'8 /$7EF9-77$' .'& L-'7*78$'8 .5/$7$8A8*78:

Y*$ #7'89*EF$' \9$5$'8$ &$7 V*EF$%F$*875<'</$5$'87 7*'& '<EF WDV^+21@C

- R789/.'/ 0-' V*EF$%F$*87O-9*8L .'& V*EF$%F$*87A*9' 7-#*$ $*'$% 7*EF$%2 F$*87/$%*EF8$8$' [%/<'*7<8*-'J
- P$/$9.'/$' .'& W'78%.5$'8$ A.% U9<'.'/J ^K#*EL9.'/ .'& ‘ '8$%78N8A.'/ &$% 7*EF$%F$*87%$9$0<'8$' ^.6/<K$'J
- 7*EF$%F$*87/$%*EF8$8$ Y.%EF6NF%.'/ &$% ^.6/<K$' &.%EF &$' *'A$9'$'
- HK$%#<EF.'/ &$% *'F<98.'/ 0-' I-%/<K$' .'& V8<'&<%&7 7-#*$ D.8A.'/ &$7 \%6<F%.'/7%NEL69.77$7 S\%6-9/7L-'8%-99$.'& PNELL-OO9.'/X:

Y*$ T$#$%8.'/ &$7 T$*8%</$7 &$7]$'7EF$' A.% I$%5$*&.'/ -&$% T$F$%%7EF.'/ 0-' V8)%6B99$' *78 $*'$ #7'89*EF$ G$*9<.6/<K$ &$% UV^: Y*$ 0$%6N/K<%$']$8F-&$' A.% O%-K<K*9*78*7EF$' T$#$%8.'/ &$7 T$*8%</$7 &$7]$'7EF$' K$%NEL7*EF8*/$' &$%A$*8 '.% *' /$%*'/$5 ‘ 56<'/ -%/<'*7<8-%*7EF$ *'69.776<L8-%$': Y$% *'69.77 &$7 V*EF$%F$*872 5<'</$5$'87J &: F: &$% /N'78*/$' KA#: .'/N'78*/$' +$78<98.'/ <99$% 6N% &*$ V*EF$%F$*8 &$% ^'9</$ #7'89*EF$' -%/<'*7<8-%*7EF$' *'69.776<L8-%$' <.6 &*$ a.0$%9B77*/L$*8 0-' U$%7-'$'F<'&9.'/$'J #$%&$' &$%A$*8 '*EF8 5-&$99*$%8 .'& K$#$%8$8:

Y*$ &$.87EF$ T$8%*$K7$%6<F%.'/ F<8 /$A$*/8J &<77 .'/N'78*/ /$78<98$8$ -%/<'*7<8-%*7EF$ *'69.776<L8-%$' A. R$F9F<'&9.'/$' .'& &<%NK$% F*'<.7 A.5 I$%7</$' 0-' I-%L$F%.'/$' A.% R$F9$%$'8&$EL.'/ .'& A.% R$F9$%L-5O$'7<8*-' /$6NF%8 F<K$':W' *'A$%B99$' 6NF%8$ &*$7 A. $*'$% VEF#BEF.'/ 5$F%$%$% \K$'$' &$7 /$78<66$98$' V*EF$%F$*87L-'A$O87 &$% K$8%-66$'$' ^'9</$: Y<7 R$F9$' /$$*/'8%]$8F-&$' A.% T$#$%8.'/ 7-9EF$% a.7<55$'FB'/$ 7EF%B'L8 &*$ ^.77</$L%<68 0-' UV^ $%F$K9*EF $*':

^.6/%.'& &$% P$9$0<'A &$% K$7EF%*$K$'$' Y$6*A*8$ *78 .'8$% D.8A.'/ /$$*/'8% \%6<F%.'/$' <.7 &$5 *'8$%'<8*-'<9$' T$%$*EF $*'$ b$*8$%$'8#*EL9.'/ 0-']$8F-&$' .'& Y<8$' A.% T$#$%8.'/ &$7 V*EF$%F$*875<'</$5$'87 *5 P<F5$' &$% UV^ 0-' /%-,$% T$&$.8.'/ S7*F A: T: kVUW >3kX:

- Y*$ \'8#*EL9.'/ 0-']$8F-&$' A.% T$%NEL7*EF8*/.'/ &$7 *'69.77$7 -%/<'*7<8-%*7EF$% R<L8-%$' KA#: &$7 V*EF$%F$*875<'</5'87*' $*'$% UV^ .'&
- &*$ +$'$%*$%.'/ 0-' Y<8$' A.5 *'69.77 0-' -%/<'*7<8-%*7EF$' R<L8-%$' KA#: &$7 V*EF$%F$*875<'</$5$'87 <.6 &*$ a.0$%9B77*/L$*8 0-' U$%7-'<9F<'&9.'/$' <.7 &$% T$8%*$K7$%6<F%.'/:

- **Entwicklung von Methoden zur approximativen Durchführung von Unsicherheits- und Sensitivitätsanalysen für probabilistische Dynamikrechnungen**

T$* L-5O9$e$' Z-5O.8$%5-&99'J #*$ 7*$ A: T: K$* &$% Y.%EF6NF%.'/ 0-' O%-K<K*9*78*7EF$' Y_'<5*L%$EF'.'/$' A.% ^'#$'&.'/ L-55$'J L)''$' K$*&$ ^%8$' 0-' ''7*EF$%F$*8$' 2 <9$<8-%*7EF$.'& $O*78$5*7EF$ 2 *' &$% P$/$9 '.% 5*8]$8F-&$' &$%]-'8$ Z<%9- V*5.9<8*-'K$F<'&$98 #$%&$': Y*$ <'/$55$77$'$ T$F<'&9.'/ K$*&$% ^%8$' 0-' ''7*EF$%F$*8$' *78 $*'$ 7-/: A#$*78.6*/ 0$%7EF<EF8$98$]-'8$ Z<%9-V*5.9<8*-'C

- a.6<997<.7#<F9 0-' b$%8$' &$% $O*78$5*7EF$' +%),$' /$5B, &$%$' 7.Kh$L8*0$' b<F%7EF$*'9*EFL$*870$%8$*9.'/$' SB.,$%$|V* 5.9<8*-'X .'&
- a.6<997<.7#<F9 0-' b$%8$' &$% <9$<8-%*7EF$' I<%*<K9$' /$5B, *F%$' K$&*'/8$' b<F%7EF$*'9*EFL$*870$%8$*9.'/$' S!*''$%$; V*5.9<8*-'X:

f$&$ *''$%$ V*5.9<8*-' #N%&$ <97 \%/$K'*7 $*'$ $5O*%*7EF$ b<F%7EF$*'9*EFL$*872 0$%8$*9.'/ 6N% &*$ *'8$%$77*$%$'&$ U%-A$77/%),$ 9*6%': ^97 \%/$K'*7 &$% A#$*78.6*/$'

V*5.9<8*-' $%F*$88$ 5<' 7EF9*$,9*EF $*'$ V8*EFO%-K$ 7-9EF$% $5O*%*7EF$' b<F%7EF$*'9*EFL$*870$%8$*9.'/$'J &*$ *' /$$*/''8% b$*7$ $*'$% ''7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$ A.A.6NF%$' #B%$':

T$*5 *'7<8A %$EF$'A$*8*'8$'7*0$% Z-5O.8$%5-&$99$ *78 &$% P$EF$'<.6#<'& <99$%&*'/77- /%-,J &<77 $*'$ A#$*78.6*/$ V*5.9<8*-' 2 <.EF .'8$% T$'.8A.'/ 9$*78.'/76BF*/$% U<%<99$9%$EF'$% 2 ''*EF8 O%<L8*L<K$9 *78: Y*$ (-'7p'A #B%$ &$5A.6-9/$ $*' 0)99*/$% I$%A*EF8 <.6 $*'$ ''7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$J #$'' 7-#-F9 <9$<8-%*7EF$ <97 <.EF $O*78$5*7EF$ ''7*EF$%F$*8$' K$%NEL7*EF8*/8 #$%&$' 7-99$': Y< &*$7 6N% O%-K<2 K*9*78*7EF$' Y_'<5*L%$EF'.'/$' 0-%/$7F' *78J $%7EF$*'8 &*$ \'8#*EL9.'/ .'& \%O%-K.'/ 0-']$8F-&$' 7*''0-99J 5*8 &$'$' 5<' .'8$% I$%5$*&.'/ &$% 0-99$' A#$*78.6*/ /$7EF*EF8$8$']-'8$ Z<%9- V*5.9<8*-' .'& 5*8 $*'$5 $%F$K9*EF /$%*'/$%$' P$EF$'<.6#<'& A. K%<.EFK<%$' <OO%-e*5<8*0$' ''7*EF$%F$*872 .'& V$'7*8*0*8B872 <.77</$' /$9<'/$' L<'':

8.2.3 Entwicklung von Werkzeugen

- **Programmtechnische Verbesserung der Schnittstelle zwischen Stufe 1 und Stufe 2 der PSA**

\7 *78 5)/9*EFJ &*$ V8.6$' 1 .'& 3 &$% UV^ ;*'8$/%<9; A. K$<%K$*8$': Y*$ %EF'%*7EF$ ^'<9_7$ &$% V8.6$' 1 .'& 3 $%6-9/8 *' &*$7$5 R<99 5*8 &$57$9K$' PEF'5-&$99 .'& $*'$ 7O$A*$99$ VEF'*8878$99$ A#*7EF$' V8.6$ 1 .'& 3 *78 ''*EF8 $%6-%&$%9*EF: Y*$ 6N% &*7 I-%/F'7#$*7$ 0$%6N/K<%$' PEF'O%-/%<55$ 78<55$' <.7 &$5 '56$9& &$% V8.6$ 1 &$% UV^ .'& 7-998$' F*'7*EF89*EF *F%$% VEF'*8878$99$'$*/$7EF<68$' -O8*5*$%8 #$%&$':

Y*$ *' &$% V8.6$ 1 $%5*88$98$' W'6-%5<8*-'$' A. ($%'7EF<&$'7A.78B'&$' K$7EF%$*K$' <99$]$%L5<9$J &*$ 6N% &*$ #$*8$%$' ''8$%7.EF.'/$' *' &$% UV^ &$% V8.6$ 3 $%6-%&$%9*EF 7*'&J <97- 'K' &$5 ($%'A.78<'& <.EF &$' a.78<'& &$% 0'8.$99 '-EF 0$%6N/K<%$' V*EF$%F$*877_78$5$.'& &$' a.78<'& &$7 V*EF$%F$*87K$FB98$%7: \7 *78 $%6-%&$%9*EFJ *' &$% V8.6$ 1 &$% UV^ &*$ cB.6*/L$*8 <99$% <.68%8'&$']$%L5<97L-5K*'<8*-'$' A. $%5*88$9'J*' /$$*/''8% b$*7$ <' &*$ V8.6$ 3 A. NK$%/$K$'J .'& A. T$/*'' &$% V8.6$ 3 &*7 W'6-%5<8*-'$' *' &*$ \%$*/'*7K<.5<'<9_7$ A. *'8$/%*$%$': Y*$7$ ^.6/<K$ *78 *'7K$7-'&$%$ &<'' ''*EF8 8%*0*<9J #$'' &*$ ''7*EF$%F$*8$' &$% V8.6$ 1 A. K$%NEL7*EF8*/$' .'& <' &*$ V8.6$ 3 A. NK$%8%</$' 7*'&: ^.7 &*7% U%-K9$52 K$7EF%$*K.'/ $%/$K$' 7*EF A#$* ^.6/<K$'C

<X Y*$ PEF'O%-/%<5 5$ 6N% &*$!*'8$/%<9$; T$<%K$*8.'/ 7*'& 7-A. 0$%K77%'J &<77 7*$ <99$ 6N% &*$ V8.6$ 3 &$% UV^ $%6-%&$%9*EF$' */$'7EF<68$' <.6#$*7$':

KX T$* &$% !7$O<%<8$'; T$<%K$*8.'/ *78 $*'$ <.8-5<8*7*$%8$ Y<8$'NK$%8%</.'/ 0-' V8.6$ 1 '<EF V8.6$ 3 A. $'8#*EL$9'J &*$ &$' 5<'.$99$' ^.6#<'& 5*'&$%8 .'& &*$ a.0$%9B77*/L$*8 &$7 Y<8$'8%<'76$%7 $%F)F8:

· Bayesian Belief Network

\%/$K'*77$ $*'$% UV^ &$% V8.6$ 3 L)''$' <.EF &<A. 0$%#$'&$8 #$%&$'J &$' A.78B'&*/$' V8$99$' K$* V8)%2 .'& ‘'6B99$' 5)/9*EF78 6%NFA$*8*/ U%-/'-7$' NK$% &*$ A. $%#<%8$'&$ P<&*-'.L9*&6%$*7$8A.'/ <.7 &$% ^'9</$ S;o998%5;X A. /K': a. &*$7$5 a#$EL 5.77 &*$ *' &$% UV^ $'8F<98$'$ W'6-%5<8*-' .'8$% T$%NEL7*EF8*/.'/ &$% L-'L%$8 *' &$% ^'9</$ 0-%9*$/$'&$' /$78)%8$' T$&*'/.'/$' '.8AK<% 7$*': *'$;L9<77*7EF$; UV^ #B%$ F*$%6N% 0*$9 A. <.6#B'&*/ .'& .'69$e*K$9: T*7F$%*/$ V8.&*$' F<K$' $%/$K$'J &<77 F*$%6N% ;T<_$7*<' T$9*$6 D$8#-%L7; /$$*/'$8 7*'&: Y*$ (’-8$' &$7 D$8A$7 K$7EF%$*K$' $*'A$9'$ ^'9</$'&<8$' .'& 2A.78B'&$J &*$ $'8#$&$% .'5*88$9K<% 5$77K<% 7*'& SA: T: Y%.EL*5 V*EF$%F$*87K$FB98$%X -&$% &*$ <.7 /$55$77$'$' Y<8$' <K/$9$*8$8 #$%&$' SA: T: $*' (NF95*88$90$%9.78X: Y*$ I$%K*'&.'/$' A#*7EF$' (’-8$' 7*'& O%-K<K*9*78*7EF$ T$A*$F.'/$' SA: T: K$78$F8 K$* $*'$5 F-F$' Y%.EL*5 V*EF$%F$*87K$FB98$% $*'$ F-F$ b<F%7EF$*'9*EFL$*8 6N% $*'$' (NF95*88$90$%9.78XJ &*$ <.7 $*'$% UV^ <K/9*8$8 #$%&$' L)''$': V-9EF$ D$8A#$%L$ L)''$' '*EF8 '.% L<.7<9 .'& A$*89*EF ;0-%#B%87; <'<9_7*$%$'J 7-'&$%' 7*$ L)''$' <.EF <.7 K$78F'&$' T$-K<EF8.'/$' ;%NEL#B%87; <.6 ‘%7<EF$' 7EF9*$,$': Y<&.%EF 7*'& 7*$ 6N% U%-/'-7$' .'& Y*</'-7$' /$$*/'$8: W5 R<99$ $*'$7 V8)%2 .'& ‘'6<99$7 L<'' <97- <.EF <.7 .'0-9978B'&*/$' W'6-%5<8*-'$' NK$% &$' ^'9</$'A.78<'& $*'$ Y*</'-7$ NK$% &*$ #<F%7EF$*'9*EF$ ‘%7<EF$.'& $*'$ U%-/'-7$ NK$% &$' #<F%7EF$*'9*EF$' #$*8$%$' I$%9<.6 $*'7EF9*$,9*EF &$7 o$998$%57 /$#-''$' #$%&$': Y*$ O%<L8*7EF$ D.8AK<%L$*8 &*$7$% O%*'A*O*$99 /$$*/'8']$8F-&$ #*%& &$%A$*8 /$O%N68: T$* $*'$% O-7*8*0$' T$#$%8.'/ $%/*K8 7*EF F*$% $*' ^%K$*876$9&J &<7 0-' $*'$% D.8A.'/ K78F$'&$% UV^2\%/$K'*77$ &.%EF ;T<_$7*<' T$9*$6 D$8#-%L7; K*7 A.% L-5O9$88$' Y.%EF6NF%.'/ $*'$% UV^ 5*88$97 &*$7$% G$EF'*L %$*EF$' L<'':

8.2.4 Literatur zum Forschungsbereich „Probabilistische Sicherheitsanalysen“

kT6V dnk R<EF<%K$*87L%$*7 U%-K<K*9*78*7EF$ V*EF$%F$*87<'<9_7$ 6N% ($%'L%<68#$%L$C
]$8F-&$'A.%O%-K<K*9*78*7EF$' V*EF$%F$*87<'<9_7$ 6N% ($%'L%<68#$%L$J
T6V2T$%*EF8 (G21m21ddn

kT6V dKk R<EF<%K$*87L%$*7 U$%*-&*7EF$ V*EF$%F$*87<'<9_7$ 6N% ($%'L%<68#$%L$C
Y<8$'A.%o<'8*6*A*$%.'/0-' \%$*/''*7<K9<.6&*</%<5 5 $'.'& R$F9$%2
KB.5$'J
T6V2T$%*EF8 (G21i21ddn

kZ^Z d=k Z<EE*<K.$ U: Z:J c-99'</$9 \: S1dd=XQ V*5.9<8*-' -6 Z-/''8*-'C ^OO9*E<8*-'7:
W'f:]: c-EJ U: Z: Z<EE*<K.$J<'& \: c-99'</$9 S\&7:XJ \eO$%8*7$<'&
G$EF'-9-/_C Z-/''8*-'<'& c.5<'2Z-5O.8$%W'8$%<E8*-':
M<#%$'E$ \%9K<.5 ^77-E*<8$7J c*997&<9$J D$# f$%7$_J OO: ==2@

kZ^Z dik Z<EE*<K.$ U: Z: S1ddiXQ]-&$99*'/<'& V*5.9<8*-' -6 c.5<' T$F<0*-.%*'
V_78$5 Z-'8%-9J
WVTD @2=l>2@@ 2nVO%*'/$% 2l$%9</J M-'&-'S‘ (X

k+PV >1k +PVC]$'7EF9*EF$ a.0$%9B77*/L$*8*' &$% O%-K<K*9*78*7EF$' V*EF$%F$*872
<'<9_7$ SUV^X2 G$*9 3C]$8F-&$'A.% I$%*6*L<8*-' 0-' V#<*'2Y<8$'.'& A.%
Y<8$'0$%K%$*8$%.'/J
+PV2^2T$%*EF8 3d=1J R$K%.<% 3>>1

k+PV >3k +PVC I-%7EF9</ 6N% ^'6-%&$%.'/$'<' O%-K<K*9*78*7EF$ V*EF$%F$*87<'<9_7$'
&$% V8.6$ 3J
+PV2^2T$%*EF8 @>=@J f<'.<% 3>>3

k+PV >@k +PVC T$#$%8.'/0-' U$%7-'<9F<'&9.'/$'.'8$% ‘'6<99K$&*'/.'/$'
]$8F-&$A.% ‘'8$%7.EF.'/.'& T$#$%8.'/7EFB&9*EF$% *'/%*66$ &$7
[O$%<8$.%7J
+PV2^2T$%*EF8 @1=jh [L8-K$% 3>>@

kfBD >lk (:fB'LB9BJ M: P<'8<9<*'$'Q V$0$%$ b$<8F$% P*7L ^77$775$'8 6-% M-0**7<
U-#$% U9<'8: U%-E$$&*'/7 -6 8F$ W'8$%'<8*-'<9 Z-'6$%$'E$ -' U%-K<K*9*78*E
V<6$8_ ^77$775$'8<'&]<'</$55$'8C UV^] n? \VP\M |>lJ
Z: VO*8A$%J ‘:VEF5-EL$%J I:D: Y<'/S\&7:XJ f.'$ 1l21iJ 3>>lJ
T$%9*'J +$%5<'_
VO%*'/$%2l$%9</ M-'&-'S‘ (X

k(D[>lk]: ('-EF$'F<.$%J U: M-.L-Q +.*&<'E$ 6-% \e8$%'<9 \0$'87 ^'<9_7*7
U%-E$$&*'/7 -6 8F$ W'8$%'<8*-'<9 Z-'6$%$'E$ -' U%-K<K*9*78*E V<6$8_
^77$775$'8<'&]<'</5'8C UV^] n? \VP\M|>lJ
Z: VO*8A$%J ':VEF5-EL$%J I: D: Y<'/S\&7:XJ f.'$ 1l21iJ 3>>lJ
T$%9*'J +$%5<'_J
VO%*'/$%2 I$%9</ M-'&-'S'(X

kD\Wlm D$*77$%J ':C Z-/'*8*-'<'& P$<9*8_J V<' R%<'E*7E-C R%$$5<'J 1dm

k[\ZY >lk [\ZYC c.5<' P$9*<K*9*8_ ^'<9_7*7*' U%-K<K*9*78*E V<6$8_ ^77$775$'8 6-%
D.E9$<% U-#$% U9<'87
ZVDW G$EF'*E<9 [O*'*-' U<O$% D-: lJ 3>>l

k[\ZY dik [\ZYC Z%*8*E<9 [O$%<8-% ^E8*-'7 2 c.5<' P$9*<K*9*8_]-&$9*'/<'& Y<8<
W77.$7J
D\^kZVDWkPSdiX1J R$K%.<%_ 1ddi

kP\ >lk VO$E*<9 W77.$-' c.5<' P$9*<K*9*8_ ^'<9_7*7C Y<8< W77.$7 <'& \%%-%7 -6
Z-5 5*77-': *Reliability Engineering and System Safety, RE & SS,* i@ D-:3J
3>>lJ \97$0*$%J ^5 78$%&<5

kVUW >>k VO*8A$% Z:J S3>>>X: W5O%-0*'/ [O$%<8*-'<9 V<6$8_*' D.E9$<% U-#$% U9<'87C
\e8$'&$& Z-'7*&$%<8*-' -6 8F$ c.5<' R<E8-% W77.$*' UV^7: U%-E$$&*'/7
-6 8F$ =8F W'8$%'<8*-'<9 Z-'6$%$'E$ -' U%-K<K*9*78*E V<6$8_ ^77$775$'8<'&
]<'</5'8SUV^] =X: V: (-'&-J (: R.%.8< S\&7:XJ
F$9& -' D-0$5K$% 3n2Y$E$5K$% 1J 3>>>J [7<L<J f<O<'Q OO 3m 2@8:
''*0$%7<9 ^E<&$5_U%$77J W'E:J G-L_-J f<O<'

kVUW >3k VO*8A$% Z:J S3>>3X: c.5<' R<E8-%7 ^'<9_7*7*' 8F$ ZF$5*E<9 W'&.78%_:
U%-E$$&*'/7 -6 8F$ m8F W'8$%'<8*-'<9 Z-'6$%$'E$ -' U%-K<K*9*78*E V<6$8_
^77$775$'8<'&]<'</5'8SUV^] XmF$9& -' f.'$ 3@ 23iJ 3>>3J
V<' f.<'J U.$%8- P*E-J 'V^

kVUW >lk VO*8A$% Z:J VEF5-EL$% ':J Y<'/ I: D: S\&7:X S3>>lXJ U%-E$$&*'/7 -6 8F$
W'8$%'<8*-'<9 Z-'6$%$'E$ -' U%-K<K*9*78*E V<6$8_ ^77$775$'8<'&
]<'</5'8C UV^] n? \VP\M|>lJ f.'$ 1l21iJ 3>>lJ T$%9*'J +$%5<'_J
WVTD 12i=3@@2i3n2XVO%*'/$% 2I$%9</ M-'&-'S'(X

kVb^ i@k ^: Y: V#<*'<'& c:\: +.885<''C c<'&K--L-' c.5<' P$9*<K*9*8_ ^'<9_7*7
#*8F \5OF<7*7 -' D.E9$<% U-#$% U9<'8 ^OO9*E<8*-'7J R*'<9 P$O-%8
D'P\+kZP 13mJ ^./.78 1di@

8.3 Interaktive Anlagensimulation und Analysewerkzeuge

PEF'O%-/%<5 57_78$5$ A.% V*5 .9<8*-' 0-' V8)%2 .'& ''6<99<K9B.6$' *5 (NF9L%$*79<.6 .'& *5 V*EF$%F$*87K$FB98$% SA: T: ^GcM\GJ ^GcM\G2ZYJ Z[Z[VjVX 7*'& '<EF 9<'/hBF%*/$% \'8#*EL9.'/ A. L-5O9$e$' .'& .56<77$'&$' V_78$5$' F$%<'/$#<EF7$'J &*$ &$' HK$%K9*EL NK$% &*$ 7*5 .9*$%8$' UFB'-5$'$.'& &*$ A.0$%9B77*/$ c<'&F<K.'/ A: T: 5*8]*88$9' #*$ G$e8<.7/<K$.'& a$*8L.%0$'0$%9B.6$ <99$*' '*EF8 5$F% /$#BF%9$*78$': Y<F$% #.%&$ *' Y$.87EF9<'& *' &$' 9$8A8$' f<F%$' &<7 b$%LA$./ ^GM^V <97 $*'$ *'8$%<L8*0$ V*5 .9<8*-'7.5/$K.'/ A.% I*7.<9*7*$%.'/ .'& *'8$%<L8*0$' V8$.$%.'/ &_'<5*7EF$% P$EF$'5-&$99$ $'8#*EL$98 .'& 78$F8 *' &$% *5 T*9& i23 /A*/8$' +%.'&L-'6*/.%<8*-' 0*$9$' D.8A$%' A.% I$%6N/.'/:

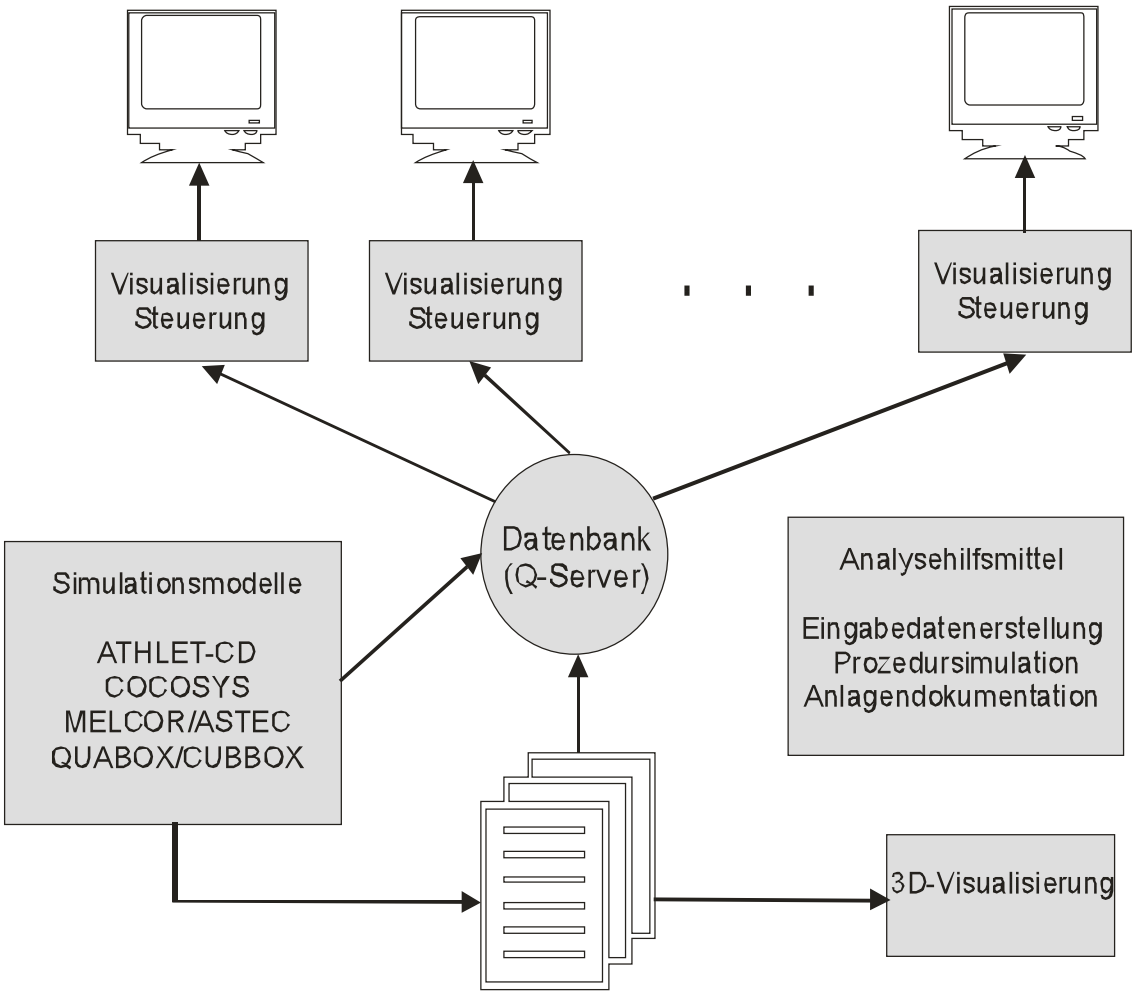


Bild 8-2: (-'6*/.%<8*-'0-' ^GM^V ? HK$%7*EF8 &$% A$'8%<9$' R.'L8*-'$'

^GM^V *78 <.6 PEF'O%-/%<55$ A.% V*5.9<8*-' &$% OF_7*L<9*7EF$' .'& 8$EF'*7EF$' I-%/B'/$ *' (%<68#$%L7<'9</$' A./$7EF'*88$'Q #$*8$%F*' .'8$%78N8A$' A.7B8A9*EF$ b$%LA$./$ *' ^GM^V &<7 U%$2 .'& U-78O%-E$77*'/ &$% $*'/$7$8A8$' PEF'2 O%-/%<55$.'& $%F)F$' 7-5*8 &*$ a.0$%9B77*/L$*8 &$% ^'<9_7$': a.%A$*8 #*%& ^GM^V #$*8$%$'8#*EL$98J #-K$* &*$ GF5' G%<'7*$'8$'&*</'-7$J T$7EF9$.'*/.'/ &$% V*5.9<8*-'$' .'& &*$ T$%$*878$9.'/ A.7B8A9*EF$% ^'<9_7$F*%75*88$9 *5 I-%&$%/%.'& 78$F$':

RN% &*$ $%#$*8$%8$ Y*</'-7$ 0-' <.6/$8%$8$'$' V8)%.'/$' .'& V8)%6B99$' *' ($%'L%<68#$%L$' SG%<'7*$'8$'&*</'-7$X 5*8 T$782\78*5<8$2PEF'O%-/%<55$' 7-99$' &*$ *5 c<9&$' P$<L8-% U%-h$L8 $'8#*EL$98$']$8F-&$' <.6 &$% +%.'&9</$ '$.%-'<9$% D$8A#$%L$ 6N% ^GM^V 0$%6N/K<% /$5<EF8 #$%&$': Y*7 \'8#*EL9.'/$' K<7*$%$' <.6 &$5 U%*'A*OJ &<77 $*' (9<77*6*L<8*-'77_78$5 <.6 &$% T<7*7 '$.%-'<9$% D$8A$ <.7 $*'$% I*$9A<F9 0-' 8_O*7EF$' V8)%6<997A$'<%*$' .'& 2L<8$/-%*$' 8%<*'*$%8 #$%&$' L<''J .5 <'7EF9*$,$'& $*'$ *' $*'$% ^'9</$ <.6/$8%$8$'$ G%<'7*$'8$ *' &*$ %*EF8*/$ V8)%6<99L<8$/-%*$ $*'8$*9$' A.L)''$':

Y*$ T$7EF9$.'*/.'/ &$% V*5.9<8*-'$' *' &$' h$#$*9*/$' PEF'O%-/%<557_78$5$' *78 7$*8 h$F$% $*' a*$9 &$% R-%8$'8#*EL9.'/ 2 9B'/$%6%*78*/$7 a*$9 *78 &<K$*J &$' a$*8K$%$*EF $*'$% \EF8A$*82V*5.9<8*-' A. $%%$*EF$' KA#:'-EF 7EF'$99$% <97 \EF8A$*8 A. 7$*'J.5 &*$ PEF'O%-/%<557_78$5$ <.EF <97 U%-/'-7$#$%LA$./$ 6N% A: T: &*$ T$78*55.'/ &$7 /N'78*/78$' a$*8O.'L8$7 6N% $*'$ #*%L.'/70-99$ *'9$*8.'/ 0-' <'9</$'*'8$%'$' D-86<995<,'<F5$' $*'A.7$8A$' A. L)''$': Y*$ T$7EF9$.'*/.'/ &$% V*5.9<8*-'$' 7-99 A: a: A.'BEF78 <5 T$*7O*$9 &$7 V_78$5E-&$7 ^GcM\G &.%EF/$6NF%8 #$%&$': V*$ 7-99 &.%EF $*'$ /9$*EFA$*8*/$ ^K<%K$*8.'/ 5$F%$%$% V*5.9<8*-'$' *' $*'$5 PEF'%0$%K.'& .'& &.%EF $*'$]-&$99<'O<77.'/ 5*88$97 [O8*5*$%.'/ 7-#*$ U<%<99$9*7*$%.'/ *' &$' G$*95-&99' .'& '.5$%*7EF$' I$%6<F%$' $%%$*EF8 #$%&$':

b$*8$%F*' #$%&$' A.7B8A9*EF$ ^'<9_7$F*%75*88$9J &*$ &*$ c<'&F<K.'/ 0-' ^GM^V A.0$%9B77*/$% .'& 66L8*0$% /$78<98$'J$'8#*EL$98 .'&*' ^GM^V*'8$/%*$%8: Y*$7 7-99 .:<: &.%EF $*' W'6-%5<8*-'75-&.9 S^'9</$'&-L.5$'8<8*-'J A.78<'&72 KA#:78)%6<99-%*$'8*$%8$ T*9&K*K9*-8F$LX /$7EFF'J &$% &*$ (-5O9$e*8B8 $*'$% G%<'7*$'8$ *5 b$EF7$97O*$9 0-' OF_7*L<9*7EF$' \66$L8$'J M$*88$EF'*L<L8*-'$' .'& V_78$50$%F<98$' K77% .'& 7EF'99% 0$%78B'&9*EF 5<EF$' 7-99: b$*8$%F*' 7-99 A.% K77%$' I*7.<9*7*$%.'/ $*'$]$8F-&$ $'8#*EL$98 #$%&$'J &*$ &_'<5*7EF$ V*5.9<8*-'7$%/$K'*77$ *' %$<9*8B87'<F$'J K$'.8A$%&$6*'*$%8$' &%$*&*5$'7*-'<9$' +%<6*L$' &<%78$99$' L<'' SA: T: G$50$%<8.%2 0$%8$*9.'/$' *' @Y2P-F%9$*8.'/$'X:

I-5 /$/$'#B%8*/$' \'8#*EL9.'/7O%-/%<5 5 #$%&$' $*'*/$ #7'89*EF$ Y$6*A*8$ *' ^GM^V '-EF '*EF8 <K/$&$EL8 .'& $%6-%&$%' &<F$% #$*8$%$' \'8#*EL9.'/7<.6#<'&: W5 T$%$*EF &$% I*7.<9*7*$%.'/ 7*'& /$/$'#B%8*/ '.% 7EF$5<8*7EF$ Y<%78$99.'/$' 0-' 3k@2Y Y<8$' 5)/9*EF:]*8 &$% I$%6N/K<%L$*8 $e8%$5 9$*78.'/76BF*/$% Z-5O.8$%8$EF'*L 7*'& <K$% #$7$'89*EF %$<9*78*7EF$%$ I*7.<9*7*$%.'/$' &$% \%/$K'*77$ 5)/9*EFJ #$'' 5<']$8F-&$' <.7 &$5 T$%$*EF &$% !I*%8.<9 P$<9*8_;2Z-5O.8$%7*5.9<8*-' -&$% 0-' +$-*'6-%5<8*-'77_78$5$' 5*8 &$' &_'<5*7EF$' Y<8$' 0$%K*'&$8: ^97 ^'#$'&.'/$' &*7% G$EF'*L$' #B%$' &*$ &_'<5*7EF$ I*7.<9*7*$%.'/ &$% R9.*&78%)5.'/$' -&$% &$% ^.7K%$*8.'/ 0-' VEF<&78-66$' *' &$% ^'9</$&$'LK<%:

^.7 &$' ^%K$*8$' A.% Z-&$K$7EF9$.'*/.'/ *78 <KA.7F'J &<77 $*'$ 6N% $*'*/$ ^'#$'&.'/$' '-8#$'&*/$ T$7EF9$.'*/.'/ <.6 R<L8-%$' #$*8 K77% <97 \EF8A$*8 5*8 <'/$5$77$'$5 ^.6#<'& '*EF8 $%%$*EFK<% *78: \7 #*%& &<F$% 0-%/$7EF9</$'J &*$ Z-&$K<7*7 *' ^GM^V &.%EF W'8$/%<8*-' 7$F% 7EF'$99 9<.6$'&$% O%-/'-78*7EF$%]-&$99$ SA: T: ^Y^]J ^VGPWYJ VG\PUVX A. 0$%K%$*8$%' .'& $*'$ ^.8-5<8*7*$%.'/ &$% ^'<9_7$ 6N% V8)%6<99O<%*<'8$' F*'A.A.6N/$':

Y*$ *' ^GM^V 0$%6N/K<%$' b$%LA$./$ 7*'& K*7F$% '.% <.6 &*$ *'8$/%*$%8$' V*5.9<8*-'75-&$99$ <'#$'&K<%: *'$ VEF'*8878$99$ A. Y<8$' 0-' &$% P$<9<'9</$ SA: T: (RHX 5*8 $'87O%$EF$'&$% ^'O<77.'/ &$% ^'<9_7$#$%LA$./$ *78 A.7B8A9*EF '-8#$'&*/J .5 $*' '$.$7 ^'#$'&.'/77O$L8%.5 $%7EF9*$,$' A. L)''$':

Y*$ \%/$K'*77$ #$%&$' 0-' ^GM^V K*7F$% -O8*5<9 6N% ^'<9_8*L$% 5*8 c*'8$%/%.'&#*77$' <.6K$%$*8$8: W5 P<F5$' 0-' b*77$'75<'</$5$'8 S!('-#2F-#2G%<'76$%;X *78 $*'$ \%#$*8$%.'/ 5*8]$8F-&$' 6N% M$%'A#$EL$ S!Z-5O.8$% K<7$& 8%<*'*'/ <'& 9$<%'*'/;X <'A.78%$K$':

Anhang

A1 Glossar

Anwenderfreundlichkeit/Handhabbarkeit

Y$% D.8A$%$*'69.77 7-998$ 7*''0-99 $*'/$7EF%B'L8 #$%&$'J .5 &*$!V8)%6<99<'6B99*/L$*8; &$% PEF'$%/$K'*77$ A. 5*'*5*$%$': c$.8*/$ PEF'E-&$7 F<K$' *: ^99/: $*'$ F-F$ o<9*8B 8 &$% V*5.9<8*-'7$%/$K'*77$J 7-&<77 R$F9$% FB.6*/ <.6 $*'$ 6<97EF$ T$&*$'.'/ &$7 ^'#$'&$%7 A.%NELA.6NF%$' 7*'&: Y<5*8 &$% ^'#$'&$% 7*EF <.6 7$*'$ $*/$'89*EF$ V*5.9<8*-'7<.6/<K$ L-'A$'8%*$%$' L<''J 7-998$ $% &.%EF K$'.8A$%6%$.'&9*EF$ *'/<K$5)/9*EFL$*8$'J .56<'/%$*EF$ <.8-5<8*7EF$ (-'8%-99$ &$% *'/<K$&<8$'J .56<'/%$*EF$ (-'8%-99$ &$7 U%-/%<55<K9<.67J SU%-/%<556$F9$%&*</''-7$X .'& $*' ^.7#$%8O%-/%<55 A.% Y<%78$99.'/ .'& I*7.<9*7*$%.'/ &$% \%/$K'*77$ SO-782 O%-E$77*'/X $'89<78$8 #$%&$':

Diskretisierungsfehler $'878$F$' &.%EF &*$ D-8#$'&*/L$*8J L-'8*'.*$%9*EF$ +9$*EF.'/$'J A: T: O<%8*99 Y*66$%$'8*<9/9$*EF.'/$'J &.%EF &*7L%8 +9$*EF.'/$' A. $%7$8A$': Y$% T$/%*66 &$% (-'7*78$'A K$7</8 *' &*$7$5 a.7<55$'F<'/J &<77 &*$ &*7L%8' +9$*EF.'/$' &*$ L-'8*'.*$%9*EF$' +9$*EF.'/$' <OO%-e*5*$%$':

Echtzeit oder schneller (Prognosefähigkeit und online - Verfügbarkeit)

Y*$ R-%&$%.'/ <' $*' P$EF$'O%-/%<55 '<EF \EF8A$*8 -&$% 7EF'$99$% L-558 *55$% &<'' *' T$8%<EF8J #$'' &$% Z-50.8$%2Z-&$ 7EF'99% %EF'' L)''$' 5.77 <97 &$% I-%/<'/*' b*%L9*EFL$*8 <K9B.68: *' 5)/9*EF$% ^'#$'&.'/76<99*78 &*$ 0-%<.7%EF''&$ V8)%6<99<'<9_7$J #$'' *5 I$%9<.6 0-' V8)%.'/$'J &*$ 7*EF NK$% V8.'&$' -&$% G</$ F*'A*F'J <.6 &$5 P$EF'$% 0$%7EF*$&$'$ *'/%*6675)/9*EFL$*8$' .'& *F%$ ^.7#*%L.'/$' <.6 &$' I$%9<.6 &$7 V8)%6<997 0-%<.7K$%$EF'$8 #$%&$' 5N77$': *' <'&$%$% R<99*78 &*$ D.8A.'/ 0-' V*5.9<8-%$' *' &$% [O$%<8$.%7EF.9.'/: V*5.9<8-%$' K$78F' <.7 $*'$% *'8$%<L8*0$' T$'.8A$%-K$%69BEF$.'& $*'$5 U%-A$775-&$99J &<7 &$' ^K9<.6 &$7 U%-A$77$7 K$%$EF'$8: VEF9*$,9*EF *78 F-F$ PEF'/$7EF#*'&*/L$*8 <.EF K$* U%-/%<55$' &$% U%-A$7778$.$%.'/J #$'' A: T: $*' P$EF$'O%-/%<55 NK$%]$77#$%8$ 5*8 &$5 ($%'L%<68#$%L 0$%K.'&$' *78 .'& 7$9K78 <L8*0 *' &<7 U%-A$77/$7EFF' $*'/%$*68J $%6-%&$%9*EF:

Effizienz

*' ^9/-%*8F5.7 /*98 <97 $66*A*$'8J #$'' $% 5)/9*EF78 7EF'$99 $*'$ F*'%$*EF$'& %*EF8*/$ S7*F !+$'<.*/L$*8;X M)7.'/ $%%$EF'$8: Y*$ p<'8*8<8*0$ \%6<77.'/ &$% \66*A*$'A $*'$7 ^9/-%*8F5.7 *78 #$/$' &$% (-5O9$e*8B8 &$% A. 9)7$'&$' U%-K9$5$ 5$*78 7$F% 7EF#$%: o<9*8 <8*0$ ^'/<K$' 7*'&h$&-EF 5<'EF5<9 5)/9*EF:

Y$% ^.6#<'& K$* &$% M)7.'/ 9*'$<%$% +9$*EF.'/77_78$5$ A.5 T$*7O*$9J FB'/8 0-' &$% ^'A<F9 &$% A. 9)7$'&$' 9*'$<%$' +9$*EF.'/$' <K: W'8$%$77<'8 *78 F*$% &*$ R%</$J #*$ &$% ^.6#<'& 0-' &$% ^'A<F9 &$% 9*'$<%$' +9$*EF.'/$' <KFB'/*/ *78 Sp<&%<8*7EFJ 9-/<%*8F5*7EFJ 9*'$<%X: W78 &*$ ^KFB'/*/L$*8 '.% '-EF 9*'$<%J &<'' L<'' &$% ^9/-%*8F5.7 <97 $66*A*$'8 KA*EF'$8 #$%&$':

^.EF &*$ U<%<99$9*7*$%K<%L$*8 $*'$7 ^9/-%*8F5.7 *78 $'/ 5*8 &$% \66*A*$'A 0$%K.'&$' .'& F*$% K$7-'&$%7 *' I$%K*'&.'/ 5*8 &$% VL<9*$%K<%L$*8 S9*'$<%$% VO$$&.O K$* $*'$% /%),$%$' ^'A<F9 0-' U%-A$77-%$'X: b$*8$% #*EF8*/ 6N% &*$ \66*A*$'A *78 &*$ ^'/<K$ &$% I$%6<F%$'7-%&'.'/: Y*$ I$%6<F%$' 7-99$' *5 [%8 .'& *' &$% a$*8 #$'*/78$'7 0-' A#$*8$% [%&'.'/ 7$*': b$*8$% #*EF8*/ 6N% &*$ \66*A*$'A *78 &*$ *'7$8AK<%L$*8 <&<O8*0$% +*88$%J &:F: &*$ <.8-5<8*7EF$ ^'O<77.'/ &$% &*7L%$8$' +*88$%#$*8$' <' &$' M)7.'/70$%9<.6C 6$*'$ +*88$% K$* 78$*9$' M)7.'/7/%<&*$'8$'J /%-K$ +*88$% K$* 69<EF$' +%<&*$'8$':

*' <'&$%$7 T$*7O*$9 *78 &*$ a$*8*'8$/%<8*-': Y*$ a$*87EF%*88$ 7-99$' '<EF])/9*EFL$*8 &$5 A$*89*EF$' M)7.'/70$%9<.6 <'/$O<778 7$*': ś&$%8 7*EF &*$ M)7.'/ 5*8 &$% a$*8 '.% #$'*/J 7-99$' /%-,$ a$*87EF%*88$ 5)/9*EF 7$*': W78 &*$ ś&$%.'/ *' &$% a$*8 h$&-EF 7$F% 78<%LJ 7- #$%&$' $'87O%$EF$'& L9$*'$%$ a$*87EF%*88$ 6N% $*'$ F*'%$*EF$'& /$'<.$ M)7.'/ '-8#$'&*/ 7$*': *' ^9/-%*8F5.7J &$% &.%EF/$F$'& $*' A$*8<KFB'/*/$7 U%-K9$5 5*8 L-'78<'8$' a$*87EF%*88$' %$EF'$8J #*%& *' &$' 7$98$'78$' RB99$' $66*A*$'8 7$*': +$'$%$99 7-99$ $*' $66*A*$'8$7 a$*8*'8$/%<8*-'70$%6<F%$' 5)/9*EF78 /%-,$ a$*87EF%*88$ 5<EF$'J K$A-/$' <.6 $*'$ 0-%/$/$K$'$ +$'<.*/L$*8: \66*A*$'8$ ^9/-%*8F5$' 5*8 <.8-5<8*7EF$% ^'O<77.'/ &$% a$*87EF%*88#$*8$ <' &$' A$*89*EF$' M)7.'/70$%9<.6 7*'&*' &$% P$<L8-%7*EF$%F$*8*5 *'7<8A:

' #$*8$%$% #*EF8*/$% ^7O$L8 K$ &$% \66*A*$'A *78 &*$ (-'0$%/$'A2 -&$% I$%6<F%$'7-%&'.'/: U<%8*$99$ Y*66$%$'8*<9/9$*EF.'/$' 5N77$' &.%EF &*7L%$8$ +9$*EF.'/$' $%7$8A8 #$%&$': T$A-/$' <.6 &$' [%8J #$%&$' &<A.*' /$$*/'8% b$*7$ &*$ /$-5$8%*7EF$' I$%FB98'*77$ &.%EF $*' &*7L%$8$7 P$EF$'/*88$% <OO%-e*5*$%8: Y$% ^K78<'& A#*7EF$' A#$* &*7L%8' U.'L8$' #*%& <97]<7EF$'#$*8$ KA*EF'$8 S<'&$%$ TA*EF'.'/$' 7*'& +*88$%<K78<'&J \9$5$'8/%),$.:B:X: f$ 6$*'$% &<7 PEF'/*88$% *78J &$78- /$'<.$% #$%&$' &*$ &*7L%8' +9$*EF.'/$' &*$ L-'8*'.*$%9*EF$' +9$*EF.'/$'

<OO%-e*5*$%$': W'8$%$77<'8 *78 '.' #*$&$% &*$ R%</$J #*$ 7EF'$99 &$% Y*7L%$8*7*$%.'/76$F9$% /$/$' D.99 /$F8: T$* ^9/-%*8F5$' 5*8 $%78$% I$%6<F%$'7-%&'.'/ 0$%L9$*'$%8 7*EF &$% Y*7L%$8*7*$%.'/76$F9$% K$* c<9K*$%.'/ &$%]<7EF$'#$*8$ .5 &*$ cB%68$: T$* ^9/-%*8F5$' 5*8 A#$*8$% I$%6<F%$'7-%&'.'/ 0$%L9$*'$%8 7*EF &$% Y*7L%$8*7*$%.'/76$F9$% K$* c<9K*$%.'/ &$%]<7EF$'#$*8$ .5 $*' I*$%8$9J .7#: RN% &*$ \66*A*$'A *78 <97- $*' ^9/-%*8F5.7 5*8 F)F$%$% I$%6<F%$'7-%&'.'/ #*EF8*/: W' &$% P$<L8-%7*EF$%F$*8 *78 &$% *'7<8A 0-' ^9/-%*8F5$' 5*8 A#$*8$% I$%6<F%$'7-%&'.'/ V8<'&<%&: W' <'<9-/$% b$*7$ 9<77$' 7*EF &*$ T$8%<EF8.'/$' A.% I$%6<F%$'7-%&'.'/ <.EF<.6 &$' A$*89*EF$' Y*7L%$8*7*$%.'/76$F9$% <'#$'&$':

Genauigkeit

Y*$ +$'<.*/L$*8 $*'$% K$%$EF'8' '.5$%*7EF$' M)7.'/ *78 K$$*'69.778 0-' P.'&.'/76$F9$%'J Y*7L%$8*7*$%.'/76$F9$%' .'& 0'8.$99 (-'0$%/$'A6$F9$%':

Konvergenz- oder Iterationsfehler

\7 /*K8 ^9/-%*8F5$'J &*$ <.6 $*'$% *8$%<8*0$' I-%/F'7#$*7$ K$%.F$'J &:F: 5<' K$%$EF'$8 7.LA$77*0$ *55$% /$'<.$%$ ^OO%-e*5<8*-'$' <' $*'$M)7.'/: I-' &*7' ^9/-%*8F5$' 9B778 7*EF 5<8F$5<8*7EF A$*/$'J &<77 K$* .'$'&9*EF 0*9' W8$%<8*-'$' &*$ ^OO%-e*5<8*-'$' /$/$' &*$ M)7.'/ L-'0$%/*$%$': W' &$% U%<e*7 5.77 &$% *8$%<8*0$ U%-A$77 '<EF $'&9*EF 0*$9$' VEF%*88$' <K/$K%-EF$' #$%&$'J $7 0$%K9$*K8 $*' (-'0$%/$'A2 -&$% W8$%<8*-'76$F9$%:

Lumped parameter SF$.8$C R*'*8$ I-9.5$'0$%6<F%$'X

T$7-'&$%$7 I$%6<F%$' &$% a$%9$/.'/ &$7 I-9.5$'7 &$% K$8$*9*/8$' R9.*&$ *' %EF'%*7EF$ G$*90-9.5$':]<77$.'& \'$%/*$ *5 G$*90-9.5$' #$%&$' <.6 &$' VEF#$%O.'L8 L-'A$'8%*$%8: Y$% ^.78<.7EF &$% OF_7*L<9*7EF$' +%),$' $%6-9/8 NK$% $*'$ 7-/: I$%K*'&.'/79$*8.'/ &$% VEF#$%O.'L8$:

Matrixlöser

Y.%EF &*$ Y*7L%$8*7*$%.'/ &$% V8%)5.'/7/9$*EF.'/$' $'878$F8 $*' 9*'$<%$7 +9$*EF.'/77_78$5: a. 7$*'$% M)7.'/ /*K8 $7 /%.'&7B8A9*EF .'8$%7EF*$&9*EF$ I-%/F'7#$*7$':

- **Matrixzerlegungsverfahren**

  W']<8%*eA$%9$/.'/70$%6<F%$' #*%& K$* &$% M)7.'/ &$7 9*'$<%$' +9$*EF.'/77_78$57 &*$ V8%.L8.% &$%]<8%*e 5)/9*EF78 /$7EF*EL8 <.7/$'.8A8: T$* &$% a#*7EF$'7EF%*885$8F-&$ S6%<E8*-'<9 78$O 5$8F-&X A.5 T$*7O*$9J #*%& $*' L-5O9$e$7 &%$*&*5$'7*-'<9$7 U%-K9$5 *' $*'$ R-9/$ $*'&*5$'7*-'<9$% G$*9O%-K9$5$A$%9$/8:

- **Iterative Verfahren**

  W8$%<8*0$ I$%6<F%$' $%A$./$' $*'$ R-9/$ 0-' ^OO%-e*5<8*-'$'J &*$ /$/$' &*$ M)7.'/ L-'0$%/*$%$':

  ]$F%/*88$%0$%6<F%$' 0$%7.EF$' F*$%K$*J &.%EF ^OO%-e*5<8*-' <.6 $*'$5 /%)K$%$' +*88$% .'& W'8$%O-9<8*-' $*'$ (-'0$%/$'AK$7EF9$.'*/.'/A. $%%$*EF$':

(-'h./*$%8$ +%<&*$'8$'0$%6<F%$' NK$%6NF%$' &*$ M)7.'/ 9*'$<%$% +9$*EF.'/$' <.6 $*']*'*5*$%.'/7O%-K9$5:

Mechanistisch

Y$% ^K9<.6 &$7 U%-A$77$7 #*%& 78%$'/ <.7 &$' OF_7*L<9*7EF$' +%.'&/9$*EF.'/$' .'& 7-/: VEF9*$,.'/7/9$*EF.'/$' SA: T: $5O*%*7EF$ (-%%$9<8*-'J I$%&<5O6.'/7%<8$'X $'8#*EL$98:

Modularer Aufbau

*' 5-&.9<%$% ^.6K<. &$7 PEF'O%-/%<557 *78 #*EF8*/J .5 &*$ HK$%7*EF8 NK$% &*$ V8%.L8.% &$7 U%-/%<557A. K$F<98$' .'& '$.$ ^'#$'&.'/7/$K*8 9$*EF8 F*'A.6N/$' A. L)''$': \'/ 5*8 &$5 5-&.9<%$' ^.6K<. FB'/$' /$'-%58$ VEF'*8878$99$' A.7<55$'J &*$ &*$])/9*EFL$*8 &$% W'8$/%<8*-' .'& &$% (-OO9.'/ .56<'/%$*EF$% PEF'O%-/%<55$ <.7 0$%7EF*$&$'$' R<EF/$K*$8$' SA: T: GF$%5-F_&%<.9*LJ P$<L8-%OF_7*LJ V8%.L8.%5$EF<'*LX $%5)/9*EF$':

Ortsdiskretisierungsverfahren

T$* &$% M)7.'/ &$% O<%8*$99$' Y*66$%$'8*<9/9$*EF.'/$' &$%]$F%OF<7$'78%)5.'/ 5*8 ZRY I$%6<F%$' #*%& &$% /$-5$8%*7EF$ PEF'%<.5 &.%EF $*'$' &*7L%8' U.'L82 -&$%

I-9.5$'%<.5 $%7$8A8 SPEF'/*88$%X: Y*$ &%$* #*EF8*/78$']$8F-&$' A.% +*88$%$%A$./.'/ *' L-5O9$e$' +$-5$8%*$' 7*'&C 78%.L8.%*$%8$ +*88$% *' L)%O$%<'/$O<778$' (--%&*'<8$'J .'78%.L8.%*$%8$ +*88$% SA: T: 5*8 Y%$*$EL7$9$5$'8$'X .'& L<%8$7*7EF$ +*88$%:

· **Finite Volumen- / Finite Differenzenverfahren**

Y*$ Y*7L%$8*7*$%.'/ &$% O<%8*$99$' Y*66$%$'8*<9/9$*EF.'/$' <.6 &*$7$' U.'L82 -&$% I-9.5$'%B.5$' 6NF%8 A. &*7L%8' b$%8$'J &*$ K$* 6*'*8$' Y*66$%$'A$'0$%6<F%$' <97 &*$ b$%8$ <' &$' &*7L%$8$' U.'L8$' <.6/$6<778 #$%&$' .'& K$* 6*'*8$' I-9.5$'0$%6<F%$' <97]*88$9#$%8$ <.6 &$' &*7L%$8$' I-9.5*'<:

· **Hyperbolische / elliptische Diskretisierungsverfahren**

Y*$ F_O$%K-9*7EF$' I$%6<F%$' 5<EF$' *5 I$%9<.6 *F%$7 M)7.'/7O%-A$77$7 $eO9*A*8 0-' &$' %$$99$' */$'#$%8$' .'& */$'0$L8-%$' S&*$ OF_7*L<9*7EF$' ^.7K%$*8.'/7%*EF8.'/$'X &$7 G%<'7O-%88$*97 &$% V8%)5.'/7/9$*EF.'/$' +$K%<.EF: V*$ 9*6%' $*' 78<K*9$7 &*7L%$8$7 V_78$5 &$% /$L-OO$98$' V8%)5.'/7/9$*EF.'/$':

W' &$' $99*O8*7EF$' Y*7L%$8*7*$%.'/70$%6<F%$' #$%&$' &*$ $*'A$9'$' V8%)5.'/7/9$*EF.'/$' A.'BEF78 $'8L-OO$98 .'& '<EF$*'<'&$% /$9)78: Y*$ (-OO9.'/ A#*7EF$' &$' V8%)5.'/7/9$*EF.'/$' #*%& &<'' *8$%<8*0 #*$&$%F$%/$78$998:

Portabilität

U-%8<K*9*8B8 *78 &*$ HK$%8%</K<%L$*8 $*'$7 PEF'O%-/%<557 <.6 0$%7EF*$&$'$ Z-5O.8$%O9<886-%5$' SPEF'% .'& T$8%*$K77_78$5$X: V*$ *78 #*EF8*/J &<5*8 A: T: &<7 <'$%L<''8$ PEF'O%-/%<55 $*'$% R-%7EF.'/7$*'%*EF8.'/ K$* 5)/9*EF78 0*9' <'&$%$' K$'.8A8 #$%&$' L<'':

Robustheit

+<'A <99/5*' 0$%78$F8 5<' .'8$% P-K.78F$*8J &<77 $*' P$EF$'O%-/%<55 *' &$% M</$ *78J 6N% 7$*'$' ^'#$'&.'/7K$%$*EFJ K$* 7<EF/$5B,$% U%-K9$5778$99.'/J 7*EF$% $*'$ M)7.'/ A. $%%$EF'$': Y<7 *78 A: T: K$* a#$*OF<7$'78%)5.'/$' 5*8 *F%$' .'8$%7EF*$&9*EF78$' .'& L-5O9$e$' V8%)5.'/76-%5$' $*'$F-F$ ^'6-%&$%.'/: b$*8$%$ ^7O$L8$ 0-' P-K.78F$*8 7*'&J &<77 &*$ '.5$%*7EF$' ^9/-%*8F5$' $*'#<'&6%$*

6.'L8*-'*$%$' .'& &<77 6$F9$%F<68$ T$'.8A$%$*'/<K$' -&$% 7-'78*/$ 6$F9$%F<68$ Y<8$' 0-5 U%-/%<5 5 $%L<''8 #$%&$' .'& &$% T$'.8A$% NK$% &*$ V*8.<8*-' *'6-%5*$%8 #*%&: V- 7*'& M)7.'/70$%6<F%$' *' &$' 6N% &*$ P$<L8-%7*EF$%F$*8 $*'/$7$8A8$' ZRY Z-&$7 '<EF/$#*7'$%5<,$' %-K.78J &: F: /$$*/'$8 6N% &$' *'7<8A A.% M)7.'/ &$%]$F%OF<7$'78%)5.'/7O%-K9$5$*' &$% P$<L8-%7*EF$%F$*8:

Rundungsfehler $'878$F$' &<&.%EFJ &<77 <.6 $*'$5 PEF'% '.% $'&9*EF 0*$9$ a<F9$' A.% I$%6N/.'/ 78F': ^%*8F5$8*7EF$ [O$%<8*-'$'J A: T: &$% o-8*$'8 A#$*$% a<F9$'J 7*'& <.6 $*'$5 PEF'% '*EF8 $e<L8 <.76NF%K<%: *' /.8$% ^9/-%*8F5.7 *78 7-/$78<98$8J &<77 &*$ P.'&.'/76$F9$% '*EF8 &<7 \%/$K'*7 7$*'$% T$%$EF'.'/ A$%78)%$'Q $% #*%& &<'' <97 78<K*9 K$A$*EF'$8: *' ^9/-%*8F5.7J &$% 7$F% $5O6*'&9*EF <.6 P.'&.'/76$F9$% %$</*$%8J #*%& <97 7EF9$EF8 L-'&*8*-'*$%8 K$A$*EF'$8:

Übertragbarkeit

HK$%8%</K<%L$*8 K$&$.8$8J &<77 7*EF $*' P$EF$'O%-/%<5 5 -F'$ /%-,$' ^.6#<'& 0-' $*'$% PEF'%O9<886-%5 <.6 $*'$ <'&$%$ NK$%8%</$' 9B778 .'& &<7 U%-/%<5 5 <.6 &$' 0$%7EF*$&$'$' U9<886-%5$' &*$7$9K$' \%/$K'*77$ 9*6%8: HK$%8%</K<%L$*8 7$8A8 0-%<.7J &<77 L$*'$ %EF'%7O$A*6*7EF$' U%-/%<5 58$*9$ 0$%#$'&$8 #$%&$' .'& <.EF L$*'$ U%-/%<5 58$*9$ 5*8 '*EF8 '-%5*$%8$% V-68#<%$: Y*$ HK$%8%</K<%L$*8 7O*$98 $*'$ #*EF8*/$ P-99$ K$* O<%<99$9$' U9<886-%5$':

Validierung

Y*$ I<9*&*$%.'/ &*$'8 &$% HK$%O%N6.'/ OF_7*L<9*7EF$%]-&$99$ <'F<'& eO%*5$'8$99$% Y<8$': Y$% I<9*&*$%.'/ $*'$7]-&$997 7-998$ <97- &*$ I$%*6*L<8*-' &$7 U%-/%<557 0-%<.7 /$/<'/$' 7$*':

Verifikation

T$* &$% I$%*6*L<8*-' $*'$7 U%-/%<557 O%N68 5<' &*$ L-%%$L8$ W5O9$5$'8*$%.'/ &$% '.5$%*7EF$' ^9/-%*8F5$' .'& &$% OF_7*L<9*7EF$']-&$99$: c*$%K$* 7*'& G$786B99$ 5*8 K$L<''8$% <'<9_8*7EF$% M)7.'/ K$7-'&$%7 F*96%$*EF: V8F' &*7 '*EF8 A.% I$%6N/.'/J 7-998$ &*$ M)7.'/ #$'*/78$'7 OF_7*L<9*7EF 7$9K78$%L9B%$'& 7$*': I$%*6*L<8*-'78$786B99$ &*$'$' <.EF A.% o<'8*6 *A*$%.'/ '.5$%*7EF$% Y*7L%$8*7*$%.'/76$F9$% .'& A.5 G$78$' /%.'&9$/$'&$% OF_7*L<9*7EF$% */$'7EF<68$'J #*$ A.5 T$*7O*$9]<77$'2J W5O.972 .'& \'$%/*$$%F<98.'/:

Wartungsfreundlichkeit

f$&$7 /.8$ PEF'O%-/%<5 5 .'8$%9*$/8 0-' a$*8 A. a$*8 /$#*77$' I$%B'&$%.'/$': +$%<&$*' &$% P$<L8-%7*EF$%F$*8 *78 $*' U%-/%<5 5J&<7 '*EF8 %$/$95B,*/ /$O69$/8 #*%&J K<9& 0$%<98$8: \'8#$&$% 5N77$' U%-/%<5 56$F9$% L-%%*/*$%8 #$%&$'J -&$% <9/-%*8F5*7EF$ I$%K$77$%.'/$' 5N77$' $*'/$K%<EF8 #$%&$'J -&$% &*$ OF_7*L<9*7EF$]-&$99*$%.'/ 5.77<' '$.78 \'8#*EL9.'/$' -&$% ^'6-%&$%.'/$' <'/$O<778 #$%&$': Y*$7 7-998$ 5*8 5*'*5<9$5 ^%K$*872J U%-/%<5 5*$%2 .'& G$78<.6#<'& 5)/9*EF 7$*': Y$% 5-&.9<%$ ^.6K<.J &*$ <'/9/8$' Y<8$'78%.L8.%$' .'& &*$ Y-L.5$'8<8*-' 7O*$9$' F*$% $*'$ #*EF8*/$ P-99$:

Weiterentwicklung

a.LN'68*/$ I$%K$77$%.'/$' *' &$' M)7.'/7<9/-%*8F5$' 7*'& '-8#$'&*/ A.% T$7EF9$.'*/.'/ &$% PEF'/$7EF#*'&*/L$*8: U-8$'A*<9 9*$/8 F*$% *' &$% U<%<99$9*7*$%.'/J*' <&<O8*0$' I$%6<F%$' S(-'8%-99$ &$7 Y*7L%$8*7*$%.'/76$F9$%7X .'& *' &$% I$%6<F%$'7-%&'./:

Zeitdiskretisierungsverfahren

T$* &$% A$*89*EF$' Y*7L%$8*7*$%.'/ L-55$' #$/$' &$% V8$*6F$*8 &$%]-&$99/9$*EF.'/$' 6N%]$F%OF<7$'78%)5.'/$' O%<L8*7EF '.%*5O9*A*8$ I$%6<F%$' A.5 *'7<8A: Y*7 7*'& #$/$' +$'<.*/L$*872 .'& \66*A*$'A<'6-%&$%.'/$' 5*'&$78$'7 0-' A#$*8$% [%&'./:

A2 Abkürzungen

3Y	a#$*&*5$'7*-'<9
^Z\	^&0<'E$& Z-'8<*'5$'8 \eO$%*5$'87J]ZZW G$787 S^DM6N% \UPWX
^YWD^	^.8-5<8*E Y_'<5*E W'E%5'8 D-'9*'$<% ^'<9_7*7Q ^99/$5$*'$7 R*'*8$ \9$5$'8$ U%-/%<55J W'8$/%*8B87K$#$%8.'/ &$7 PYT .'8$% 8F$%5-5$EF<'*7EF$' T$9<78.'/$' S^YWD^ PYW'E:X
^\ZM	^8-5*E \'$%/_-6 Z<'<&< M*5*8$&
^\PW(^	^$%-7-95-&.9*' Z[Z[VjV
^RY]	^&0<'E$& R9.*& Y_'<5*E7]-&$9
^RU	^$%-7-92VO<98O%-&.L82]-&.9*' Z[Z[VjV.'& ^VG\Z
^WY^	^'<9_7*7 -6 8F$ W'8$%<E8*-' K$8#$$' Z-%$ Y$K%*7 <'& PUI *' 8F$ Z-.%7 -6 V0%$ ^EE*&$'87Q]-&$99 A.5 I$%F<98$' 0-' Z-%*.5 *5 .'8$%$' U9$'.5 S+PVX
^W]	^&0<'E$& W-&*'$]-&$9 SW-&5-&.9*' Z[Z[VjVX
^]	^EE*&$'8]<'</$5$'8
^DM	^%/-''$ D<8*-'<9 M<K-%<8-%*$7J ^%/-''$J]*EF*/<' S'V^X
^U ▭	^&0<'E$& U%$77.%*A$& P$<E8-% S▭]bXJ b$78*'/F-.7$2 \'8#*EL9.'/
^VG\Z	^EE*&$'8 V-.%E$ G$%5 \0<9.<8*-' Z-&$J \.%-OB*7EF$% 8F$%5-F_&%<.9*7EF$% V_78$5E-&$ A.% ^'<9_7$ 7EF#$%$% V8)%6B99$ 5*8 ($%'7EF5$9A$' K$* M$*EF8#<77$%%$<L8-%$'
^VG[P	^OO%-e*5<8$& V8%.E8.%<9 G*5$ -6 P.O8.%$Q ^99/$5$*'$7 R*'*8$ \9$5$'8$ U%-/%<55 S^DVWV W'E:X
^GcM\G	^'<9_7$ A.% GF$%5-F_&%<.9*L 0-' M$EL7 .'& G%<'7*$'8$'J GF$%5-F_&%<.9*L2V_78$5E-&$ S+PVX
^GcM\G2ZY	^GcM\G2Z-%$2Y$/%<&<8*-'Q PEF'O%-/%<55 A.% ^'<9_7$ 7EF#$%$% '6B99$ 5*8 ($%'7EF5$9A$'
T\G^	T$8-'2VEF5$9A$ I$%7.EF72^'9</$SRa(X
T]b^	T.'&$75*'*78$%*.5 6N% b*%87EF<68 .'& ^%K$*8 Sh$8A8C T.'&$75*'*78$%*.5 6N% b*%87EF<68 .'& G$EF'-9-/*$ST]b*XX

T] b*	T.'&$75*'*78$%*.5 6N% b*%87EF<68 .'& G$EF'-9-/*$ S0-%5<97C T.'&$75*'*78$%*.5 6N% b*%87EF<68 .'& ^%K$*8 ST] b ^XX
TU+	T$78 U%<E8*E$ +.*&$9*'$7
Z^W] ^D	W-&2 I$%7.EF7<'9</$ SR%<'L%$*EFX
Z^Gc^P\	R%<'A)7*7EF$% GF$%5-F_&%<.9*L2V_78$5E-&$ SZ\^X
ZZW	]-&.9 A.% V*5.9<8*-' &$7 VEF5$9A0%F<98$'7*' Z[Z[VjV
Z\^	Z-55*77<%*<8 z|'$%/*$ ^8-5*$J 6%<'A)7*7EF$ ^8-5$'$%/*KF)%&$
ZR^VG	a-'$'5-&$99
ZRY	Z-50.8<8*-'<9 R9.*& Y_'<5*E7 S'.5$%*7EF$ V*5.9<8*-' 0-' 69.*&2 &_'<5*7EF$' I-%/B'/$'X
ZRx	ZRY2Z-&$ S^DVjVX
Z[Z[VjV	Z-'8<*'5$'8 Z-&$ V_78$5 S+PVX
Z[ ]@Y	ZRY2U%-/%<55 A.% b<77$%78-660$%K%$''.'/
Z[DG^WD	I-' V^DYW^ D<8*-'<9 M<K-%<8-%*$7J ^9K.p$%p$J 'V^J*5 ^.68%</ 0-' 'VDPZ $'8#*EL$98$7 Z-'8<*'5$'82PEF'O%-/%<55
Z[P^	TN'&9eO$%*5$'8$ A.% [e*&<8*-' .'&]<8$%*<9*'8$%<L8*-'J Ra(
Z[PZ[D	]ZZW2Z-&$ SV<'&*< D<8*-'<9 M<K-%<8-%*$7J <.EF*']\MZ[P 0$%#$'&$8X
Z[P\V^	Z-%*.5 -' P$6%<E8-%_ <'& V<E%*6*E*<9]<8$%*<97Q I$%K.'&O%-h$L8 0-' V*$5O$9L<5OJ T<88$99$J V*$5$'7J Gc ^<EF$'
Z[PWDD^	^9/-%*8F5.7 6N% &*$ Y<%78$99.'/ &$% A$*89*EF$' \%-7*-' &$% (<0$%'$
Z[V^Z[	]ZZW2Z-&$ 5*8 &$8<*99*$%8$% T$%NEL7*EF8*/.'/ 8F$%5-EF$5*7EF$% UFB'-5$'$ SR%<5<8-5$ ^DUX
ZU^	Z-'8<*'5$'8 U<%8 -6 ^VG\Z
ZPYM[Z	ZF$5*E<9 P$<E8*-'7J Y*78%*K.8*-'7J M-E<9 Z-'&*8*-'7 S]-&$99 A.% T$%$EF'.'/ 0-' g92 .'& (<K$9K%B'&$'X
ZVDW	Z-55*88$$ -' 8F$ V<6$8_ -6 D.E9$<% W'78<99<8*-'7 S[\ZYkD\^X

Y<

Y<5L)F9$%2a<F9

YZc

Y*%$E8 Z-'8<*'5$'8 c$<8*'/

YYG

HK$%/<'/0-' Y$69</%<8*-' A.% Y$8-'<8*-' SY$69</%<8*-' 8-
Y$8-'<8*-' 8%<'7*8*-'X

Y\Z[TW

\eO$%*5$'8$<5 P-_<9W'78*8.8$ -6 G$EF'-9-/_J VEF#$&$'

Y\Z[P

c32I$%K%$''.'/75-&$99*' Z[Z[VjV

Y\V

Y$8<EF$& \&&_V*5.9<8*-'

Y\G@Y

Z-&$ A.% V*5.9<8*-' 0-' Y$8-'<8*-'$'*' @2Y2+$-5$8%*$' SRa(X

YcR

Y%_-.8 c$<8R9.e

YWVZ[

Y*7O$%7*-'70$%7.EF$ 5*8 ($%'7EF5$9A$ SRa(X

YDV

Y*%$E8 D.5$%*E<9V*5.9<8*-'

YP^VjV

]-&$99A.%V*5.9<8*-' &$% c_&%-&_'<5*L*' Y%.EL<KK<.7_78$5$'*'
Z[Z[VjV.'& ^VG\Z

YbP

Y%.EL#<77$%%$<L8-%

\Z[VG^P

\e20$77$9Z-%$]$98V8<K*9*A<8*-' P7<%EF
S=:\'2P<F5$'O%-/%<55X

\&R

\9$E8%*E*8 &$ R%<'E$

\UPW

\9$E8%*E U-#$% P7<%EF W'78*8.8$J 'V^

\'

\.%-OB*7EF$ ''*-'

\'PV^R\

\.%-O$<' eO%8 '$8#-%L 6-% 8F$ %$&.E8*-' -6 .'E$%8<*'8*$7*' 7$0$%$
<EE*&$'8 7<6$8_*77.$7

\IWG^

\.%-O$<' 0<9*&<8*-' -6 8F$*'8$/%<9E-&$ ^VG\Z

R^P[

R.$9]$98 ^'& P9<7$ [0$'J W'8$%<L8*-' 0-' VEF5$9A$78%<F9$' .'&
b<77$%J VEFN88K$88K*9&.'/SfPZ W7O%<X

R\

R*'*8$ \9$5$'8$

RYV R*%$ Y_'<5*E7 V*5 .9<8-% SZRY2U%-/%<5 5X

R\T\ R-%#<%& \.9$% T<EL#<%& \.9$%

RWUc[VG]-&.9 A.% V*5 .9<8*-' &$7 D.L9*&8%<'7O-%87*' Z[Z[VjV

RWUWV[ ]-&.9 A.% V*5 .9<8*-' &$7 D.L9*&0$%F<98$'7 SD<EFA$%6<9979$*78.'/X*' Z[Z[VjV

RWUM[Z R*77*-' U%-&.E8 M-E<9*7<8*-' S]$F%%<.5%$EF$'5-&$99 6N% GF$%5-F_&%<.9*LJ ^$%-7-92 .'& W-&0$%F<98$'Q I-%9B.6$%E-&$0-' Z[Z[VjVX

RM^]]\2V a-'$'5-&$99

RM'XT^WD]-&$99 A.5 bB%5$NK$%/<'/<.7 VEF5$9A$7$$' SZ\^X

RPDZ R9<5$ P$8<%&<'8 D-' Z-%%-7*0$ SV-'&$%L<K$9 5*8 F<9-/$'6%$*$' (<K$9*7-9<8*-'7#$%L78-66$'X

Raf R-%7EF.'/7A$'8%.5 fN9*EF

Ra(R-%7EF.'/7A$'8%.5 (<%97%.F$

RaP R-%7EF.'/7A$'8%.5 P-77$'&-%6

+PV +$7$997EF<68 6N% ^'9</$'2 .'& P$<L8-%7*EF$%F$*8 5Kc

c^YZPG M.5O$& O<%<5$8$%2U%-/%<5 5

cYP c$*,&<5O62P$<L8-%J (<%978$*'

c\Z' c$<8 Z-'&.E8-%J V8%.E8.%2]-&$99*' ^GcM\G

cU]\ c*/F U%$77.%$]$98 \h$E8*-'

cjZ[] U%-h$L8*5 =:\'2P<F5$'O%-/%<5 5 A.% c32I$%K%$''.'/

W^\^ W'8$%'<8*-'<9 ^8-5*E \'$%/_^/$'E_J b*$'

WZ^P\ R%<'A)7*7EF$% ($%'7EF5$9A2V_78$5E-&$ SWPVDX

WZ\ W'/%$77 -6 Z--9<'8 \0$'8 Sh<O<'*7EF$7 \eO$%*5$'8<.6 &$5 +$K*$8 &$% ($%'6.7*-'X

WZR]U W'8$%'<8*-'<9 E-9<K-%<8*0$ 6*%$ 5-&$99*'/O%-h$E8

WY\ ] [23Y PEF'O%-/%<55 A.% T$7EF%$*K.'/0-' Y<5O6$eO9-7*-'$' SW(\X

W(\ W'78*8.86N% ($%'$'$%/$8*L .'& \'$%/*$7_78$5$J ''*0$%7*8B8 V8.88/<%8

W(\f\G U%-/%<55 A.% T$7EF%$*K.'/ &$% R%</5$'8<8*-'7O%-A77 <5 VEF5$9A$78<F9 SW(\X

W(\]Wx U%-/%<55 A.% T$7EF%$*K.'/ &$% b$EF7$9#*%L.'/ &$% VEF5$9A$2 8%-O6$'J R%</5$'8$ 5*8 &$5 P$78#<77$%J I-%0$%5*7EF.'/K$* &$% Y<5O6$eO9-7*-' SW(\X

W]U^WP Z-&$ A.% V*5.9<8*-' &$7 W-&0$%F<98$'7*5 Z-'8<*'5$'8 SUVWkVEF#$*AX

WDVU\ZG f-&5-&$99

WPVD W'78*8.8 &$ P<&*-O%-8$E8*-' $8 &$ V%$8 D.E9<*%$J R%<'L%$*EF

WVU W'8$%'<8*-'<9$7 V8<'&<%&O%-K9$5

f^V]WD\ PEF'E-&$ A.5 ^.6K%EF' 0-' VEF5$9A$78%<F9$' .'& A.% I-%0$%5*7EF.'/J VN&L-%$< S(^\PWX

fPZ f-*'8 P7<%EF Z$'8%$ &$% \'

(\VV (\%' VEF5$9A V_78$5J ($%'7EF5$9AE-&$J G$78K$88 <5 W(\ A.]-&$99$'8#*EL9.'/$' 6N% ^GcM\G2ZYQ PEF'O%-/%<55 A.% V*5.9<8*-' &$% ($%'7EF5$9A0-%/B'/$*5 P$<L8-%&%.ELK$FB98$%

(]IV (NF95*88$90$%9.782V8)%6<99

(G^ ($%'8$EF'*7EF$% ^.77EF.77

M^Z[]\P^ \eO$%*5$'8$ A.5 *' 0$77$92($%'7EF5$9A$' S\'X

M^DM M-7 ^9<5-7 D<8*-'<9 M<K-%<8-%_J 'V^

M^I^ +PV2Z-&$ A.% ($%'7EF5$9A$<.7K%$*8.'/

M\V M<%/$ \&&_ V*5.9<8*-'

MWR M-E<9 W'78<'8 R-%5.9<8*-'

MWPWZ M*K%<%_ -6 W-&*'$ P$<E8*-'7*' Z-'8<*'5$'8

MWI\ M<8$ W'2I$77$9 UF<7$ \eO$%*5$'87J \eO$%*5$'8$ A. 7OB8$' UF<7$' &$7 ($%'7EF5$9A$'7 SRa(X

M [Z^ M-77 -6 Z--9<'8 ^EE*&$'8

MU M.5O$& U<%<5$8$% S'.5$%*7EF$7 I$%6<F%$'X

Mb P M$*EF8#<77$%%$<L8-%

] ^^U GF$%5-F_&%<.9*E V_78$5E-&$ A.% ^'<9_7$ 7EF#$%$% V8)%6B99$ SR<.7L$ ^77- E*<8$7X

] ^Z\ ]$98 ^88<EL <'& Z--9<K*9*8_ \eO$%*5$'87J ''8$%7.EF.'/$' A.% VEF5$9A$2T$8-'2b$EF7$9#*%L.'/ .'& A.% (NF9.'/ $*'$% O%-8-8_O*7EF$' Z-%*.52VEF5$9A$ &.%EF b<77$%A.6.F% 0-' -K$' S^DMX

] ^Z\ ]$98 ^88<EL <'& Z--9<K*9*8_ \eO$%*5$'87 S\UPWX

] ^+WZ a-'$'5-&$99

] ^VZ^]<8$%*<9 VE<9*'/C \eO$%*5$'8$ A.5 I$%F<98$' 0-' Z-%*.5 *5 ''8$%$' U9$'.5 S(.%EF<8-0W'78*8.8J P.779<'&X

] ^GGWD^ PEF'O%-/%<55 A.% T$7EF%$*K.'/ &$% I-%0$%5*7EF.'/ K$* &$% Y<5O6$eO9-7*-' SRa(X

] Z@Y PEF'O%-/%<55 A.% T$7EF%$*K.'/ &$% I-%0$%5*7EF.'/ K$* &$% Y<5O6$eO9-7*-' SZ\^X

] ZZW]-98$' Z-%*.5 Z-'E%$8$W'8$%<E8*-'

] \YWZWV]-&$9 \0<9.<8*-' Y$0$9-O5$'86-%W'0$78*/<8*-' -6 Z-%*.5 W'8$%<E8*'/ #*8F V.K78%<8$

] \MZ [P W'8$/%<9E-&$ A.% ^'<9_7$ 7EF#$%$% V8)%6B99$ 5*8 ($%'7EF5$9A$' K$* M$*EF8#<77$%%$<L8-%$' SVDMX

] \V [Z [ ]\98*'/ <'& V[9*&*6*E<8*-' -6 Z[%$]<8$%*<9J (\VV2]-&.9 A.% VEF5$9A$0$%9</$%.'/*' V8%.L8.%$' SW(\X

] \b ^]\V [Z [b^T\J(-OO9.'/0-']\V [Z [.'& b^T\ SW(\J+PVX

] [x]*7EF-e*&

] IWG^]-&$99 A.5 8F$%5*7EF$' I$%F<98$' $*'$7 VEF5$9A$7$$7 *5 ''8$%$' U9$'.5 SVEF#$&$'X

D\^ D.E9$<% \'$%/_^/$'E_

DPZ D.E9$<% P$/.9<8-%_ Z-55*77*-'J b<7F*'/8-' YZ S'V^X

DPV D.E9$<% P$<E8-% V<6$8_

[\ZY [%/<'*7<8*-' 6-% \E-'-5*E Z-2-O$%<8*-' <'& Y$0$9-O5$'8

[PW+WD D.L9*&K*K9*-8F$L

U^P U<77*0$ ^.8-E<8<9_8*E P$E-5K*'$%Q (<8<9_7<8-%A.% P$L-5K*'<8*-' 0-' b<77$%78-66*5 Z-'8<*'5$'8

UYR U%-K<K*9*8_ Y$'7*8_ R.'E8*-'

U\PZ[M^ \eO$%*5$'8$ &$% Z\^

Uc\T‘V TN'&9eO$%*5$'8$ A. ($%'0$%7</$' .'& VO<98O%-&.L86%$*7$8A.'/ SZ\^JRX

Uc\T‘VRU I$%7.EF77$%*$ R*77*-' U%-&.E8<5 Uc\T‘V2P$<L8-%SZ\^JRX

UWPG UF$'-5$'<W&$'8*6*E<8*-' <'& P<'L*'/ G<K9$7 S&.%EF/$6NF%8*5 =: P<F5$'O%-/%<55 &$% \‘X

UV^ U%-K<K*9*78*7EF$ V*EF$%F$*87<'<9_7$

UGV U%$77.%*A$& GF$%5<9 VF-EL

UI] U<%<99$9 I*%8.<9]<EF*'$

ó\DZc TN'&9eO$%*5$'8$ A.% [e*&<8*-' .'&]<8$%*<9*'8$%<L8*-' SRa(X

P^M[Z P<&*-9_7*7 <'& M-E<9 Z-'E$'8%<8*-'Q &$.87EF$7 Z-'8<*'5$'82 U%-/%<55 A.% P<&*-9_7$2J I$%8$*9.'/72 7-#*$ c32 .'& T%<'&%$EF'.'/$'*5 Z-'8<*'5$'8S+PVX

P^DV P$_'-9&7 ^0$%</$& D<0*$%2V8-L$7

PT](V*$&$#<77$%%$<L8-%%.77*7EF$% T<.<%8S+%<OF*85-&$%*$%8X

PYT P$<L8-%&%.ELK$FB98$%

PW^ P$<E8*0*8_W'*8*<8$& ^EE*&$'8

PWG P-_<9W'78*.8$ -6 G$EF'-9-/_ SV8-ELF-95J VEF#$&$'X

P[^^] P*7L -%*$'8$& ^EE*&$'8 ^'<9_7*7]$8F-&-9-/_

PUI P$<E8-% U%$77.%$ I$77$9

PV(P$<L8-%7*EF$%F$*87L-55*77*-'

PGR P<&*-*-&*'G78R<E*9*8_SZ^DY‘ [#'$%7+%-.OJ(<'<&<X

P‘U‘WZ‘I 6%<'A)7*7EF$7]-&$99A.5VEF5$9A$$*'8%</*'&$'PYT

V^PD\G V0%$ ^EE*&$'8 P$7$<%EF D$8#-%L
SD$8#-%L-6 \eE$99$'E$6N% 7EF#$%$V8)%6B99$XQ \‘

V^V VE<9$ ^&<O8*0$V*5.9<8*-'

VZ^Z\x VZ^9*'/-6Z-'8<*'5$'8 \eO$%*5$'87S\‘2U%-h$L8X

VZY^UkP\M^U GF$%5-F_&%:V_78$5E-&$A.% ^'<9_7$7EF#$%$%V8)%6B99$SWD\\MX

VZ] VO9*8Z-$66*E*$'8]<8%*e

V\P\D^ V8$<5 \eO9-7*-' P$7-9.8*-'6-%D.E9$<% ^OO9*E<8*-'7S[\ZY2U%-h$L8X

VcT V*EF$%F$*87K$FB98$%

VU VO<98O%-&.L8$

VU^PZ PEF'E-&$A.% \%5*889.'/0-' ^K7EF$*&$0-%/B'/$'*'
b<77$%0-%9</$'

VVG VF$<%V8%$77G%<'70-%8

VbP V*$&$#<77$%%$<L8-%

GRY GF$%5-2R9.*&&_'<5*L

GF^W GF$%5-F_&%<.9*L ^$%-7-9$W-&S&$.87EF$ I$%7.EF7<'9</$X

Gcj GF$%5-F_&%<.9*L2]-&.9*'Z[Z[VjV.'& ^VG\Z

G]W GF%$$]*9$W79<'&

G[VðD 6%<'A)7*7EF$7 I$%7.EF70%-/%<55

GIY G-8<9 I<%*<8*-' Y*5*'*7F*'/

‘U ‘OO$% U9$'.5

‘ UGR ‘ OO$% U9$’ . 5 G$78 R<E*9*8_
SGF$% 5 -F_&%<. 9*L2W’ 8$/ %<90$%7 . EF7<’ 9</$J Y$. 87EF9<’ &X

‘ V ‘ 98%<7EF<99

‘ VDPZ ‘ ’*8$& V8<8$7 D . E9$<% P$/ . 9<8-%_ Z - 5 5*77*- ’

‘ P^DV ‘ ’78$<&_ P$_’ -9&72^0$%</$& D<0*$% V8-L$7

I \ Z [I \ 77$9 Z [-9<K*9*8_J P$EF$’ O%- /%< 5 5 A . % T$7EF%$*K . ’ / &$%
U<%8*L$9K*9&. ’ / . ’ & ?LNF9. ’ / *5 ‘ ’8$%$’ U9$’ . 5 SW (\X

I + T G$EF’ : I $%$*’ */ . ’ / &$% +%- , L%<68#$%LK$8%$*K$%

IM \ V I $%_ M<%/$ \&&_ V*5 . 9<8*- ’

I I \ P Y% . EL#<77$%%$<L8-% % . 77*7EF$% T<. <%8 S b <77$% 5 -&$%*$%8X

b ^ T \ b <8$% T$&J Z -&$2] -&. 9 A . % T$%$EF’ . ’ / &$7 b B% 5 $8%<’ 7O-%87 *’
/$69 . 8$8$’ VEFN88. ’ /$’ SW (\X

b \ Z c VM Z -&$ A . % V*5 . 9<8*- ’ &$% VEF 5 $9A$2T$8- ’2 b $EF7$9#*%L . ’ / SRa (X

b \ x Z -&$ A . % V*5 . 9<8*- ’ &$% VEF 5 $9A$2T$8- ’2 b $EF7$9#*%L . ’ /
S b $*8$%$’ 8#*EL9. ’ / 0- ’ b \ Z c VMX

b \ a b B% 5 $$*’ 69 . 77A- ’$

b b \ P Y% . EL#<77$%%$<L8-% 7 -#h$8*7EF$% T<. <%8 S b <77$%2 b <77$%2 \ ’$%/*$2
P$<L8-%X

A3 Tabellen 1 – 6:

PEF'O%-/%<5 5$ 6N% &*$ <'<9_8*7EF$' R-%7EF.'/7/$K*8 &$%

P$<L8-%7*EF$%F$*8

Tabelle 1: Rechenprogramme zur Komponentensicherheit				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
ABAQUS		V8%.L8.%5$EF<'*L	^99/5*'$7 R*'*8$ \9$5$'8$ U%-/%<55Q T$'.8A$%&$6*'*$%8$ b$%L78-665-&$99$ 7O$A*$99 6N% '*EF89*'$<%$ T$%$EF'.'/$'J \%5*889.'/ &$% (%*$EF7EFB&*/.'/ .'& 6N% P<8EF$8*'/2 ''8$%7.EF.'/$':	^T^óVJW'E: 'V^
			!+$'$%<92U.%O-7$2U%-/%<557_78$5; SM*A$'AO%-&.L8Q b$*8$%$'8#*EL9.'/*5 o$99E-&$ K$*5 c$%78$99$%X	
ADINA **A**.8-5<8*E **D**_'<5*E **I**'E%5'8<9 **N**-'9*'$<% **A**'<9_7*7		V8%.L8.%5$EF<'*L	^99/5*'$7 R*'*8$ \9$5$'8$ U%-/%<55Q VEFB&*/.'/75$EF<'*LC T$78*55.'/ &$7 P*770$%F<98$'7JW'8$/%*8B87K$#$%8.'/ PYT .'8$% 8F$%5-5$EF<'*7EF$' T$9<78.'/$' SA:T: K$* D-8LNF95<,'<F5$'XJW'8$/%*8B8 &$7 PYT2T-&$'7 K$* ($%'7EF5$9AK$9<78.'/$'J G%</6BF*/L$*8 0-' V8<F9K$8-'78%.L8.%$':	^YWD^J P YJ W'E: 'V^
			!+$'$%<92U.%O-7$2U%-/%<557_78$5; SM*A$'AO%-&.L8Q b$*8$%$'8#*EL9.'/*5 o$99E-&$ K$*5 c$%78$99$%X	
ANSYS		V8%.L8.%5$EF<'*L	^99/5*'$7 R*'*8$ \9$5$'8$ U%-/%<55Q T$'.8A$%&$6*'*$%8$ b$%L78-665-&$99$ S9*'$<%$.'& '*EF89*'$<%$ T$%$EF'.'/$' A.% V8%.L8.%5$EF<'*LJ T$78*55.'/ &$% (%*$EF7EFB&*/.'/Q P<8EF$8*'/:	^DVWV W'E: 'V^
			!+$'$%<92U.%O-7$2U%-/%<557_78$5; SM*A$'AO%-&.L8Q b$*8$%$'8#*EL9.'/*5 o$99E-&$ K$*5 c$%78$99$%X	
ASTOR	**A**OO%-e*5<8$& **S**8%.E8.%<9 **T***5$ **o**6 **R**.O8.%$	V8%.L8.%5$EF<'*L	I$%$*'6<EF8$7 I$%6<F%$' A.% ^K7EFB8A.'/ 0-' I$%7</$'7A$*8$' &$7 P$<L8-%&%.ELK$FB98$%K-&$'7 .'8$% ($%'7EF5$9AK$&*'/.'/$' 5*8 .'& -F'$ c-87O-8:	+PV
DICTRA		V8%.L8.%5$EF<'*L	GF$%5-&_'<5*7EF$ V*5 .9<8*-' &$% T*9&.'/7L*'$8*L .'& &$% EF$5*7EF$' a.7<55$'7$8A.'/ 0-' ^.77EF$*&.'/$' *5 V8<F9 6N% &$' 8F$%5-&_'<5*7EF$' +9$*EF/$#*EF87A.78<'& <.EF 6N% D*EF82+9$*EF/$#*EF87A.78B'&$ SA: T: '<EF $*'$% b B%5KF<'&9.'/X:	GF$%5-2Z<9E ^TJ V8-ELF-95
FEMAP		V8%.L8.%5$EF<'*L	U-78O%-A$77-% 6N% R*'*8$ \9$5$'8$ T$%$EF'.'/$':	\YV c$<&p<%8$% 'V^
JCALC		V8%.L8.%5$EF<'*L	^'<9_7$#$%LA$./ 6N% P*77K$<'7O%.EF.'/7O<%<5$8$% S\%#$*8$%.'/ &$7 +N98*/2 L$*87K$%$*EF7 &$7 f2W'8$/%<97XQ T$%$EF'.'/ &$7 f2W'8$/%<97 '<EF &$M-%$'A*J &$7 G 2W'8$/%<97 '<EF ^89.%* 7-#*$ &$7 f 2W'8$/%<97 '<EF V*5- K<7*$%$'&<.6 R*'*8$2 \9$5$'8$2T$%$EF'.'/ &$% VO<''.'/$' .'& Y$F'.'/$' *' &$% '5/$K.'/ $*'$% P*776%-'8:	+PV

Tabelle 1: Rechenprogramme zur Komponentensicherheit				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
PATRAN		V8%.L8.%5$EF<'*L	^99/5*'$% U%$2 .'& U-78O%-A$77-% 6N% R*'*8$ \9$5$'8$ T$%$EF'.'/$':	]VZ V-68#<%$J Z^J 'V^
PROST	**Pro**K<K*9*78*7EF$ **St**%.L8.%2 K$%$EF'.'/	V8%.L8.%5$EF<'*L	^K7EFB8A.'/ &$% V8%.L8.%A.0$%9B77*/L$*8 /$7EFB&*/8$% P-F%9$*8.'/$'.'8$% O-78.9*$%8$' T$8%*$K72 .'& V8)%6<99K$9<78.'/$' SK*7F$% '.% VEF<&$'75$EF<'*72 5.7 \%5N&.'/X:	+PV
PRAISE	**P***O*'/ **R**$9*<K*9*8_ **A**'<9_7*7 **I**'E9.&*'/ **S**$*75*E **E**0$'87	V8%.L8.%5$EF<'*L	U%-K<K*9*78*7EF$ T$78*55.'/ &$7 G%</0$%5)/$'7 &6L8K$F<68$8$% P-F%9$*8.'/$': I-%/$F$'7#$*7$.'&]<8$%*<95-&99 '*EF8 &*%$L8 <.6 &$.87EF$ I$%FB98'*77$ NK$%8%</K<%:	'V2DPZQ +PV
QUAMET	**Qua**9*6*A*$%.'/72 **Met**F-&*L	V8%.L8.%5$EF<'*L	M<.6$'&$ \'8#*EL9.'/ A.% o<9*6*A*$%.'/ 0-' ^'<9_7$5$8F-&$' A.%W'8$/%*8B87K $2 #$%8.'/ 0-' P$<L8-%&%.ELK$FB98$%' .'& &$%$' ^'#$'&$%' SO$%K77%8$ U%N6.'/ &$% ^'<9_7$5$8F-&$' F*'7*EF89*EF */'.'/ 6N% V*EF$%F$*87'<EF#$*7Q o<9*6*A* $2 %.'/ &$7 U$%7-'<97X:	+PV
ROHR2		V8%.L8.%5$EF<'*L	P-F%9$*8.'/7K$%$EF'.'/7O%-/%<55 A.% \%5*889.'/ %<9% T$9<78.'/70-%/<K$' A.5 5$EF<'*7EF$' I$%F<98$' 0-' P-F%9$*8.'/$' .'& ^KA#$*/$':	VW+]^W'/$2 '*$.%/$7$997EF<68 Y-%85.'&
R6		V8%.L8.%5$EF<'*L	T%.EF5$EF<'*7EF$7 T$%$EF'.'/7O%-/%<55 5*8 &$5 32(%*8$%*$'2I$%6<F%$':	T%*8*7F \'$%/_ +$'$%<8*-' M8&:
SIGMAKT		V8%.L8.%5$EF<'*L	^'<9_8*7EF$ ^'7B8A$ A.% T$78*55.'/ 0-' VO<''.'/$' .'& P*77K$<'7O%.EF.'2 /$': W'/$'*$.%5B,*/$ I$%6<F%$' A.% T$78*55.'/ 8F$%5*7EF$% .'& 5$EF<'*7EF$% VO<''.'/$' *' L%$*7A_9*'&%*7EF$' T$FB98$%' 7-#*$ &$% T$<'7O%.EF.'/ .'8$%78$%92 8$% [K$%69BEF$'2 '56<'/7%*77$*' R-%5 &$7 VO<''.'/7*'8$'7*8B876<L8-%7: bB%5$7O<''.'/$' K$*%-8<8*-'77_55$8%*7EF$% G$50$%<8.%0$%8$*9.'/ .'& K<9L$'8F$-%$8*7EF$% ^'7<8A 6N% .'7_55$8%*7EF$ 8F$%5*7EF$ T$9<78.'/$' A:T: K$* 78%BF'$'6)%5*/$% (NF9.'/ $*'$7 T$FB98$%7X:	+PV
THERMOCALC		V8%.L8.%5$EF<'*L	GF$%5-&_'<5*7EF$ V*5.9<8*-' &$% T*9&.'/7L*'$8*L .'& &$% EF$5*7EF$' a.7<52 5$'7$8A.'/ 0-' ^.77EF$*&.'/$' *5 V8<F9 6N% &$' 8F$%5-&_'<5*7EF$' +9$*EF/$#*EF87A.78<'&:	
WinLeck		V8%.L8.%5$EF<'*L	^'<9_7$#$%LA$./ 5*8]-&$99$' A.% T$%$EF'.'/ &$% M$EL%<8$' .'& M$EL69BEF$' 0-' P-F%9$*8.'/$' 5*8 %*77<%8*/$' M$EL</$':	+PV

Tabelle 1: Rechenprogramme zur Komponentensicherheit				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
WINLIFE		V8%.L8.%5$EF<'*L	U-78O%-A$77-% 6N% R*'*8$ \9$5$'8$ T$%$EF'.'/$': VO$A*99 ^.7#$%8.'/$' F*'7*EF89*EF]$F%<EF7*/L$*8 &$7 VO<''.'/7A.78<'&$7:	V8$*'K$*7 G%<'76$%A$'8%.5J '95

Tabelle 2: Rechenprogramme zur Reaktorphysik

Code	Akronym von	Fachgebiet	Beschreibung	Entwickler
ARCOSI		($%'7*5.9<8-%	RYbP \'8#*EL9.'/ A.% T$78*55.'/ \p*9*K%*.5 ($%': *'/$7$8A8 6N% MbP .'& ^YV \%78L$%'%$EF'.'/$': \'8FB98 $*/$'$ T*K9*-8F$L778%.L8.% 6N% <KK%<'&<KFB'/*2 /$ V :	Ra(
CITATION		P$<L8-%OF_7*L	@2Y Y*66.7*-'7%$EF'.'/$' 5*8 6*'*8$' Y*66$%$'A$':	[PDM
COLLUP		P$<L8-%OF_7*L	T$%$*878$99.'/ 0-' O%-K9$570$A*6*7EF$' b$'*/2+%.OO$' S1>X T*K9*-8FL' *5 V8<'&<%& +P'T^ R-%5<8J <.7/F'& 0-' $*'$% +P'T^]<78$%2T*K9*-8F$L SA:a: dh+%.OO$'J bW]V V8%.L8.%X :	Ra(
D3E/ AUDI3		P$<L8-%OF_7*L	@2Y].98*2+%.OO$' Y*66.7*-'7%$EF'.'/$' 5*8 6*'*8$' Y*66$%$'A$' w^.7#$%8.'/$' .'& V8)%.'/7%$EF'.'/$':	Ra(
DANTSYS/ PARTISN		P$<L8-%OF_7*L	@2Y].98*2+%.OO$' Y*7L%$8$ [%&*'<8$' 6*'*8$' Y*66$%$'A$' G%<'7O-%8O%-/%<55 SU^PGWVD A$*8<KFB'/*/X:	[PDM
DIF3D/ VARIANTK		P$<L8-%OF_7*L	@2Y].98*2+%.OO$' Y*66.7*-'72 .'& G%<'7O-%82 U%-/%<55 5*8 6*'*8$' Y*66$%$'A$' -&$% 6*'*8$' \9$5$'8$':	^DM
DIXY2 + Auswertung		P$<L8-%OF_7*L	32Y].98*2+%.OO$' Y*66.7*-'7%$EF'.'/$' 5*8 6*'*8$' Y*66$%$'A$' w^.7#$%8.'/$' .'& V8)%.'/7%$EF'.'/$':	Ra(
DORT/TORT		P$<L8-%OF_7*L	G$*9$ &$7 U%-/%<557_78$5 Y[[PV2@:3: a#$*2 KA#: &%$*&*5$'7*-'<9$ &8%5*'*78*7EF$ G%<'7O-%82Z-&$7 6N% %$/.9B%$ +$-5$8%*$ *' L<%8F$7*7EF$' -&$% a_9*'&$%L--%&*'<8$': M)7.'/ &$% T-98A5<''2G%<'7O-%8/9$*EF.'/ 5*8 &$%]$8F-&$ &$% &*7L%$8$' [%&*'<8$: b*%L.'/7p$%7EF'*88$ <.7 0-%<K $%A$./8$' O%-K9$570$A*6*7EF$' Y<8$' *'].98*/%.OO$'&<%78$99.'/ S<.7 &$' 5*L%-7L-O*7EF$' b7 I-%<KK$%$EF'.'/ &$% 0-' &$%]<8$%*<9A.7<55$'7$8A.'/J &$']-&$%<8*-'70$%FB98'*77$' .'& &$% G$5O$%<8.% <KFB'/*/$' 5<L%-7L-O*7EF$' b7 6N% &$' L-'L%8' ^'#$'&.'/76<99X: Y<%< .7 \%%$EF'.'/ &$% %$<L8-%OF_7*L<9*7EF$' +%),$' 6N% V_78$5$ 5*8 0-%/$/$K$'$' o99' -&$% 6N% (%*8*L<9*8B87%$EF'.'/$':	[PDM

Tabelle 2: Rechenprogramme zur Reaktorphysik				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
DYN3D		P$<L8-%OF_7*L	@Y2($%'5-&$99 YjD@Y 5*8 @2 &*5$'7*-'<9$% D$.8%-'$'L*'$8*L A.% T$%$EF'./ 0-' 7*EF$%F$*87%$9$0<'8$' +%),$' &$7 P$<L8-%L$%'7: Y%$*&*5$'7*-'<9$ M$*72 8.'/7&*EF8$0$%8$*9.'/ *5 P$<L8-%L$%'J0-9978B'&*/$ T$7EF%$*K.'/ <99$% PNEL#*%2 L.'/7$66$L8$ 0-' T%$''78-668$5O$%<8.%.'& (NF95*88$9&*EF8$: D$.8%-'$'L*'$8*L 5*8 &$% Y*66.7*-'78F$-%*$ K$%$EF'$8*' &$% 32+%.OO$''BF$%.'/ 5*8 '-&<9$']$8F-&$' <99$ 7*EF$%F$*87%$9$0<'8$' +%),$': GF$%5-F_&%<.9*L8$*9 0-' YjD@Y K<7*$%8<.6 $*'$5 1Y I2+9$*EF.'/75-&$99 6N% 12.'& 32UF<7$'78%)5.'/$': P<&*<9$ bB%5$2 9$*8.'/*' T%$''78<K.'& cN99$:W5 GF$%5-F_&%<.9*L8$*9 L)''$' T-%0$%5*7EF.'/72 5-&99*'L-%O-%*$%8 #$%&$': T$7-'&$%F$*8C -O8*-'<9$ T$%$EF'./ 0-' p<&%<8 *2 7EF$'.'& F$e</-'<9$' T%$''$9$5$'8$'J7-#*$ @ (-OO9.'/7<%8$' 0-' D$.8%-2 '$'L*'$8*L SD(X.'& GF$%5-F_&%<.9*L SGcX X *'8$%'$ (-OO9.'/C D(*5 ($%' 0-' YjD@YJ Gc*5 ($%'.'&*' &$% VEF9$*6$ 0-' ^GcM\GJ KX $e8$%'$ (-OO9.'/C D(.'& Gc*5 ($%' 0-' YjD@YJ Gc*' &$% VEF9$*6$ 0-' ^GcM\GJ EX O<%<99$9$ (-OO9.'/C D(.'& Gc*5 ($%' 0-' YjD@YJ Gc*5 ($%'.'&*' &$% VEF9$*6$ 0-' ^GcM\G:	RaP
GRUCAL/ **GRUBA**		P$<L8-%OF_7*L	T$%$EF'./ 0-' 5<L%-7L-O*7EF$'.'& 5*L%-7L-O*7EF$' +%.OO$'p$%7EF'*88$ 0-' +P‘T^ T*K9*-8FL' 5*8 $*/$'$5 VO$*EF$%6-%5<8:	Ra(
HEXNOD/ **HEXNODYN**		P$<L8-%OF_7*L	@2Y].98*2+%.OO$' Y*66.7*-'72.'& G%<'7O-%8 P$EF'./$' 5*8 6*'*8$' \9$5$'8$:	(b‘kR%<5<8-5$
KAPROS-E		P$<L8-%OF_7*L	\%#$*8$%8$7 (^UP[V V_78$5.'8$% ‘DW›XMWD‘¥k6N% (-OO9.'/ 0-' $e8$%'$' Z-&$7 0*<W'8$%6<E$ R*9$7: (-OO9.'/$' 7*'& 0-%F<'&$' 6N% D$.8%-'$'OF_7*L.'& G%<'7*$'8$' U%-/%<5 5$:	Ra(

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Tabelle 2: Rechenprogramme zur Reaktorphysik

Code	Akronym von	Fachgebiet	Beschreibung	Entwickler
KAPROS/ KARBUS		P$<L8-%OF_7*L	] -&.9<%$7 U%-/%<5 57_78$5 A.% 69$e*K9$' Y.%EF6NF%.'/ 0-' &8%5*'*78*7EF$'].98*2+%.OO$' P$<L8-%%$EF'.'/$': Y<7 V_78$5 #.%&$ K$* Ra(A.'BEF78 6N% VEF'$99$ P$<L8-%$' L-'A*O*$%8 .'&*5 P<F5$' 0-' ''8$%7.EF.'/$' 6N% .'8$%5-2 &$%*$%8$ M b P SRY b PX <.EF 6N% M b P $*'7$8AK<% /$5<EF8: (^UP [Vk(^PT 'V #.%&$ p<9*6*A*$%8 6N% ^.79$/.'/7 2 .'& ^KK%<'&%$EF'.'/$' 6N% 8F$%5*7EF$J $O*2 8F$%5*7EF$.'& 7EF'99 P$<L8-%$': Y<7 V_78$5 $'8FB98 $*'$ P$*F$ 0-' VEF9N77$95-&.9':	Ra(
KENOREST		P$<L8-%OF_7*L	P$<L8*O*8B872 .'& D.L9*&*'0$'8<%2T$%$EF'.'/$' 5*88$97 (-OO$9.'/ &$7]-'8$ Z<%9- U%-/%<557 (\D[2I<SD$.8%-'$'69.772T$%$EF'.'/*5 T%$''$9$5$'8X 5*8 ^KK%<'&O%-/%<55 [P\VG S^KK%<'&%$EF'.'/*5 T%$''78<KX: \'8#*EL9.'/ &$7 ^KK%<'&O%-/%<557 #.%&$ &.%EF (-OO9.'/ $*'$% VO$L8%.57K$%$EF'.'/ 5*8 c^] \P2Gc\P] [V .'& &$% D.L9*&*'0$'8<%K$%$EF'.'/ <.6 &$% +%.'&9</$ 0-' [PW+\D: I$%#$'&8 b*%L.'/7p$%7EF'*887 2T*K9*-8F$L$' #.%&$' h$#$*97 <.6 &$' <L8.$99$' V8<'& /$K%<EF8 Sf\R3:3J \DYRkT2IWX:	[PDMQ b$*8$%$'8#*EL2 9.'/C +PV
KENO-Va/VI		P$<L8-%OF_7*L	U%-/%<557_78$5 VZ^M\2I:I< 6N% V*EF$%F$*87<'<9_7$' $'8FB98]-&.9$ A.% T$%$EF'.'/0-' (%*8*L<9*8B8J ^KK%<'&J ^K7EF*%5.'/.'& bB%5NK%8%</.'/0-' '.L9$<%$' V_78$5$': RN% (%*8*L<9*8B87%$EF'.'/$' #*EF8*/ 7*'& &*$]-'8$2Z<%9-2 Z-&$7 (\D[2I<.'& (\D[2IW: I$%#$'&.'/0-'].98*/%.OO$'&<8$' 6N% b*%2 L.'/7p$%7EF'*88$ S#*$ K$* &$8$%5*'*78*7EF$' U%-/%<55$'X: (.%A$ PEF'A$*8$' S<99$%&*'/7 K$* &$% $%9<.K8$' U%-K9$5/$-5$8%*$ %$9<8*0 78<%L$ *'7EF%B'L.'/$'X:	[PDM
KORIGEN 2001		P$<L8-%OF_7*L	\%#$*8$%8$ ([PW+\D I$%7*-'J /$L-OO$98 5*8 (^UP [V:]-&.9$ VW+3\I $%A$./8 VO$A*<92T*K9*-8F$L$' 6N% ([PW+\D:	Ra(k[PDM
MCNP-4c		P$<L8-%OF_7*L	I*$9A#$EL2]-'8$2Z<%9-2U%-/%<55 6N% G%<'7O-%8O%-K9$5$ 5*8 D$.8%-'$'J UF-8-'$' .'& \9$L8%-'$' S^K7EF*%5.'/72 .'& ^L8*0*$%.'/7%$EF'.'/$' 6N% 0-%/$/K'$ o99'Q */$'#$%8K$78*55.'/0-' L%*8*7EF$' V_78$5$'X: V_78$5$ 5*8 '<F$A. K$9*$K*/ L-5O9*A*$%8$% +$-5$8%*$ K$%$EF$'K<%: b*%L.'/7p$%7EF'*88$C '.L9$<%$ U.'L8&<8$'J &<F$% L$*'$ 5*8 DBF$%.'/$' 0$%K.'&$'$ I-%K$F<'&9.'/ &$% b*%L.'/7p$%7EF'*88$ $%6-%&$%9*EF: \%/$K'*77$ <99$*' 0-' &$% o<9*8B8 &$% bø<KFB'/*/J &< L$*'$*'8$%'$' DBF$%. '/$' 0$%#$'&$8: \8<K9*$%8$% P6%$'A2 E-&$ 6N% 7EF'99%$J <K$% #$'*/$% /$'<.$ Z-&$7:	M^DM
NJOY		P$<L8-%OF_7*L	T$%$*878$99.'/0-' T*K9*-8F$L$' 5*8]ZDU2k +%.OO$'L-'78<'8$' T*K9*-8F$L$':	[PDM
OREST		P$<L8-%OF_7*L	D.L9*&&<8$'J VO<98O%-&.L8*'0$'8<%J D<EFA$%6<99:	+PV

Tabelle 2: Rechenprogramme zur Reaktorphysik

Code	Akronym von	Fachgebiet	Beschreibung	Entwickler
PARCS	**P**.%&.$ **A**&0<'E$& **R**$<E8-% **C**-%$ **S***5 .9<8-%	P$<L8-%OF_7*L	Y$% @Y ($%'7*5 .9<8-% U^PZV SU.%&.$ ^&0<'E$& P$<E8-% Z-%$ V*5 .9<8-%X #*%& 0-' &$% U.%&.$ ' '*0$%7*8_ $'8#*EL$98: U^PZV *78 &$% P$6$%$'AE-&$ &$% DPZ A.% ' '8$%7.EF.'/ &$% V*EF$%F$*870$%6-%5<'E$ 0-' M b P: \7*78 /$L-OO$98 5*8 &$' V_78$5E-&$7 P\M^U= .'& GP^Z\: U^PZV *78 0-9978B'&*/ *' R[PGP^D2d> /$7EF%*$K$' .'& 5-&.9<% <.6/$K<.8: \7 9)78 &*$ A$*8<KFB'/*/$J A#$*k7$EF7 +%.OO$' @Y2D$.8%-'$'&*66.7*-'7/9$*EF.'/ 6N% p<&%<8*7EFkFe</-'<9$ D-&$7: I$%7EF*$&$'$]-&99 $%5)/9*EF$' &*$ &*%$L8$ ^L8.<9*7*$%.'/ &$% b*%L.'/7p$ %2 7EF'*88$*' ^KFB'/*/L$*8 8F$%5-F_&%<.9*7EF$% +%),$' #BF%$'& $*'$% V*5 .9<8*-': U^PZV $*/'$8 7*EF .:<: A.% ' '8$%7.EF.'/ 0-' */$'#$%8O%-K9$5$'J$'-' 2 G%<'7*$'8$'J U*'2U-#$%2P$L-'78%.L8*-'J <&h.'/*$%8$' R9.77%$EF'.'/$'J L%*8*7EF$' T-%L-'A$'8%<8*-'$'J 1Y2(*'$8*LO%-K9$5$' 0-' V b P: Y<7 Ra(kWPV K8*9*/8 7*EF*' a.7<5 5$'<%K$*8 5*8 '<8*-'<9$' U<%8'$%' <' &*$ o<9*6*A*$%.'/ 0-' U^PZV KA#: U^PZVkP\M^U= &.%EF &*$ G$*9'<F5$ <' *'8$%'<8*-'<9$ T$'EF2 5<%L7 .'& <' Z^]U S 'V DPZ Z-&$ ^77$775$'8<'&]<*'8$'<'E$ U%-/%<5X:	**QUABOX/** **CUBBOX**		P$<L8-%OF_7*L	@Y2($%'5-&$99 A.% M)7.'/ &$% D$.8%-'$'&*66.7*-'7/9$*EF.'/$' 5*8 A#$* \'$%/*$/.OO$' 6N% 78<8*-'B%$.'& A$*8<KFB'/*/$ U%-K9$5$ 5*8 $*'$5 +%-K/*88$%2 0$%6<F%$' <.6 &$% T<7*7 0-' U-9_'-5<OO%-e*5<8*-'$' &$7 D$.8%-'$'69.77$7: T$%$EF'.'/ &$% &%$*&*5$'7*-'<9$' M$*78.'/7&*EF8$0$%8$*9.'/ *5 P$<L8-%L$%'Q 0-9978B'&*/$ T$7EF%$*K.'/ <99$% PNEL#*%L.'/7$66$L8$ 0-' T%$'' 78-668$5O$%<8.% .'& (NF95*88$9&*EF8$: T$%$*878$99.'/ &$% '.L9$<%$' b*%L.'/7p$%7EF'*88$S b k6N% A#$* \'$%/*$/%.OO$' *' 69$e*K9$' b o2T*K9*-8F$L$' ST$%NEL7*EF8*/.'/ <99$% ^KFB'/*/L$*8$' 0-' a.78<'&7O<%<5$8$%'X: a$*8<KFB'/*/$ T$%$EF'.'/$' 5*8 K*7 A. m+%.OO$' 0$%A)/$%8$% D $.8%-'$': \66*A*$'8$ a$*8*'8$/%<8*-' &.%EF 78<K*9$J *5O9*A*8$]<8%*eA$%9$/.'/75$8F-&$: a.% \%6<77.'/ 8F$%5-2F_&%<.9*7EF$% PNEL#*%L.'/$' (-OO$9.'/ 5*8 U<%<99$9L<'<95-&$99 c j Z^ .'& &$5 8F$%5-2 F_&%<.9*7EF$' V_78$5E-&$ ^GcM\G:	+PV
R5PROC		P$<L8-%OF_7*LJ D$.8%-'$'L*'$8*LJ GF$%5-F_&%<.9*L	(-OO9.'/ 0-' (^UP[Vk(^PT 'VJ Y^DGV j V .'& P\M^U= SWD\\MX:	

Tabelle 2: Rechenprogramme zur Reaktorphysik				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
SAS4ADS		P$<L8-%OF_7*L D$.8%-'$'L*'$8*LJ G%<'7*$'8$'	(-OO9.'/0-' (^UP [Vk(^PT 'VJ ZWG^GW [DkYWR@Y2I^PW^DG(.'& V^V I:	
TD-TORT		P$<L8-%OF_7*L	@2Y].8*2+%.OO$' Y*7L%$8$ [%&*'<8$' 6*'*8$' Y*66$%$'A$' A$*8<KFB'/*/$7 G%<'7O-%8O%-/%<5 5:	[PDM
WEKCPM		P$<L8-%OF_7*L	12Y V8-77#<F%7EF$*'9*EFL$*8$' G%<'7O-%8O%-/%<5 5 <.7 bW]V:	Ra(

Tabelle 3: Rechenprogramme zum Brennstabverhalten				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
BETHY-AX		T%$' '78<K2 0$%F<98$'	PEF'O%-/%<5 5 A.% T$%$EF'.'/ &$7 Y$F'$' .'& T$%78$' $*'$7 T%$' '78<K7 .'8$% M[Z^2T$&*'/.'/$': T\Gcj2^x78 &<7 PEF'O%-/%<5 5 &$7 c$%78$99$%7: \7 #*%& A.% T$78*5 5.'/ &$7 VEF<&$'7.56<'/7 $*'/$7$8A8: I-5 U%-/%<5 5 #$%&$' &*$ 8F$%5-F_&%<.9*7EF$' ^'<9_7$$%/$K'*77$ &$7 P$EF$'O%-/%<5 57 V2P\M^U <97 P<'&K$&*'/.'/$' NK$%'-5 5$': R$%'$% #$%&$' &*$ 5*8 &$5 ^.7 9$/.'/7E-&$ Z^P[2\ K$%$EF'8' T%$' '78<K2U<%<5$8$% <97 P<'&K$&*'/.'2 /$' 6N% T\Gcj2^xNK$%'-5 5$': Y<7 P$EF$'O%-/%<5 5 T\Gcj 2^x*$6$%8 <97 \%/$K'*7J-K &$% T%$' '78<K 0$%7</8: KA#: &$% T$9<78.'/ 78<'&FB98:	R^DU
CARO-E		T%$' '78<K2 0$%F<98$'	PEF'O%-/%<5 5 &$7 T%$' '78<K2c$%78$99$%7 R^DUJ &<7 A.% ^.79$/.'/ $*'$7 T%$' '78<K7 $*'/$7$8A8 #*%&: ^.7/$F$'& 0-' &$' Y$7*/'2U<%<5$8$%' &$7 T%$' '78<K7 #$%&$' &*$ \'8#*EL9.'/$' 0-' VO<98/<7&%.ELJ cN99%-F%2 .'& U$99$82 I$%B'&$%.'/ .'8$% &$' T$&*'/.'/$' &$7 D-%5<9K$8%*$K7 K$%EF'8: W5 a.7<5 5$'F<'/ 5*8 &$5 VEF<&$'7.56<'/ 9*$6$%8 &*$7$7 P$EF$'O%-/%<5 5 &*$ *5 U$99$8 /$7O$*EF$%8$ \'$%/*$ 7-#*$ &$' W''$'&%.EL A.M[Z^2T$/*'J &*$ *' &<7 PEF'O%-/%<5 5 T\Gcj2^x$*'/$F$':	R^DU
COPERNIC		T%$' '78<K2 0$%F<98$'	Y<7 PEF'O%-/%<5 5 Z[U\PDWZ *78 &<7 0$%/9$*EFK<%$ U%-&.L8 0-' RP^]^G[ ]\A. Z^P[2\: Y.%EF &*$ R.7*-' 0-' VW\]\DV 5*8 RP^]^G[ ]\ #*%& LN'68*/ '.% $*'$% &$% K$*&$' Z-&$7 K$')8*/8: b<F%7EF$*'9*EF #*%& K$* R^DU LN'68*/ Z[U\PDWZ 6-%8/$6NF%8:	RP^]^G[ ]

Tabelle 3: Rechenprogramme zum Brennstabverhalten

Code	Akronym von	Fachgebiet	Beschreibung	Entwickler
TESPA-ROD		T%$''78<K2 0$%F<98$'	Y$F'2 .'& T$%782 I$%F<98$' $*'A$9'$% T%$''78BK$' .'8$% V8)%6<992T$&*'/.'/$': D.8A.'/ &.%EF GH I$*5 &$.87EF$' +$'$F5*/.'/70$%6<F%$' A.%o<'8*6*A*$%.'/ &$7 VEF<&$'7.56<'/7 K$* (NF95*88$90$%9.7878)%6B99$': M)7.'/ &$% %<&*<9$' *'78<8*-'B%$' bB%5$8$*8.'/7/9$*EF.'/ *' 7$'L%$EF8$% VEF'*882\K$'$A.%T%$''2 78<K2^EF7$: GF$%5-F_&%<.9*7EF$ T$%$EF'.'/$' <97 *'/<K$*' R-%5 0-' Y<8$'2 R$9&$% <97 P<'&K$&*'/.'/ G\VU^2P [Y: Y<%78$99.'/ &$% +<72I$%8$*9.'/*5 T%$''78<K &.%EF $*'$ P$*F$ 0-' +<72(-5O<%85$'87J &*$.'5*88$9K<% 5*8$*'<'&$% L-55.'*A*$%$': T$%NEL7*EF8*/8$' c-EF<KK%<'&2\66$L8$C ^KK%<'&2<KFB'/*/$ bB%5$9$*8.'/Q P*52V8%.L8.% 5*8 L-'A$'8%*$%8$% bB%5$6%$*7$8A.'/*5 P*5Q VEF#99'J D<EF0$%&*EF8$'J P$9-E<8*-' &$7 U$99$87Q VO<98/<72]-&$99 A.% T$78*55.'/ &$7 bB%5$NK$%/<'/7J cN99%-F%2(%*$EF2*/$'7EF<68$' *' ^KFB'/*/2 L$*8 0-' $*'$% b<77$%78-662T$9<&.'/J Y_'<5*7EF$ UF<7$'.5#<'&9.'/ *' &$% cN99$J ''8$%7EF$*&.'/ 0$%7EF*$&$'$% cN99%-F%2M$/*$%.'/$': G\VU^2P [Y L<'' 7-#-F9 $*/$'78B'&*/ NK$% $*'$ T$'.8A$%-K$%69BEF$ <5 UZ $*'/$7$8A8 #$%&$'J <97 <.EF A.% Y.%EF%$EF'.'/ $*'$% L-5O9$88$' ($%'K$9<&.'/ 5*8 $8#< =>:>>> V8BK$' .'8$%F<9K $*'$% Y<8$'K<'L2 [K$%69BEF$ /$'.8A8 #$%&$':	W'78*8.8 6N% G%<'7.%<'$ SWG'X (<%97%.F$J S+$5$*'7<5$ R-%7EF.'/778$99$ &$% \'X \%#$*8$%.'/ &.%EF GH I2D-%&
TRANS-URANUS		T%$''78<K2 0$%F<98$'	]-&$99*$%.'/ 0-' T%$''78-66J VO<98 .'& cN99%-F%*' A_9*'&%*7EF$% T%$''78<K/$-2 5$8%*$J +$L-OO98 T$%$EF'.'/ &$7 8F$%5*7EF$' .'& 5$EF<'*7EF$' I$%F<98$'7J P$<L8-%8_O$'C MbPJ cbPJ II\PJ RTPJ P<&*<9$.'& <e*<9$ D-&<9*7*$%.'/C 69$e*K9$ Y$6*'*8*-' &.%EF D.8A$%J a$*87L<9$'C]*99*7$L.'&$' K*7 f<F%$J T$8%*$K7K$2 &*'/.'/$'C '-%5<9$% T$8%*$K $*'7EF9: M$*78.'/78%<'7*$'8$'J V8)%6<99 SM [Z^J P^XJ T%$''78-662a#*7EF$'9</$%.'/J [O8*-' 6N% 78<8*78*7EF$ P$EF'.'/$' 5*88$97]-'8$2 Z<%9-J ^.7/<K$/%),$'J &<%78$99K<%*' ^KFB'/*/L$*8 0-' P<&*.7J ^e*<9L--%&*'<8$.'& T$78%<F9.'/7A$*8C G$5O$%<8.%$'J VO<''.'/$'J Y$F'.'/$'J V8<K*''$'&%.ELJ D.L9*&L-'A$'8%<8*-'$' S'J U.J $J (%J Z7J D&XJ VO<98/<76%$*7$8A.'/ :	

Tabelle 4: Rechenprogramme zum Kühlkreislauf				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
AIDA	**A**'<9_7*7 -6 8F$ **I**'8$%<E8*-' K$8#$$' Z-%$ **D**$K%*7 <'& PU I *' 8F$ E-.%7$ -6 V0%$ **A**EE*&$'87	($%'7EF5$9A$'	Y%$*&*5$'7*-'<9$ V*5 .9<8*-' &$% OF_7*L<9*7EF$' .'& EF$5*7EF$' I-%/B'/$*5 .'8$%$' U9$'.5 5*8 c*%$ 5*8]-0*'/ I-9.5$7: Y<K$* #*%& &<7 .'8$%$ U9$'.5 *' L9$*'$ I-9.5*'<.6/8*98J &*$ 7*EF K$* T$&<%6 6%$* K$#$/$' L)''$' .'&]<77$.'& \'$%/*$ 5*8 &$' K$'<EFK<%8$' I-9.5*'<.78<.7EF$':]-&$99*$%8 #$%&$' b B%5$9$*8.'/J (-'0$L8*-'J]<77$'8%<'7O-%8J EF$5*7EF$ W'8$%<L8*-'$'J ^K7*'L$' 0-' R$78L)%O$%' *5 R9.*&J Y.%EF5*7EF.'/70-%/B'/$.'& &<7 Y.%EF7EF5$9A$' 0-' Z-%*.5 &.%EF &*$ T$FB98$%#<'&: Y$% I-%8$*9 &*7%]$8F-&$ *78J &<77 7*$.'*0$%7$99 $*'7$8AK<% *78 .'& '*EF8 '.% <.6 7O$A*6*7EF$ +$-5$8%*$' .'&]<8$%*<9*$' K$7EF%B'L8 *78: V*$ 5-&$99*$%8 &$']<77$'2 .'& \'$%/*$$%F<98 *5 V_78$5 -F'$ h$/9*EF$' Y6L8 $e<L8J &< &*$ T*9<'A/9$*EF.'/$' &*%$L8 <.7/$#$%8$8 #$%&$': Y$7F<9K *78 7*$ K$7-'&$%7 6N% M<'/A$*8%$EF'.'/$' /$$*/'$8: Y*$ I<9*&*$%.'/ $%6-9/8<' K$L<''8$' <'<9_8*7EF$' M)7.'/$' .'& \eO$%*5$'8$'J 7O$A*$99 P^VUM^I .'&]^VZ^ \eO$%*5$'8$':	
ASTRID		W'8$/%<9E-&$Q GF$%5-F_&%<.9*L *5 P$<L8-%2 7_78$5Q VO<98O%-&.L8$ *5 U%*5B%L%$*7 .'& *5 V*EF$%F$*87K$2 FB98$%Q ^L8*0*8B876%$*7$82 A.'/ *' &*$ '5/$K.'/	\.%-OB*7EF$ \'8#*EL9.'/ 7$*8 1ddmA.$%78 VG\UV SV-.%E$ G$%5 \0<9.<8*-' K<7$& -' U9<'8 VO$E*6*E<8*-'X*5 I: \' P<F5$'O%-/%<5 5J &<'' ^VGPWY S^77$775$'8 -6 V-.%E$ G$%5 6-% \5$%/$'E_ P$7O-'7$ K<7$& -' W'78<99<8*-' Y<8<X U%-/%<5 52\'8#*EL9.'/ *5 =: \' P<F5$'O%-/%<5 5: a*$9 *78 &*$ ''8$%78N82 A.'/ &$7 S8$EF'*7EF$'X D-86<992]<'</5'87 #BF%$'& &$7 ''6<99<K9<.67: Y$% W'8$/%<9E-&$ ^VGPWY #.%&$ <.7 0$%$*'6<EF8$']-&$99$' 6N% &*$ #7'89*EF$' ''6<99<K9B.6$*' M$*EF8#<77$%2P$<L8-%$' SY b PJ V b PJ I I \PX 0-5 YT^ K*7 A.% ^.7K%$*8.'/ &$% ($%'7EF5$9A$*' &$' V*EF$%F$*87K$FB98$% SA: T: VT [J VTM [Z^ 5*8 8$*9#$*7$5 -&$% 8-8<9$5 I$%7</$' <99$% V*EF$%F$*877_78$5$X $'8#*EL$98: Y$% Z-&$ 5.77 #7'89*EF 7EF'99% <97 \EF8A$*8 %$EF'$'J &<5*8 5<' .'8$% a.F*6$2 '<F5$ &$% 0-' &$% ^'9</$ NK$%8%</$'$' Y<8$' &$' ''6<99<K9<.6 K$#$%8$' .'& 0-%<.7%EF'' L<'': Y<5*8 $%)66'$8 7*EF &*$])/9*EFL$*8J &*$ ''6<996-9/$' *' T$A./<.6 &*$ '5/$K.'/ 6%NFA$*8*/ <KA.7EFB8A$' .'& 0'8.$99 ')8*/$ \0<L.*$2 %.'/$' /$A*$98 $*'A.9$*8$': 	WPVDJ (--%&*'<8-% \' (-'7-%8*.5C Ra(J c^\^J +PVJ V(WJ VG' (J I' f\

Tabelle 4: Rechenprogramme zum Kühlkreislauf				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
ATHLET	**A**'<9_7*7 -6 **TH**$%5<92 F_&%<.9*E7 -6 **LE**<L7 <'& **T**%<'7*$'87	(NF9L%$*79<.6J V_78$5E-&$	^'<9_7$ &$7 /$7<58$' VO$L8%.57 &$% M$EL78)%B99$.'& G%<'7*$'8$' *' Y b PJ V b PJ b b \PJ PT] (J '$.$' P$<L8-%L-'A$O8$' .'& R-%7EF.'/7%$<L8-%$': R-%8/$7EF%*88$'$ GF$%5-F_&%<.9*LJ 5-&.9<%$ U%-/%<5578%.L8.% SG%$''./ A#*7EF$' OF_7*L<9*7EF$']-&$99$' .'& '.5$%*7EF$']$8F-&$'XJ O-%8*$%K<% <.6 <99$ /$K%B.EF9*EF$' PEF'%<%EF*8$L8.%$':]-&.9$C GRY S$*'2&*5$'7*-'<9$ GF$%5-2R9.*&&_'<5*L 5*8 U<%<99$9L<'B9$' .'& o$%78%)5.'/ XJ c\Z' S b B%5$2 NK$%/<'/ .'& b B%5$9$*8.'/XJ D\' (WD SU.'L82 .'& 1Y2D$.8%-'$'L*'$8*LXJ +Z] V SV8$.$%.'/72 .'& P$/$97_78$5$X .'& R\T\S'.5$%*7EF$ a$*9*'8$/%<8*-'X: GRY2]-&.9 K<7*$%$'&<.6 32R9.*&2]-&$99 5*8 m2+9$*EF.'/77_78$5 -&$% =2+9$*EF.'/77_78$5 S1 W5O.97/9$*EF.'/ 6N% b<77$% .'& Y<5O6 5*8 Y%*685-&$99XJ T$%NEL7*EF8*/.'/ 0-' K*7 A.= '*EF8L-'&$'7*$%K<%$' +<7$' *' &$% Y<5O6OF<7$J T-% .'& /$9)78$5 V8*EL78-66*' &$% b<77$%OF<7$: (NF9L%$*79<.6 &.%EF I$%K*'&.'/ 0-' 69.*&2&_'<5*7EF$' V8<'&<%&2 .'& V-'&$%$9$5$'8$': @Y2D$.8%-'$'L*'$8*L &.%EF (-OO9.'/ 5*8 ó^T [kZ ' TT [x-&$% Y j D@Y: I<9*&*$%.'/ $%6-9/8<' c<'& &$% D<EF%$EF'.'/ 0$%7EF*$&$'78$% W'8$/%<92 .'& *'A$9$66$L8 \eO$%*5$'8$J &*$ '<EF &$% ZVDW]<8%*e <.7/$#BF98 #.%&$':	+PV
ATHLET-CD	**A**'<9_7*7 -6 **TH**$%5<9 c_&%<.9*E7 -6 **LE**<L7 <'& **T**%<'7*$'87 #*8F **C**-%$ **D**$/%<&<8*-'	(NF9L%$*79<.6 V_78$5E-&$ 5*8 ($%'7EF5$9A$'	T$7EF%$*K8 &<78F$%5-F_&%<.9*7EF$ I$%F<98$' &$7 (NF9L%$*79<.67 S^GcM\G2GRYXJ &*$ 0$%7EF*$&$'$' UF<7$' &$% ($%'A$%78)%.'/ .'& &$7 ($%'7EF5$9A$'7 ScN99%-F%O$%6-%5.'/J [e*&<8*-'J$.8$L8*7EF$ a%2' [32W'8$%<L8*-'J cN99%-F%O$%7<2 /$'J T*9&.'/J I$%9</$%.'/ .'& \%78<%%$' 0-' 5$8<99*7EF$% .'& L$%<5*7EF$% VEF5$9A$XJ &<7 VO<98O%-&.L82 .'& ^$%-7-90$%F<98$' #BF%$'& 7EF#$%$% V8)%B99$J K$%EF'8 &$' o$998$%5 6N% &*$ Z-'8<*'5$'8<'<9_7$ <97 +%.'&9</$A.% T$# $%2 .'/ 0-' <EE*&$'825<'</5'82]<,'<F5$':]-&$99$ 6N% Y b PJ V b PJ b b \P .'& PT] (: W' a.7<55$'<%K$*8 5*8 &$5 W(\J ' '*2V8.88/<%8J #$%&$' &*$]-&99 A. &$' I-%/B'/$' &$% ($%'A$%78)%.'/ *5 P$<L8-%&%.ELK$FB98$% $'8#*EL$98: ^GcM\G2ZY $'8FB98 &$' Z-&$ V[Uc\P[V A.% T$7EF%$*K.'/ &$7 ^$%-7-92 .'& VO<98O%-&.L88%<'7O-%87*5 (NF9L%$*79<.6J &$% 0-' WPVD $'8#*EL$98 #*%&: I<9*&*$%.'/ $%6-9/8<' c<'& &$% D<EF%$EF'.'/ 0$%7EF*$&$'$% W'8$/%<92 .'& *'A$9$66$L8 \eO$%*5$'8$J &*$ '<EF &$% ZVDW]<8%*e <.7/$#BF98 #.%&$':	+PVJ W(\

Tabelle 4: Rechenprogramme zum Kühlkreislauf				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
CATHARE	**C**-&$ 6-% **A**'<9_7*7 -6 **TH**$%5-2 F_&%<.9*E7 &.%*'/ **A**EE*&$'87 <'& **R**$<E8-% V<6$8_ **E**0<9.<8*-'	(NF9L%$*79<.6 V_78$5E-&$	^'<9_7$ &$7 /$7<58$' VO$L8%.57 &$% M$EL78)%B99$.'& G%<'7*$'8$' *' Y b PJ V b PJ b b \PJ PT](J '$.$' P$<L8-%L-'A$O8$' .'& R-%7EF.'/7%$<L8-%$': R-%8/$7EF%*88$'$ GF$%5-F_&%<.9*LJ 5-&.9<%$ U%-/%<5578%.L8.%J O-%8*$%K<% <.6 <99$ /$K%B.EF9*EF$' PEF'%<%EF*8$L8.%$':]-&.9$C $*'2 .'& @2&*5$'7*-'<9$ GF$%5-2 R9.*&&_'<5*L S1Y 0-99*5O9*A*8J @Y 7$5*2*5O9*A*8XJ b B%5$NK$%/<'/ .'& b B%5$9$*2 8.'/ S%<&*<9 .'& <e*<9<' &$% o$'EF6%-'8XJ U.'L8 2J 1Y2 .'& @Y2D$.8%-'$'L*'$8*LJ V8$.$%.'/72 .'& P$/$97_78$5$: GRY2]-&.9 K<7*$%$'&<.6 32R9.*&2]-&$99 5*8 m2+9$*EF.'/77_78$5J T$%NEL7*EF8*2 /.'/0-'K*7 A. I '*EF8L-'&$'7*$%K<%$' +<7$' .'& @3 P<&*-'.L9*&$' *' &$% Y<5O6OF<7$J T-%*' &$% b<77$%OF<7$: T%$''78<K5-&$99 5*8 cN99%-F%O$%6-%5.'/ .'& V8%<F9.'/75-&$99: (-OO9.'/ 5*8 WZ^P\ .'& V[Uc^P[V: I<9*&*$%.'/ $%6-9/8<' c<'& &$% D<EF%$EF'.'/ 0$%7EF*$&$'78$% W'8$/%<92 .'& *'A$9$66$L8 \eO$%*5$'8$J &*$ '<EF &$% ZVDW]<8%*e <.7/$#BF98 #.%&$':	Z\^J \YRJ R%<5<8-5$
CFX		R9.*&&_'<5*L	]$F%&*5$'7*-'<9$ V8%)5.'/77*5.9<8*-'7O%-/%<55$ &$% (9<77$ &$% ZRY2Z-&$7: \7 /*K8 0$%7EF*$&$'$ I<%*<'8$' ZRx2IJ ZRx2= .'& ZRx2G^VZ69-#J &*$ 7*EF *5 ^'#$'&.'/7K$%$*EFC V8%)5.'/$' *5 (NF9L%$*79<.6 .'& *5 Z-'8<*'5$'8 -&$% '.% *5 (NF9L%$*79<.6J *5 \'8#*EL9.'/778<'& 2T$F<'&9.'/ D$#8-'7EF$%2J '*EF82 D$#8-'7EF$% R9.*&$J L-5O%$77*K9$%2k W5L-5O%$77*K9$% R9.*&$J 78<8*-'B%$k *'78<8*-'B%$ P$EF'.'/ .'8$%7EF$*&$': ^']-&99' #*%& .:<: b B%5$8%<'7O-%8J b B%5$78%<F9.'/J ^.68%*$KJ P$_'-9&72VO<''.'/ .'& G.%K.9$'A K$%NEL7*EF8*/8:	^\^ G$EF'-9-/_
FIPREM	**FI**77*-' **P**%-&.E8 **RE**9<7 **M**-&$99*'/	($%'7EF5$9A$'	U%-/%<55 A.% T$7EF%$*K.'/ &$% VO<98O%-&.L82 .'& ^$%-7-96%$*7$8A.'/ <.7 &$5 T%$''78<K .'& ^K7-%K$%78<K S^/J W'J Z&X 5*8 P<8$'<'7<8A -&$% Y*66.7*-'75-&$99:	W(\J +PV
FLUBOX		GF$%5-F_&%<.9*L	3Yk@Y R9.*&2]-&$99 6N% &*$ T$7EF%$*K.'/ A#$*OF<7*/$ V8%)5.'/:	+PV

Tabelle 4: Rechenprogramme zum Kühlkreislauf

Code	Akronym von	Fachgebiet	Beschreibung	Entwickler
ICARE		($%'7EF5$9A$'	U%-/%<55 A.% T$7EF%$*K.'/ &$7 T%$''2 .'& ^K7-%K$%78<K0$%F<98$' S^/J W'J Z&-&$% TIZX*' UFK.7 2I$%7.EF$' .'& K$* 7EF#$%$' V8)%2 .'& ''6B99$' *' Y b PC cN99%-F%0$%6-%5.'/J [e*&<8*-'J $.8$L8*7EF$ a%2' [32W'8$%<L8*-'J cN99%-F%0$%7</$'J T*9&.'/J I$%9</$%.'/ .'& \%78<%%$' 0-' 5$8<99*7EF$% .'& L$%<5*7EF$% VEF5$9A$ S]</5<XJ VO<98O%-&.L86%$*7$A.'/ S]-&$99 \MV^XQ <98$%'<8*0$%]-&$99<'7<8A 6N% 3Y2VEFN88K$885-&$99 5*8 VEF5$9A$' .'& \%78<%%$'Q R9.*&&_'<5*LC $*'0F<7*/$ Y<5O62+<72V8%)5.'/ SU<%<99$9L<'<9X -&$% b<77$%O--9Q (-OO9.'/ 5*8 Z^Gc^P\ A.% (NF9L%$*79<.62V*5.9<8*-' .'&k-&$% V[Uc^\P[V: I<9*&*$%.'/ $%6-9/8<' c<'& &$% D<EF%$EF'.'/ 0$%7EF*$&$'$% W'8$/%<92 .'& *'A$9$66$L8 \eO$%*5$'8$J &*$ '<EF &$% ZVDW]<8%*e <.7/$#BF98 #.%&$':	W(\
IDEMO-2D	**I**'78<8*-'B%$7 **DE**8-'<8*-'72 **MO**&$99	Y<5O6$eO9-7*-'	WY\][K$7EF%$*K8 &*$ \eO9-7*-'7OF<7$ K$* $*'$% Y<5O6$eO9-7*-'	W(\
IKEJET	**IKE JET**2 R%</5$'8<8*-'	($%'7EF5$9A$'	U%-/%<55 A.% T$7EF%$*K.'/ &$% R%</5$'8*$%.'/7O%-A$77$ $*'$7 VEF5$9A$78%<F97 *5 P$78#<77$% &$7 .'8$%$' U9$'.57:	W(\
IKEMIX	**IKE MIX***'/ 0-' Z-%*.5 5*8 b<77$%	($%'7EF5$9A$'	U%-/%<55 A.% T$7EF%$*K.'/ &$% b$EF7$9#*%L.'/ &$% VEF5$9A$8%-O6$' .'& R%</5$'8$ 5*8 &$5 P$78#<77$%Q I-%O$%5*7EF.'/ 2 ^K7*'L$' 0-' VEF5$9A$8%-O2 6$' *5 P$78#<77$%Q ^KLNF9.'/ &$% G%-O6$' .'& T*9&.'/ $*'$% U<%8*L$97EFN88.'/ *5 .'8$%$' U9$'.5Q Y<5O6O%-&.L8*-' .'& Y<5O6/$F<98 *5 T$%$*EF &$7 G%-O6$'2 7EF#<%57 #BF%$'& &$7 ^K7*'L$'7Q PNEL#*%L.'/ <.6 &*$ ^KLNF9.'/:	W(\
KESS	**KE**%'**S**EF5$9A$ **S***5.9<8*-'	($%'7EF5$9A$'	U%-/%<557_78$5 &$7 W(\ A.% V*5.9<8*-' .'& ^'<9_7$ &$% ($%'7EF5$9A0-%/B'/$ *5 P$<L8-%&%.ELK$FB98$%Q (\VV &*$'8 <97 }$78K$88}6N % &*$ \'8#*EL9.'/ .'& I$%*6*L<8*-' &$% $'8#*EL$98$']-&$99$]\V[Z[J b^T\JW(\f\GJW(\]Wx]\b^ .'& I\Z[0-% $*'$5 $'87O%$EF$'&$' *'K<.*' ^GcM\G2ZY:	W(\
MESOCO	**ME**98*'/ <'& **SO**9*&*6*E<8*-' -6 **CO**%$]<8$%*<9	($%'7EF5$9A$'	3Y2U%-/%<55 A.% T$7EF%$*K.'/ &$% VEF5$9A0-%/B'/$J &$7 \%78<%%$' 0-' VEF5$9A$J 0-' /%-,%B.5*/$% T9-EL<&$'2 .'& (%.78$'K*9&.'/ 7-#*$ $*'$% VEF5$9A$7$$K*9&.'/ *5 <.7/$8%-EL'$8$5 ($%'Q #$*8$%$7 I$%F<98$' &$% VEF5$9A$ K*7 A.5 ^.769*$,$' &$% VEF5$9A$ <.7 &$5 ($%'K$%$*EF S^%8 &$7 I$%7</$'7C V8%<F9$'J 7$*89*EFJ .'8$'X:]\V[Z[*78 $*' (-'8*'..575-&$99Q $7 #.%&$*' ^GcM\G2ZY *'8$/%*$%8:	W(\
MEWA	**ME**98 <'& **WA**8$%	($%'7EF5$9A$'	U%-/%<55 A.% T$7EF%$*K.'/ &$% ($%'7EF5$9A2I-%/B'/$ *5 ($%'K$%$*EF .'& *5 .'8$%$' U9$'.5 <.7 &$% (-5K*'<8*-' 0-']\V[Z[.'& b^T\:	W(\

Tabelle 4: Rechenprogramme zum Kühlkreislauf				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
N3S		[illegible]	[illegible]	[illegible]
PASULA		[illegible]	[illegible]	[illegible]
PHOENICS		[illegible]	[illegible]	[illegible]
RELAP5	**R**[illegible] **E**[illegible] **L**[illegible] **A**[illegible] **P**[illegible]	[illegible]	[illegible]	[illegible]
SATURN		[illegible]	[illegible]	[illegible]
SOPHAEROS		[illegible]	[illegible]	[illegible]

Tabelle 4: Rechenprogramme zum Kühlkreislauf				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
S-RELAP5	**S***5'7 I$%7*-' 0-' **RELAP5**	(NF9L%$*79<.6 V_78$5E-&$	V2P\M^U= *78 $*' 8F$%5-F_&%<.9*7EF$7 V_78$5O%-/%<5 5J &77' ^'#$'&.'/72 K$%$*EF 0-' MTM[Z^ K*7 A. T$8%*$K78%<'7*$'8$' %$*EF8: \7 K<7*$%8 <.6 P\M^U= .'& #.%&$ 6N% &*$ c$*,$*'7O$*7.'/ $%#$*8$%8: W5 U%-/%<5 5 #$%&$' c_&%-&_'<2 5*LJ bB%5$9$*8.'/ *' V8%.L8.%$' .'& &$% $'87O%$EF$'&$ bB%5NK%/<'/ 7*5.9*$%8: Y<7 U%-/%<5 5 F<8 $*' U.'L8L*'$8*L2]-&$99 .'&]-&.9$ A.%]-&$99*$2 %.'/ &$% M$*88$EF'*LJ 7O$A*99 (-5O-'$'8$']-&99 #*$ U.5O$J I$'8*9$J V$O<%<8-%$' .'& G.%K*'$.'& 7O$A*$99$ U%-A$775-&$99$ A.%]-&$99*$%.'/ &$% L%*8*7EF$' V8%)5.'/ .'& &$7 ZZRM: Y<7 U%-/%<5 5 K$7*8A8 &*$])/9*EFL$*8J P*'/%<.5 .'& ($%' &.%EF A#$*&*5$'7*-2 '<9$ (-5O-'$'8$' A. 5-&$99*$%$':]*88$97 &$% VEF'*8878$99$ \‘][Y 9<77$' 7*EF $e8$%'$]-&99 #*$ $*' Z-'8<*'5$'85-&$99 -&$% $*'$ @&2(*'$8*L <'L-OO$9': D.5$%*7EF$ I$%K$77$%.'/$' /$/$'NK$% P\M^U=C Y*7L%$8*7*$%.'/ &$% \'$%/*$/9$*EF.'/$'J V8-66#$%8$ 6N% 5$F%L-5O-'$'8*/$7 +<7 .'& K$* ZZRM:	R^DU
TRACE	**T**P^Zk**R**\M^U **A**&0<'E$& **C**-5O.8<8*-'<9 **E**'/*'$	(NF9L%$*79<.6 V_78$5E-&$	GP^Z\ *78 &<7 '$.78$ GF$%5-F_&%<.9*L2V_78$5E-&$ A.% V*EF$%F$*87K$#$%8.'/ 9<.6$'&$% .'& *'' -0<8*0$% P$<L8-%L-'A$O8$J &*$ A: a: 6N% &*$ ‘V DPZ <97 D<EF6-92 /$O%-/%<5 5 6N% P\M^U=J GP^Z2UJ GP^Z2T $'8#*EL$98 #*%&: \7 A$*EF'$8 7*EF &.%EF &%$*&*5$'7*-'<9$ V8%)5.'/75-&99J 3Y2bB%5$9$*8.'/J%-K.78$ D.5$%*LJ T$F<'&9.'/ .'8$%7EF*$&9*EF$% (NF95*88$9 <97 ^%K$*8755$&*$' &: F: b<77$%J c$9*.5J T9$*2b*75.8J <.7: GP^Z\K$%.F8 <.6 R-%8%<'2d> .'& $*'$ 5-&$%'$ W'6-%5<8*L2 V8%.L8.%J #$9EF$ 7*EF .: <: &.%EF]-&.9<%*8B8J U-%8<K*9*B8 .'& U<%<99$%BF*/L$*8 <.7A$*EF'$8: Y<7 \Z2]-&.9$%5)/9*EF8 &*$ (-OO9.'/0-5 GP^Z\ 5*8 <'&$%$' U%-/%<55$' #*$ A: T: @Y2D$.8%-'L*'$8*L SU^PZVXJ Z-'8<*'5$'82GF$%5-F_&%<.29*L SZ[DG^WDXJ T%$''78<K5$EF<'*LJ ZRYJ $8E: Y*$ b$*8$%$'8#*EL9.'/0-' GP^Z\ #*%& &.%EF \eO$%*5$'8*$%2U%-/%<55$.'&]-&99'8#*EL9.'/2^L8*0*B8$' K$/9$*8$8: Y.%EF &*$ U<%<99$9$'8#*EL9.'/0-' VD^U SV_5K-9*E D.E9$<% ^'<9_7*7 U<EL</$X #*%& &*$ T$'.8A$%6%$.'&9*EFL$*8 S\%78$99.'/0-' W'O.8&$EL7J Y.%EF6NF%.'/0-' V*5.9<8*-'$'J U%-A$770*7.<9*7*$%.'/X 0-' GP^Z\ .'& P\M^U= $%F$K9*EF 0$%K$77$%8 7-#*$ &*$ *'<%K$*8.'/*' &*$7$ V*EF$%F$*87<'<9_7$8--97 $%9$*EF8$%8: Y<7 Ra(kWPV K$8$*9*/8 7*EF*' a.7<55$'<%K$*8 5*8 '<8*-'<9$' U<%8'$%' <' &*$ o<9*6*A*$%.'/0-' GP^Z\ .'& U^PZVkGP^Z\ &.%EF &*$ G$*9'<F5$<' *'8$%'<8*-'<9$ T$'EF5<%L7 .'& <' Z^]U S‘V DPZ Z-&$ ^77$775$'8<'&]<*'8$'<'E$ U%-/%<5X:	‘V DPZJ M^DMkWVMkU$'' V8<8$ ‘''*0$%7*8_
TRAC-P/B		(NF9L%$*79<.6 V_78$5E-&$	T$78 \78*5<8$ GF$%5-F_&%<.9*L2Z-&$ 6N% V8)%2 .'& ‘''6<99<'<9_7$' 0-' M$EL7 <'& G%<'7*$'8$' 6N% YbPkVbP 5*8 12Y .'& @2Y (-5O-'$'8$':	‘V DPZJ M^DMkWD\M

Tabelle 4: Rechenprogramme zum Kühlkreislauf				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
TRIO		R9.*&&_'<5*L	@2Y $*'OF<7*/$% GF$%5-F_&%<.9*L2Z-&$Q A#$* -O8*-'<9$ Y*7L%$8*7*$%.'/75)/9*EF2 L$*8$'C R*'*8$7 I-9.5$' SGPW[IRX.'& R*'*8$ \9$5$'8$ GPW[\RXQ a#$*OF<7$' #*%& &*7 A. $*'$% F-5-/$'*7*$%8 7*'&:	Z\^
VECO	**VE**77$9 **CO**-9<K*9*8_	($%'7EF5$9A$'	U%-/%<5 5 A.% T$7EF%$*K.'/ &$% U<%8*L$9K*9&.'/ *5 .'8$%$' U9$'.5 .'& A.% (NF9K<%L$*8 0-' U<%8*L$97EFN88.'/$' .'& L-5O9e'J O-%)7$' V8%.L8.%$' *5 .'8$%$' U9$'.5 S+$7<585-&$99 &$7 .'8$%$' U9$'.57<.7 &$% (-5K*'<8*-' &$% U%-/%<5 5$W(\f\GJW(\]Wx.'&]\b^X:	W(\
WABE	**WA**8$% **BE**&	($%'7EF5$9A$'	3Y2U%-/%<5 5 A.% T$7EF%$*K.'/ &$% (NF9K<%L$*8 0-' U<%8*L$97EFN88.'/$' .'& L-5O9e'J O-%)7$' V8%.L8.%$' *5 ($%'K$%$*EF .'& *5 .'8$%$' U9$'.5 S^.72 &<5O6$' <.6/%.'& &$% D<EF#B%5$J R9.8$' 8%-EL$'$%J F$*,$% VEFN88.'/$'X: b<K$ *78 $*' (-'8*'..575-&$99:	W(\

Tabelle 5: Rechenprogramme zum Sicherheitsbehälter

Code	Akronym von	Fachgebiet	Beschreibung	Entwickler
AFDM		VT	^'<9_7$ 0-' YZc U%-A77':	Ra(SY: b*9F$9 5X
ASTEC	**A**EE*&$'8 **S**-.%E$ **T**$% 5 \0<9.<8*-' **C**-&$	W'8$/%<9E-&$Q UFB'-5$'$*5 V*EF$%F$*87K$2 FB98$% .'&*5 U%*5B%L%$*7	+5*'7<5$ Y\ 'kRP^2\'8#*EL9.'/ 7$*8 1ddl: V*5.9<8*-' &$7 0-9978B'&*/$' ''6<99<K9<.67C <.79)7$'&$' \%$*/''*7 K*7 o998% 5 <.7 &$5 Z-'8<*'5$'8: W'8$/%<9E-&$ <.7 8$*9#$*7$ 0$%$*'6<EF8$']-&$99$'.'& (-%%$9<8*-'$':]-&.9$C Z\V^P SGF$%5-F_&%<.9*L &$7 (NF95*88$97*5 P$<L8-%LNF9L%$*79<.6 .'& Y%.ELK$2 FB98$%XJ YWI^S($%'7EF5$9A$'XJ \MV^ SVO<98O%-&.L86%$*7$8A.'/ <.7 T%$''78BK$'XJ V^Uc^\P[V SVO<98O%-&.L88%<'7O-%8*5 P$<L8-%LNF9L%$*79<.6XJ P'U'WZ'I S&*%$L8$ ^.6F$*A.'/ &$% V*EF$%F$*87K$FB98$%2^8 5-7OFB%$ &.%EF 6$*'6%</5$'8*$%8$ VEF5$9A$XJ b\x&VE F5$9A$2T$8-'2b$EF7$9#*%L.'/XJ ZU^ SZ-'8<*'5$'8U<%8 -6 ^VG\Z 5*8 ''8$%5-&.9$' Gcj2GF$%5-F_&%<.9*L*5 V*EF$%F$*87K$FB98$%J ^RU2 ^$%-7-92 .'& VO<98O%-&.L80$%F<98$'*5 V*EF$%F$*87K$FB98$% 5*8 U%-/%<5 5$' #*$ RWUM[ZJ RWUc[VG .'& VU^PZXJW[Y\ SW-&O$%F<98$'*5 V*EF$%F$*87K$FB98$%XJ WV[Y[U SVO<98O%-&.L8 .'& ^L8*'*&2W7-8-O$'A$%6<99X .'& VjVWDG S]<'</5'8 8$EF''*7EF$% V*EF$%F$*87$*'%*EF8.'/$' #*$ A: T: U.5O$'2 .'& Z-'8<*'5$'82 VO%NF7_78$5$X: b7'89*EF$7 a*$9C VEF'$99 9<.6$'&$7 U%-/%<5 5 6N% U<%<5$8$%2 78.&*$'JO%-K<K*9*78*7EF$ V*EF$%F$*87<'<9_7$' .'& ''7*EF$%F$*87<'<9_7$': I<9*&*$%.'/ 5*8 0*$9$'6%<'A)7*7EF$'J&$.87EF$' .'&*'8$%'<8*-'<9$' \eO$%*5$'2 8$':	
COCOSYS	**Co**'8<*'5$'8 **Co**&$ **Sys**8$5	GF$%5-F_&%<.9*LJ VO<98O%-&.L80$%2 F<98$'*5 V*EF$%2 F$*87K$FB98$%	\'8#*EL9.'/ 7$*8 1ddl:]-&.9<%<.6/$K<.8$7J #$*8/F'& 5$EF<'*78*7EF$7 MU2 U%-/%<5 57_78$5 A.% V*5.9<8*-' <99$% #7'89*EF$' I-%/B'/$.'& a.78B'&$*5 Z-'8<*'5$'8 0-' MbP K$* ''6B99$' S^.79$/.'/778)%6B99$ 7*'& <K/$&$EL8X: b$*8/$F$'&$ T$%NEL7*EF8*/.'/ 0-' b$EF7$9#*%L.'/$' A#*7EF$' 0$%7EF*$&$'$' UFB'-5$'$': c<.O85-&.9$ S*''$%$% G$*9XC Gcj SGF$%5-F_&%<.9*LXJ ^RU S^$%-7-92 VO<98O%-&.L80$%F<98$'X .'& ZZW SVEF5$9A0%F<98$'XQ [%/<'*7<8*-' .'& V8$.$2 %.'/ 5*8 U%-/%<5 5 UI]: a.% V*5.9<8*-'9-L<9$% \66$L8$.'& 0-' c32Y$69</%<2 8*-'$' .'& &$8-'<8*0$' c32I$%K%$''.'/$' (-OO$9.'/ 5*8 ZRY2U%-/%<5 5$' SA: T: ZRx.'& T^VVW]X: '56<'/%$*EF$ I<9*&*$%.'/ :	

Tabelle 5: Rechenprogramme zum Sicherheitsbehälter

Code	Akronym von	Fachgebiet	Beschreibung	Entwickler
COM 3D		VTJ I$%K%$' ' . ' /	Y$% Z-&$ Z [ ] @Y #*%& 6N% &*$ V*5 .9<8*-' 0-' %$<L8*O$' 8.%K.9$'8$' V8%)5.'/$' $'8#*EL$98: Z [ ] @Y 9)78 &<7 V_78$5 @2&*5$'7*-'<9$% .'78$8*/$% L-5O%$77*K9$% D<0*$%2V8-L$7 +9$*EF.'/$' A.7<55$' 5*8 &$5 V8<'&<%& L2$2 G.%K.9$'A5-&$99 .'& &$5 5-&*6*A*$%8$' \&&_2T%$<L2'O S\T'X I$%K%$' ' . ' /75-&$99: *' $eO9*A*8$7 M)7.'/70$%6<F%$' 38$% [%&'.'/ #*%& <.6 $*'$5 P$EF8$EL/*88$% 5*8 L-'78<'8$%]<7EF$'#$*8$ %$<9*7*$%8: Y<7 5-&*6*A*$%8$ \T']-&$99 K$%NEL7*EF8*/8 ' '8$%7EF*$&$ A#*7EF$' &$% R9<55$'6%-'8K$#$/.'/ .'& &$% 8.%K.9$'8$' V8%)5.'/J &< &*$ 5*889$%$ P$<L8*-'7%<8$ 78<%L 0-' &$5 I$%FB98'*7 &$% 8.%K.9$'8$' L*'$8*7EF$' \'$%/*$ A.% 9<5*'<%$' R9<55$'/$7EF#*'&*/L$*8 <KFB'/8J #$' ' 7*$ 0-' &$' */$'7EF<68$' &$% R9<55$'6%-'8 K$$*'69.778 #*%&: Y<7 5-&*6*A*$%8$]-&$99 $%#$*8$%8 &<7 V8<'&<%&5-&$99 *' &$' T$%$*EF 0-' R9<55$' 5*8 '*$&%*/$% G.%K.9$'A*'8$'7*8B8:	Ra(
CONTAIN	**Contain** 5$'8 Z-&$	GF$%5-F_&%<.9*LJ VO<98O%-&.L80$%2 F<98$' *5 V*EF$%2 F$*87K$FB98$%	\'8#*EL9.'/ 7$*8 E<: 1di>:]-&$99$ A.% V*5 .9<8*-' &$% #$7$'80*EF$' UFB'-5$'$ *5 V*EF$%F$*87K$FB98$% K$* V8)%2 .'& ''6B99$' 0-' MbP .'& VTP SA: T: GF$%5-2 F_&%<.9*LJ ^$%-7-92 .'& VO<98O%-&.L80$%F<98$'J VEF5$9A$2T$8-'2b$EF7$9#*%2 L.'/X: I*$9$ I<9*&*$%.'/7%$EF'.'/$': Y.%EF $*'$ I*$9A<F9&.%EF/$6NF%8$% ^'#$'2 &.'/7%$EF'.'/$' 6N% .'8$%7EF*$&9*EF$ P$<L8-%8_O$'*78*' 0*9' MB'&$%' F-F$7 \%6<F%.'/7O-8$'8*<9 0-%F<'&$':	V^DYW^ D<8*-'<9 M<K-%<8-%*$7 SVDMX ^9K.p$ %p$*5 ^.68%</ 'V2DPZ
CORFLOW		VT	^.7K%$*8$' 0-' VEF5$9A$:W5 P<F5$' &$% '.L9$<%$' V*EF$%F$*876-%7EF.'/*78 &*$ ''8$%7.EF.'/ &$% T$&*'/.'/$'J .'8$% &$'$' $*'$<.7%$*EF$'& F-5-/$'$ ^.7K%$*8.'/ &$% ($%'7EF5$9A$A. $%#<%8$' *78J .5 7-5*8 &$%$' 7*EF$%$ (NF9K<%2 L$*8 '<EF $*'$5 O<77*0$' *'8%*88 &$% R9.8.'/ 5*8 b<77$% A. $%%$*EF$'J 0-' /%-,$% T$&$.8.'/: Z [PRM [b K$F<'&$98 &%$*&*5$'7*-'<9$ V8%)5.'/$' 5*8 $*'$% 6%$*$' [K$%69BEF$: Y$% *'69.77 &$% (NF9.'/ <.6 &*$ ^.7K%$*8.'/ #*%& &.%EF $*'$ 8$52 O$%<8.%<KFB'/*/$ I*7L-7*8B8 K$7EF%*$K$': Y$% ^'78*$/ &$% I*7L-7*8B8*' &$' 8F$%5*7EF$' +%$'A7EF*EF8$'J &*$ 7*EF*' &$% VEF5$9A$ F$%<.7K*9&$'J L<'' A.5 ^'F<98$' &$% ^.7K%$*8.'/76%-'8 6NF%$':	Ra(W(\G Sf: R-*8X
CRDLOC	**C**F$5*E<9 **R**$<E8*-'7J **D***78%*K.8*-'7<'& **LO**E<9 **C**-'&*8*-'7	V8)%2k ''6<99<'<9_7$	ZPYM [Z *78 $*' @2Y M.5O$& U<%<5$8$% Z-&$ A.% V*5 .9<8*-' 0-' g92 .'& (<K$9K%B'&$' <.6 &$% T<7*7 0-' P^M [Z:]*8 &$5 *'8$/%*$%8$' U_%-9_7$5-&$99 9<77$' 7*EF <.EF ^KK%<'&%<8$' K$%EF'': Y*$]-&99 &$7 Z-&$7 #.%&$' *'A#*7EF$' *' &<7 PEF'O%-/%<5 57_78$5 Z [Z [V j V SZ ['8<*'5$'8 Z [&$ V j V8$5X*'8$/%*$%8:	+PV

Tabelle 5: Rechenprogramme zum Sicherheitsbehälter				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
DET3D		VTJ I$%K%$' ' .'/	R*'*8$2Y*66$%$'A$' Z-&$ A.% V*5.9<8*-' 0-' +<72Y$8-'<8*-'$'J*'7K$7-'&$%$ 5*8 b<77$%78-66: GIY2M)7$% S$eO9*A*8X &$% @2&*5$'7*-'<9$' \.9$%/9$*EF.'/$' 6N% EF$5*7EF %$</*$%$'&$]$F%L-5O-'$'8$'78%)5.'/$' 5*8 ^%%F$'*.7 (*'$8*L2]-&$99: \'8#*EL9.'/ 7$*8 1dd3: I-9978B'&*/ O<%<99$9*7*$%8$% Z-&$ S]UWX: a<F9%$*EF$ I<9*&*$%.'/72 .'& ^'#$'&.'/7%$EF'.'/$' SZ-'8<*'5$'87J P-F%8$*8.'/$' $8E:X	Ra(
FLAME3D		VT	R*'*8$2Y*66$%$'A$' Z-&$ A.% V*5.9<8*-' 0-' 9<'/7<5$' -&$% 7EF'99' I$%K%$'2 '.'/70-%/B'/$'*' +<7$' SY$69</%<8*-'$'XJ*'7K$7-'&$%$ 5*8 b<77$%78-66: GIY2 M)7$% S$eO9*A*8X &$% @2&*5$'7*-'<9$' \.9$%/9$*EF.'/$' 6N% EF$5*7EF %$</*$%$'&$]$F%L-5O-'$'8$'78%)5.'/$' 5*8 ZP\TZ[ ] (*'$8*L2]-&$99: \'8#*EL9.'/ 7$*8 3>>1: I-9978B'&*/ O<%<99$9*7*$%8$% Z-&$ S]UWX: I<9*&*$%.'/72 .'& ^'#$'&.'/7%$EF'.'/$'*5 P<F5$' &$7 \' cjZ[ ]2U%-h$L87:	Ra(
GASFLOW		VT	@Y ZRY2U%-/%<55:M)78 &*$*'78<8*-'B%$' L-5O%$77*K9$' D<O*$%2V8-L$7 +9$*EF.'/$' 5*8 0$%7$8A8$5]<7EF$''$8A*' L<%8$7*7EF$' -&$% A_9*'&%*7EF$' (--%&*'<8$': I$%#$'&$8 78<K*9$7 ^M\ I$%6<F%$' 5*8 M</%<'/$ \e8%<O-9<8*-' SUF<7$ ^XJ $*'$% Y%.EL*8$%<8*-' SUF<7$ TXJ 7$5*2*5O9*A*8J*' &$% &*$ $e8%<O-9*$%8$' I<%*<K9$'*5 M</%<'/$ D$8A<.6 &<7 /9$*EF$ a$*8''0$<. <.7*8$%*$%8 #$%&$' .'& $*'$% PNEL8%<'76-%5<8*-' SUF<7$ ZX 0-5 $eO<'&*$%8$' M</%<'/$ D$8A<.6 &<7 6$78$ \.9$% D$8A:W&$<9$7 +<7 #*%& 7*5.9*$%8 <97]*7EF.'/ 0$%7EF*$&$'$% (-5O-'$'8$':Y<5O6kD$K$9]*7EF.'/ #*%& 5*8 F-5-/$'$5 +9$*EF/$#*EF875-2 &$99 .'& $*/$'$% a.78<'&7/9$*EF.'/ 7*5.9*$%8:V$O<%<8$ \'$%/*$/9$*EF.'/ 6N% /$7B88*/8$' Y<5O6 $%9<.K8 R*952(-'&$'7<8*-'kI$%&<5O6.'/ <.6 V8%.L8.%$': V8%.L8.%$' 7*5.9*$%8 <97 c*'&$%'*77$J &*$ /<'A$ a99' 6N99$'J -&$% <97 bB'&$ <.6 &$']<7EF$'/%$'A$':V8%.L8.%$%#B%5.'/ &.%EF (-'0$L8*-'J (-'&$'7<8*-'J V8%<F9.'/:@Y V8%<F9.'/78%<'7O-%8 7*5.9*$%8 &.%EF U1 ^OO%-e*5<8*-' &$% V8%<F9.'/7*'8$'7*8B8 -F'$ I*$#6<L8-%:1Y bB%5$9$*8.'/*' &*$ V8%.L8.%$': (2 G.%K.9$'A5-&$99: VO%NF2]-&$99 7*5.9*$%8 G%)O6EF$'*' 5$EF<'*7EF$5 +9$*EF/$2 #*EF8 S/9$*EF$ +$7EF#*'&*/L$*8X .'& 5*8 $*/$'$% \'$%/*$/9$*EF.'/ S8F$%5-&_'<2 5*7EF$7 ' '/9$*EF/$#*EF8X: (<8<9_8*7EF$ P$L-5K*'<8-%$': ^'#$'&.'/A.% V*5.9<8*-' &$% I$%8$*9.'/ 0-' b<77$%78-66k2Y<5O6/$5*7EF$' K$*7EF#$%$' ''6B99$' .'8$% *'K$A*$F.'/ 0-' +$/$'5<,'<F5$' 5*8 F-F$% ^.69)7.'/ 9-L<9$% \66$L8$: ' 56<'/%$*EF$ I<9*&*$%.'/ ScYP \11:3J G@1:=XJ T<88$99$ +ixGF^W Gcih Gc1>JWVUIn^'#$'&.'/ <.6 %$<9$ Z-'8<*'5$'87 S(-'0-*J II \P1>>>J \UPJ ^UP1I>>X:	Ra(

Tabelle 5: Rechenprogramme zum Sicherheitsbehälter				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
IMPAIR3		W-&0$%F<98$'	^'<9_7*$%8 &<7 W-&0$%F<98$' *']$F%%<.5/$-5$8%*$': Y<7 W-&0$%F<98$' #*%& &.%EF $*' Y*66$%$'8*<9/9$*EF.'/77_78$5 6N% W-&7O$A*$7 .'& P$<L8*-'7L-'78<'8$' 5-&$92 9*$%8J #-K$* A#*7EF$' &$' W-&7O$A*$7 $*'$ I*$9A<F9 0-' EF$5*7EF$' P$<L8*-'$' .'& HK$%/B'/$' #*$ A: T: P$<L8*-'$' *' &$% b<77$%2 .'& +<7OF<7$ 7-#*$ UF<7$'2 .'& G%<'7O-%8NK$%/B'/$ 5)/9*EF 7*'&:	UVW
INSPECT		W-&0$%F<98$'	]-&$99 6N% W-&2ZF$5*$*5 V*EF$%F$*87K$FB98$%:	^\^G
LAVA		VEF5$9A$<.72 K%$*8.'/	W78 $*' A#$*&*5$'7*-'<9$%J <.7K%$*8.'/77O$A*6*7EF$% ZRY2Z-&$J &$% <.EF L-5O9$e$ &%$*&*5$'7*-'<9$ VEF5$9A$<.7K%$*8.'/7O%-K9$5$ 5*8 '<F$A. K$9*$K*/$% +$-5$8%*$ K$* /N'78*/$' U%-K9$52kP$EF$'A$*80$%F<98$' 7*5.9*$%$' L<'': W78*' &$% M</$J7-#-F9 T*'/F<52 <97 <.EF D$#8-'2R9.*&$ A. 7*5.9*$%$': b.%&$ <' $*'$% P$*F$0-' I$%7.EF$' 0<9*&*$%8:	+PV
MAAP	**M**-&.9<% **A**EE*&$'8 **A**'<9_7*7 **P**%-/%<5	W'8$/%<9E-&$Q UFB'-5$'$*5 V*EF$%F$*87K$2 FB98$% .'&*5 U%*5B%L%$*7	]-&.9<%$% W'8$/%<9E-&$ A.% T$%$EF'.'/ &$7 ^'9</$'0$%F<98$'7 0-' YbP .'& VbP .'8$% T$&*'/.'/$' 7EF#$%$% V8)%2 .'& ''6B99$.'& ^EE*&$'8]<'</$5$'8]<,'<F5$': V*5.9<8*-' <99$% #$7$'89*EF$% U%-A77*5 U%*5B%L%$*7J Z-'8<*'5$'8 .'& c*%67<'9</$'C GF$%5-F_&%<.9*LJ VO<98O%-&.L80$%F<98$'J W-&EF$5*$J ($%'2 7EF5$9A$J PYT2I$%7</$' $8E: '56<'/%$*EF$ I<9*&*$%.'/:	R^WJ \YR
MELCOR		W'8$/%<9E-&$Q UFB'-5$'$*5 V*EF$%F$*87K$2 FB98$% .'&*5 U%*5B%L%$*7	\'8#*EL9.'/ 7$*8 1di3 <97 D<EF6-9/$% &$7 V-.%E$ G$%5 Z-&$ U<EL</$ 2VGZUQ W'8$/%<9E-&$J K78F$'& <.7]-&.9$' S!O<EL</$7;X 6N% OF_7*L<9*7EF$ G$*9<7O$L8$ &$7 ''6<99<K9<.67 SA: T: GF$%5-F_&%<.9*L*5 P$<L8-%LNF9L%$*79<.6 .'&*5 V*EF$%F$*87K$FB98$%J bB%5$NK$%8%</.'/ .'& ?9$*8.'/ <' -&$%*' (-5O-'$'8$'J I$%FB98'*77$*5 P$<L8-%L$%'J VEF5$9A$2T$8-'2b$EF7$9#*%L.'/J VO<98O%-&.L80$%2 F<98$'J GF$%5-F_&%<.9*L S]-&$99C (-'8%-99O-9.5$'2V8%)5.'/7O6<&Q 32UF<7$'2 V_78$5 A.% T$7EF%$*K.'/0-' b<77$%2 .'& Y<5O6OF<7$X: T$F<'&9.'/ &$7 /$7<58$' ''6<997O$L8%.57*' $*'$5 $*'F$*89*EF$' V_78$5 0-5 T$/*'' &$7 $*'9$*8$'&$' \%$*/'*77$7 K*7 A.% R%$*7$8A.'/*' &*$ '5/$K.'/: P$9<8*0 7EF'$99 9<.6$'&Q I$%#$'&.'/ 6N% U<%<5$8$%78.&*$'J O%-K<K*9*78*7EF$ V*EF$%F$*87<'<9_7$'.'& ''7*EF$%F$*87<'<9_7$':	\YR

Tabelle 5: Rechenprogramme zum Sicherheitsbehälter				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
NAUA		^$%-7-92 .'& VO<98O%-&.L82 0$%F<98$'	T$*0-%/$/K'$' 8F$%5-&_'<5*7EF$' P<'&K$&*'/.'/$' L)''$' &*$ ^//9-5$2 %<8*-' .'& &*$ ^K7EF$*&.'/0-' ^$%-7-9$' *' M$*EF8#<77$%%$<L8-%$' K$%EF'8 #$%&$': RN% &*$ 0$%7EF*$&$'$' ^//9-5$%<8*-'72 .'& ^K7EF$*&$0-%/B'/$ #$%&$' &<K$* &$8<*99*$%8$]-&$%$ K$'.8A8 #*$ A: T: 6N% &*$ T%-#'7EF$.'& +%<0*8<8*-'7 2 (-</.9<8*-'J V$&*5$'8<8*-'J 8F$%5*7EF$ Y*66.7*-'J b<77$%&<5O6L-'&$'7<8*-' <' U<%8*L$9'J Y*66.7*-OF-%$7$J GF$%5-OF-%7:
WECHSL		T$8-'2VEF5$9A$2 b$EF7$9#*%L.'/	b$*8/$F$'& 5$EF<'*78*7EF$7 P$EF$'O%-/%<55 A.% V*5.9<8*-' &$% T$8-'2 VEF5$9A$2 b$EF7$9#*%L.'/: \7 #$%&$' &*$ I-%/B'/$ K$* &$% 8F$%5*7EF$' .'& EF$5*7EF$' b$EF7$9#*%L.'/ $*'$% A. T$/*'' 69N77*/$' M b P2VEF5$9A$ 5*8 T$8-'*' $*'$% A#$*&*5$'7*-'<9$'J <EF7$'7_5$8%*7EF$' T$8-'L<0$%'$ K$7EF%*$K$': Y<7 U%-/%<55 7*5.9*$%8 &$' T$/*'' &$7 (-'8<L8$7 $*'$7 F$*,$' 69N77*/$' VEF5$9A$2 K<&$7 5*8 &$5 T$8-'6.'&<5$'8 NK$% &<7 *'7$8A$' 0-' \%78<%%.'/70-%/B'/$' K*7 A.%9<'/A$*8*/$' \%-7*-' &$7 R.'&<5$'87 NK$% 5$F%$%$ G</$ 5*8 &$%])/9*EFL$*8 &$% R.'&<5$'8&.%EF&%*'/.'/:
WEX		T$8-'2VEF5$9A$2 b$EF7$9#*%L.'/	I-' b\ZcVM <K/9*8$8$% Z-&$ 6N% VEF5$9A$2T$8-'2 b$EF7$9#*%L.'/J]-&.9*' ^VG\Z*5O9$5$'8*$%8:	Ra(k+PV

Tabelle 6: Rechenprogramme zu Querschnittsgebieten				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
ATLAS	**AT**c**L**\G **A**'9</$' **S***5 .9<8-%	V8)%2 .'& ' '6<99<'<9_7$	^GM^V *78 $*'$ *'8$%<L8*0$ V*5 .9<8*-'7.5/$K.'/ .'8$% bWDY [bV DG A.% I*7.<9*7*$%.'/ .'&*'8$%<L8*0$' V8$.$%.'/ &_'<5*7EF$% PEF'O%-/%<5 5$ SA:TC ^GcM\GQ Z [Z [V j VX 6N% &*$ %$<9*8B87'<F$ V*5 .9<8*-' .'& ^'<9_7$ 0-' T$8%*$K78%<'7*$'8$' .'& V8)%6B99$': ^GM^V .56<778 A.7B8A9*EF$ b$%LA$./$ 6N% &<7 U%$2 .'& U-78O%-A$77*'/ &$% P$EF$'O%-/%<5 5<'#$'&.'/$'J &*$ &*$ a.0$%9B77*/L$*8 &$% ^'<9_7$' $%F)F$': a.% \%5*889.'/ &$% T<'&K%$*8$ &$% \%/$K'*77$ 0-' V*5 .9<8*-'7%$EF'.'/$' 5*8 T$782\78*5<8$2PEF'O%-/%<5 5$' #.%&$ <.6 &$% +%.'&9</$ 0-' V'V^ SU%-/%<5 57_78$5 A.% ' '7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$X $*'$] $8F-&$ A.%<.8-5<8*7*$%8$' Y.%EF6NF%.'/ 0-' ' '2 7*EF$%F$*87<'<9_7$' *' ^GM^V K$%$*8/$78$998: a.%A$*8 #*%& ^GM^V #$*8$%$'8#*EL$98J #-K$* &*$ GF5' G%<'7*$'8$'&*</'-7$J T$7EF9$.'*/.'/ &$% V*5 .9<8*-'$' .'& &*$ T$%$*878$99.'/ A.7B8A9*EF$% ^'<9_7$F*9675*88$9*5 I-%&$%/%.'& 78$F$':	V<'&*< M<K: SD'P\+211=>X
EVENTRE		UV^	\I\DGP\ *78 $*' <99/$5$*' A./B'/9*EF$7 U%-/%<5 5 A.% ^'<9_7$ 0-' \%$*/'*72 KB.5$'J &<7*' A<F%$*EF$' UV^ 0$%#$'&$8 #.%&$:]*8 \I\DGP\ L<' ' 5<' 7$F% /%-,$ \%$*/'*7KB.5$ 5*8 0*9' I$%A#$*/.'/$' K$<%K$*8$' .'& A.% T$%$EF'./ &$% I$%A#$*/.'/7#<F%7EF$*'9*EFL$*8$' 6%$*O%-/%<5 5*$%K<%$ ' '8$%O%-/%<5 5$ SA: T: R$F9$%K<.5O%-/%<5 5$Q V*5 .9<8*-'7E-&$7 6N% ' '6<99OF<7$'X F*'A.6N/$': \I\DGP\ 9*6%8 <97 \%/$K'*7 0*$9$ \'&A#$*/$ 5*8 &$' A./$F)%*/$' b<F%7EF$*'2 9*EFL$*8$'J &*$ 7*EF K$'.8A$%&$6*'*$%8 A. +%.OO$' A.7<5 5$'6<77$' 9<77$':		+PV
MCDET	**M**-'8$ **C**<%9- **D**_'<5*E **E**0$'8 **T**%$$	UV^	^'<9_7$#$%LA$./ 6N% UV^ A.% T$%NEL7*EF8*/.'/ &$% b$EF7$9#*%L.'/ A#*7EF$' &$% Y_'<5*L $*'$7 \%$*/'*7<K9<.67 .'& &$' V8-EF<78*L$*'69N77$':]ZY\G 9*6%8 &_'<5*7EF$ \%$*/'*7KB.5$J &*$ 7*EF $'89<'/ $*'$% a$*8<EF7$ $'8#*EL$9':		+PV

Tabelle 6: Rechenprogramme zu Querschnittsgebieten				
Code	**Akronym von**	**Fachgebiet**	**Beschreibung**	**Entwickler**
MOSES	**MO**&$99 **S**_78$5 6-% **E**'0*%-'5$'8<9 W5O<E8 **S**8.&*$7 | ^85-7OFB%*7EF$ ^.7K%$*8.'/	] [V\V*78 $*' .%7O%N'/9*EF +%-,%$EF'$%2-%*$'8*$%8$7 5-&.9<%$7]-&$997_78$5 A.% T$%$EF'./ &$% <85-7OFB%*7EF$' ^.7K%$*8.'/ 9.68/$8%</$'$% %<&*-<L8*0$% V8-66$*' 8-O-/%<OF*7EF /$/9*$&$%8$5 +$9B'&$J &<7 A. &$5 UZ2K<7*$%8$']-&$992 7_78$5 b*G%<(Sb*'&6$9&2J G%<'7O-%82 .'& (9*5<8-9-/*$2U%-/%<55X #$*8$%$'8#*2 EL$98 #.%&$: T$*&$ V_78$5$$'8F<98$' U%-8-8_O$' 7- /$'<''8$% 5$7-7L<9*/$%]-&$99L$88$'J K$78F'&<.7 V8%)5.'/75-&99' A.% T$7EF%$*K.'/ &$7 b*'&2 6$9&$7J 5*8 &$5 $*'$ VEF<&78-66#-9L$ 8%<'7O-%8*$%8 #*%&J .'& '<EF/$7EF<98$8$' ^.7K%$*8.'/75-&$99$'J 5*8 &$'$' &*$ VEF<&78-66O$%&N''.'/ *'6-9/$ <85-7OFB%*2 7EF$% G.%K.9$'A .'& Y*66.7*-' 7-#*$ &*$ ^K9</$%.'/ $'89<'/ &$7 G%<'7O-%8#$/$7 K$7EF%*$K$' #*%&:]*8 &$' (-5O-'$'8$' &$7]-&$997_78$57L<'' 6N% R%$*7$8A.'2 /$' 9.68/$8%</$'$% %<&*-<L8*0$% V8-66$ <.7 L$%'8$EF'*7EF$' ^'9</$'J &*$ -685<97*' 8-O-/%<OF*7EF /$/9*$&$%8$5 +$9B'&$ O-7*8*-'*$%8 7*'&J &*$ ^.7K%$*8.'/ .'& &*$ ^K9</$%.'/ %<&*-<L8*0$% V8-66$' %$<9*8B87'<F K$%$EF'$8 .'& /$/K'$'6<997 O%-/''-78*A*$%8 #$%&$':| **RALLY**		UV^	U%-/%<557_78$5 &$% +PV A.% Y.%EF6NF%.'/ 0-' U%-K<K*9*78*7EF$' V*EF$%F$*872 <'<9_7$': \7 .56<778 b$%LA$./$ 6N% &*$ R$F9$%K<.5<'<9_7$ 7-#*$ 6N% &*$ ''7*EF$%F$*87<'<9_7$ SW5O-%8<'A2 .'& V$'7*8*O*8B87<'<9_7$C U%-/%<55 VGP\'VMX:	+PV
RISK SPECTRUM		UV^	U%-/%<557_78$5 A.% Y.%EF6NF%.'/ 0-' P*7*L-2 .'& a.0$%9B77*/L$*87<'<9_7$': \7 .56<778 b$%LA$./$ 6N% &*$ R$F9$%K<.52 .'& \%$*/''*7K<.5<'<9_7$J Þ*7L 5-''*8-%*'/} ^.76<99$66$L8<'<9_7$ 7-#*$ 6N% &*$ ''7*EF$%F$*87 2 .'& V$'7*8*O*8B872 <'<9_7$: PWV(VO$E8%.5 #*%& #$98#$*8*' E<: I>v&$% ($%'L%<68#$%L$ $*'/$7$8A8:	P\MZ[D ^T

Tabelle 6: Rechenprogramme zu Querschnittsgebieten

Code	Akronym von	Fachgebiet	Beschreibung	Entwickler
SNAP	**S**_5K-9*E **N**.E9$<% **A**'<9_7*7 **P**<EL</$	V*5 .9<8-%	Y<7 '$. $'8#*EL$%8$ U%-/%<5 5 VD^U *78 $*' A$'8%<9$7 b$%LA$./ &$% 'V DPZ .5 &*$ T$'.8A$%6%$.'&9*EFL$*8J *'<%K$*8.'/ .'&*:<: &<7 ^%K$*8$' 5*8 L-5O9$e$' V_78$5E-&$7 #*$ GP^Z\J P\M^UJ U^PZVJ Z [DG^WDJ $8E: $%F$K9*EF $%9$*EF8$%' 7-99: \7 K<7*$%8 <.6 f<0< .'&*78 &<&.%EF O9<886-%52.'<KFB'/*/: VD^U K78F8 6-9/$'&$%]-&.9$'C VD^U]-&$9 \&*8-%J VD^U P.'8*5$]-&.9$.'& VD^U I*7.<9 \'/*'$$%*'/ Y<8< ^'<9_A$% SI\Y^X: ^97 A$'8%<9$7 b$%LA$./ &$% ^'<9_78$' *78 $7 5)/9*EF *' VD^U &*%$L8W'O.8&$EL7 6N% ^'9</$' 5*8 +'WA. $'8#*EL$9'J V*5.9<8*-2 '$' A. 78<%8$' .'& \%/$K'*77$ <.7A.#$%8$'J*'8$%<L8*0*' V*5.9<8*-'$' $*'A./%$*2 6$' .7#: Y<7 I\Y^2]-&.9 0-5 VD^U &*$'8 A.% U%-A$770*7.<9*7*$%.'/*' 3Y -&$% @Y L-5O9e% ^'9</$'5-&$9$: Y<%NK$% F*'<.7 7-99 VD^U &*$ <.8-5<8*7EF$ (-'0$%8*$%.'/ 0-' P\M^U= KA#: GP^Z2W'O.87*' GP^Z\2W'O.8 .'8$%78N8A$': Ra(2WPV *78 *5 P<F5$' &$7*'8$%'<8*-'<9$' Z^]U2U%-/%<5 57 T$8<2G$78$% 0-5 VD^U:
SUSA	**S**-68#<%$ 6-% **U**'E$%8<*'8_ <'& **S**$'7*8*0*8_ **A**'<9_7*7	'7*EF$%F$*872 <'<9_7$'	Y*$ b-%L78<8*-'2I$%7*-' 0-' V'V^ *78 $*'$ 69$e*K9$!.O28-2&<8$; I$%7*-' <.6 &$5 '$.78' \'8#*EL9.'/778<'& KA/9:]$8F-&*L .'& \%/$K'*7&<%78$99.'/: V*$ K78F8 <.7 $*'$% V<5 59.'/ 0-' !78<'&2<9-'$; R[PGP^D U%-/%<5 5$'J &*$ h$#$*97 6N% K$78*5 58$ ^.6/<K$' .'& G$*97EF%*88$ &$% ^'<9_7$ *5 P<F5$' &$% !+PV2] $8F-&$; A.78B'&*/ 7*'&: Y*$ T$'.8A.'/ &*$7$% U%-/%<5 5$ $%6-%&$%8 $*'$ /$#*77$ I$%8%<.8F$*8 5*8 &$% !+PV2] $8F-&$; .'& &$%$' ^K9<.6 7-#*$ &*$ ($''8'*7 $*'*/$% Y$8<*97 K$* &$% T$%$EF'.'/ .'& Y<%78$99.'/ &$% \%/$K'*77$: Y*$7$ I$%7*-' #*%& &$7F<9K 0-%'$F59*EF K$* +PV2*'8$%'$' ^'#$'&.'/$' &$% ''7*EF$%F$*872 .'& V$'7*8*0*8B87<'<9_7$ $*'/$7$8A8: Y*$ UZ2I$%7*-' 0-' V'V^ 5*8 *F%$% 5$'N2 .'& &*<9-//$78$.$%8$' T$'.8A$%-K$%2 69BEF$ K*$8$8 $*'$' F-F$' +%<& <' T$'.8A$%L-56-%8J F<8 <K$% /$/$'NK$% &$% b-%L78<8*-'2I$%7*-' $*'$' &$.89*EF %$&.A*$%8$' M$*78.'/7.56<'/C]$8F-&*L .'& ^%8 &$% \%/$K'*7&<%78$99.'/7*'& <.6 &$5 V8<'& 0-' $8#< 1dd> !$*'/$6%-%$';: Y*7 I$%7*-' *78*'7K$7-'&$%$ 6N% !$e8$%'$; T$'.8A$% /$$*/'$8J &*$ 5*8 &$% !+PV2] $8F-&$; #$'*/$% 0$%8%<.8 7*'& .'& &<F$% $*'$ L-'7p'8$ T$'.8A$%6N F2 %.'/ &.%EF &*$ $*'A$9'$' G$*97EF%*88$ &$% ^'<9_7$ K$')8*/$': Y*7 I$%7*-' #*%& &$7F<9K 0-%'$F59*EF K$* +PV2$e8$%'$' .'& $*'6<EF$% 78%.L8.%*$%8$' ^'#$'&.'2 /$' $*'/$7$8A8:

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