

3KEYRELAP5 – Improvements and Applications

Igor Arshavsky

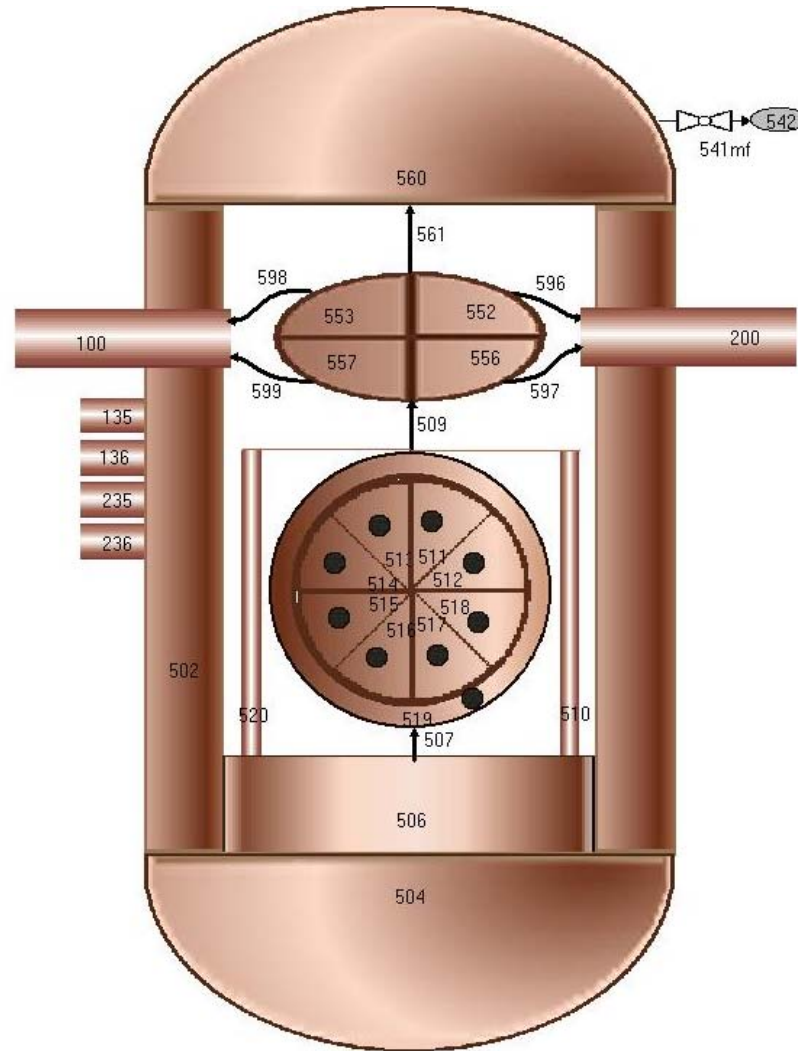
Prepared for IRUG August 2009

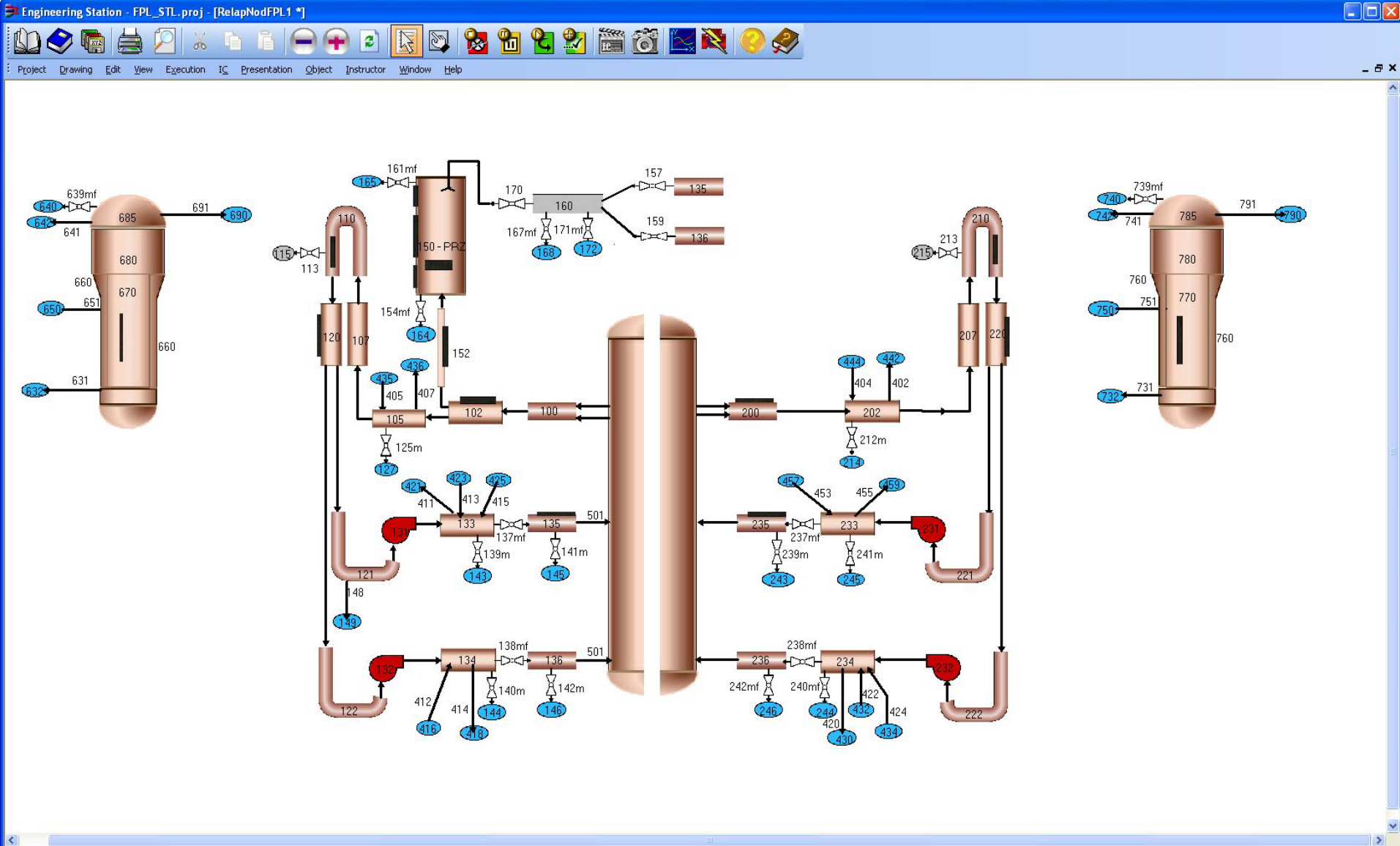


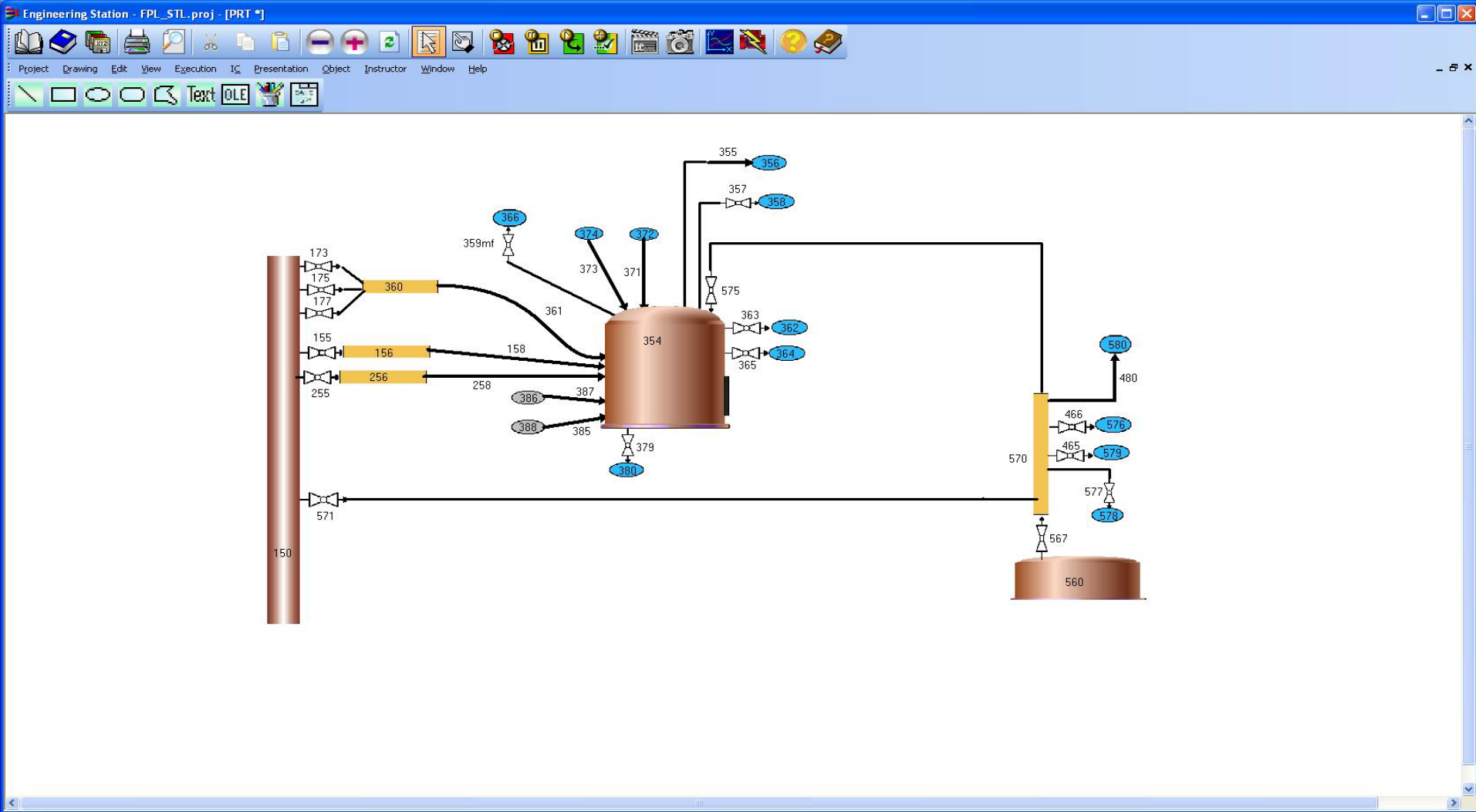
- 2007 – R&D Initiative to Develop 3KEYRELAP5
- Projects
 - PWR: FP&L St.Lucie,Turkey Point; NINGDE
 - BWR: PPL Susquehanna
 - CANDU: Bruce-B, Bruce-A
- 3KEYRELAP5 Technology
 - R3K Interface Software Layer
 - RELAP5 xml-based Editor
 - Control Interpreter - SCATER
 - RELAP5-3D Real Time Improvements



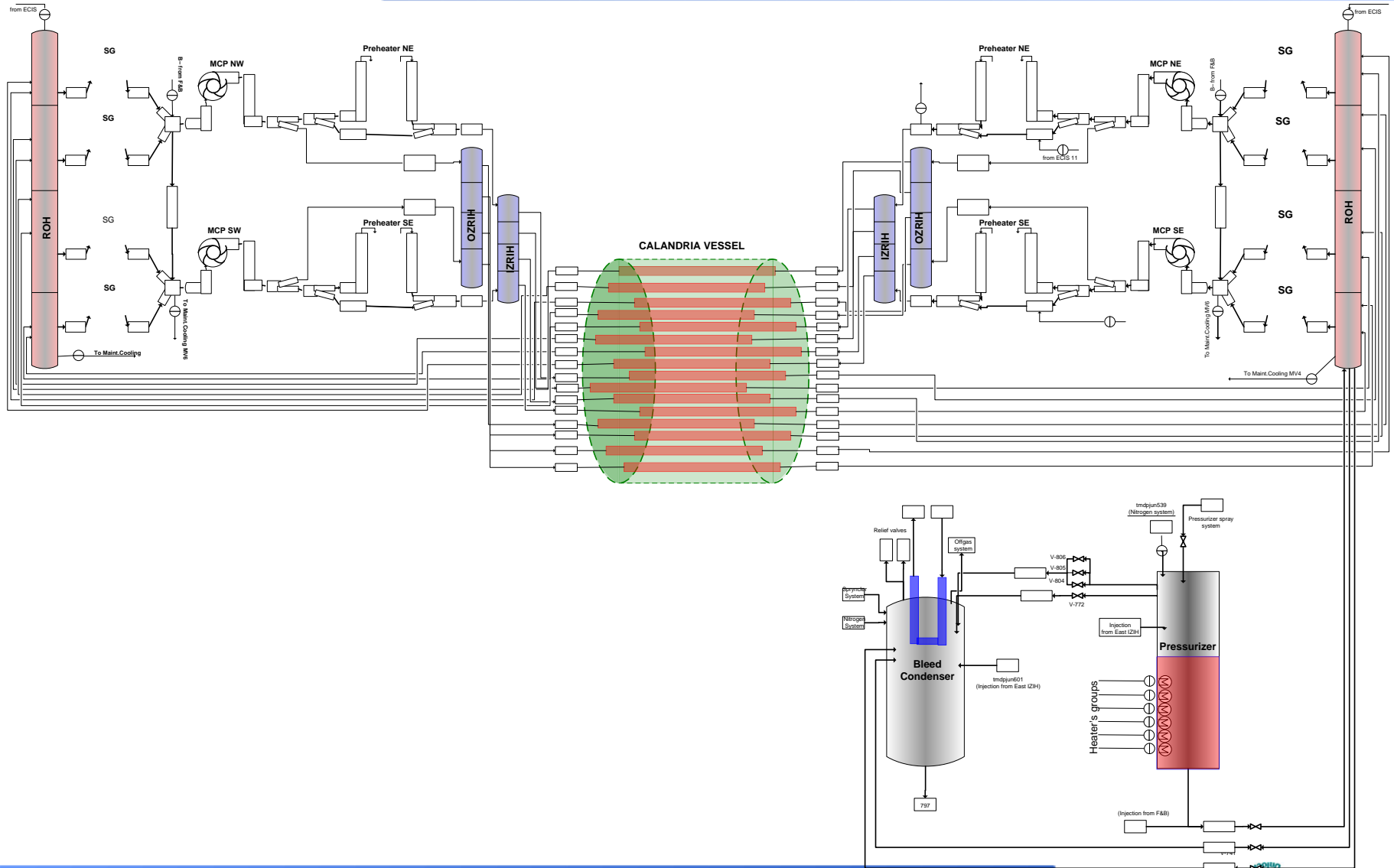
St. Lucie Reactor Vessel





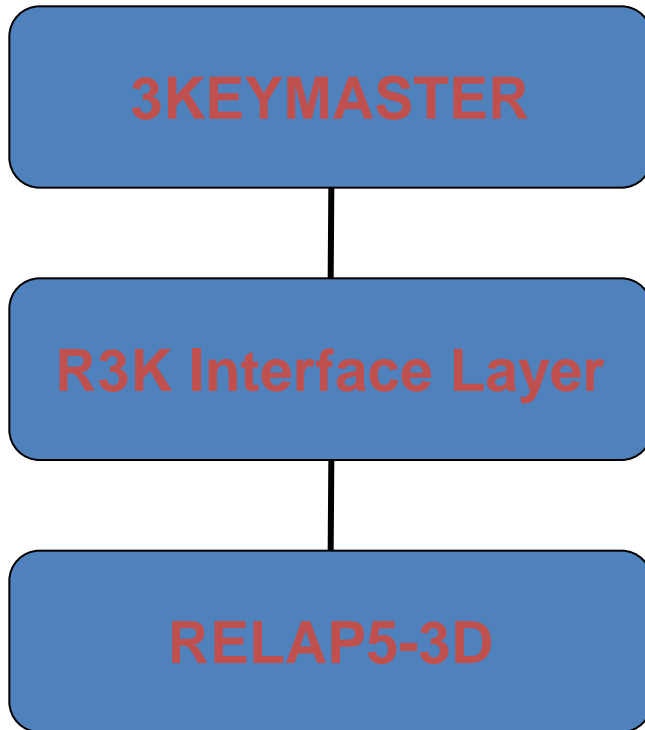


BruceB - Primary Heat Transport System



3KEYRELAP5 Technology





- all interactions between 3KEYMASTER and RELAP5
- no need to change RELAP5 source code
- possibility to run RELAP5 in stand alone mode
- solid ground for further development stages



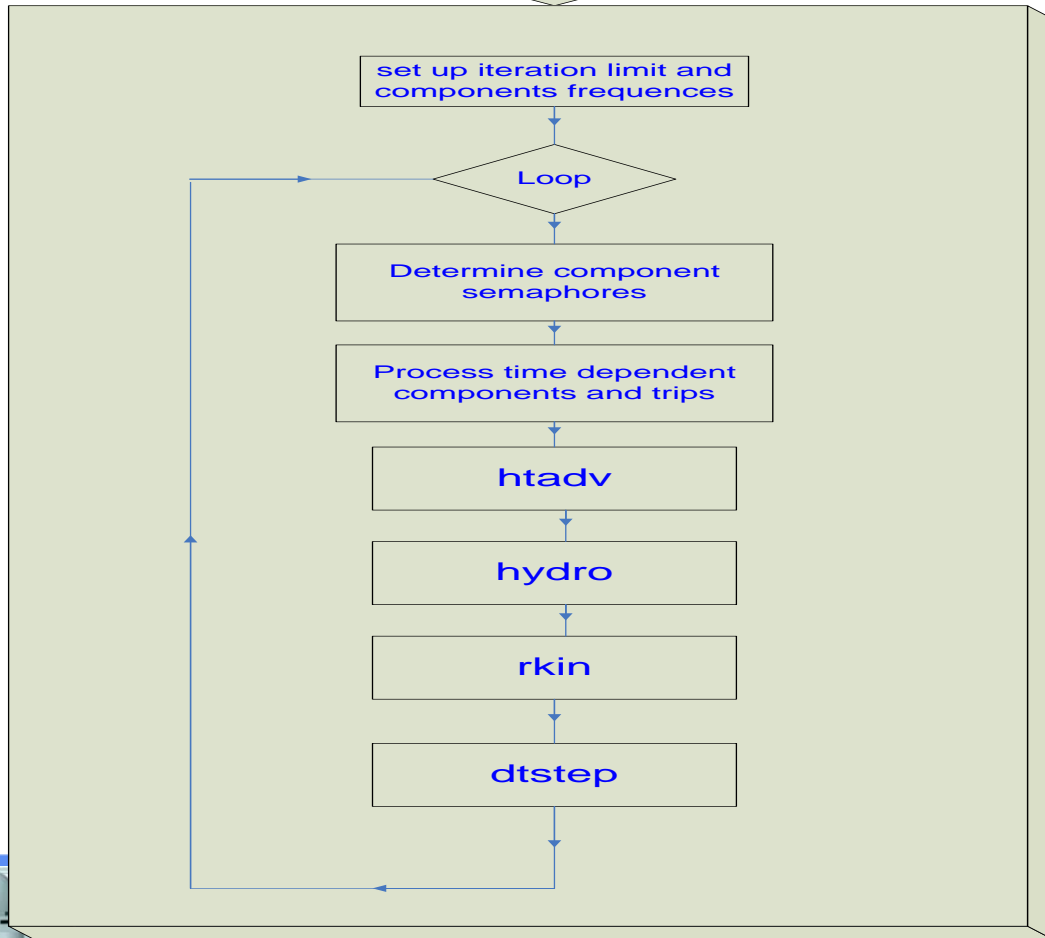
- Flexible RELAP5 Time Step Adjustment
- Flexible RELAP5 Task CPU Assignment
- RELAP5 Data Presentation in form of Trends, Tables and Dynamic Drawings
- Possibility to run several Real-Time RELAP5 Tasks under same simulator load
- Full control through Instructor Station
- Real time change of boundary conditions
- Access to all RELAP5 ME variables



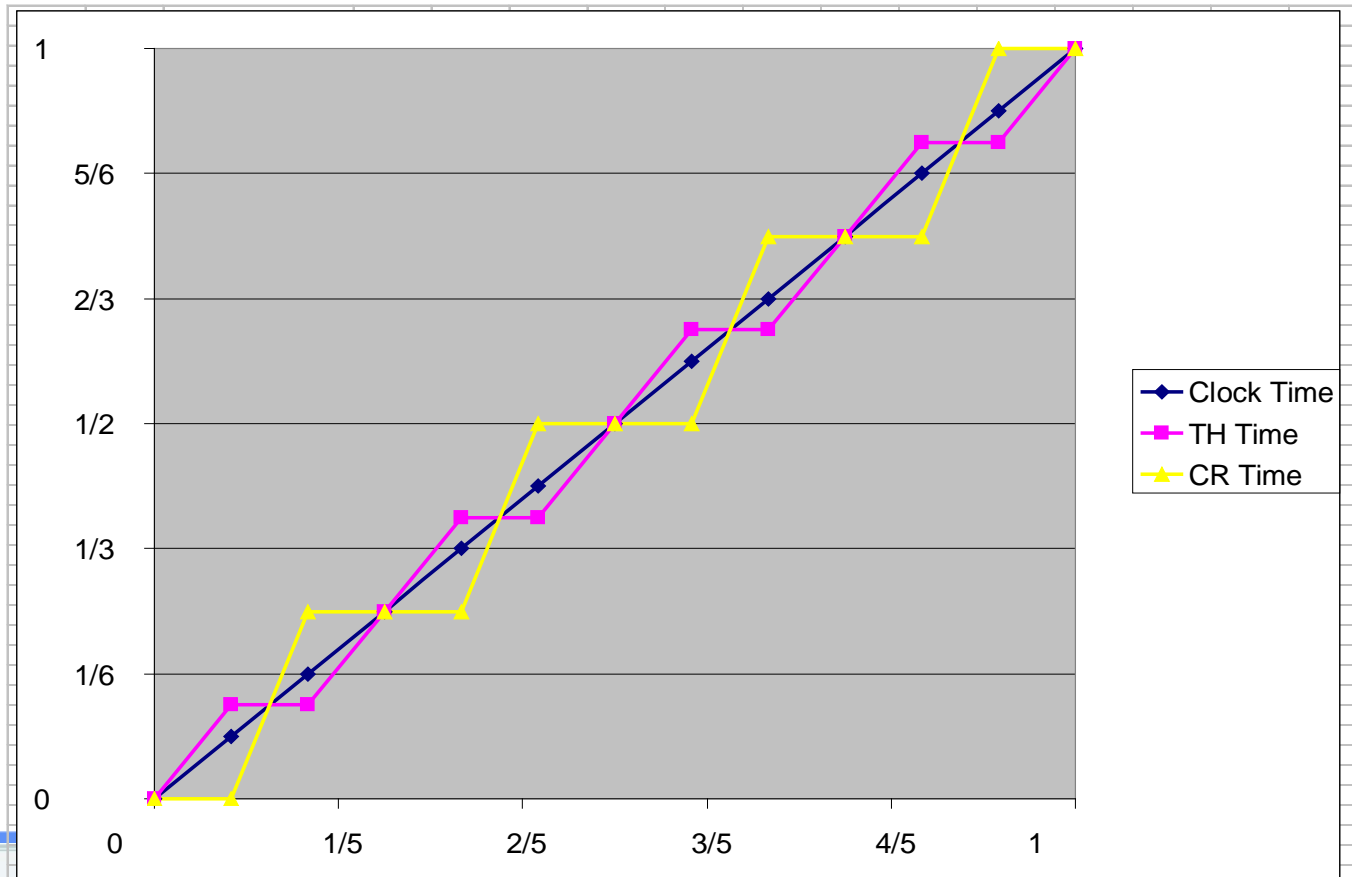
- make time advancement
- write restart file
- read restart file
- setup model time
- setup mode
 - steady-state / transient
 - components to run (hydro, htadv, rkin)
 - print major edit
 - debug mode on/off
- generate list of ME variables
- output specified variables
- input parameters of TDC and control variables
- programming features
 - LAG input/output parameter
 - change heat capacity of specified material
 - change fouling factor of specified heat structure
 - change form loss coefficients and/or hydraulic diameter of specified junction

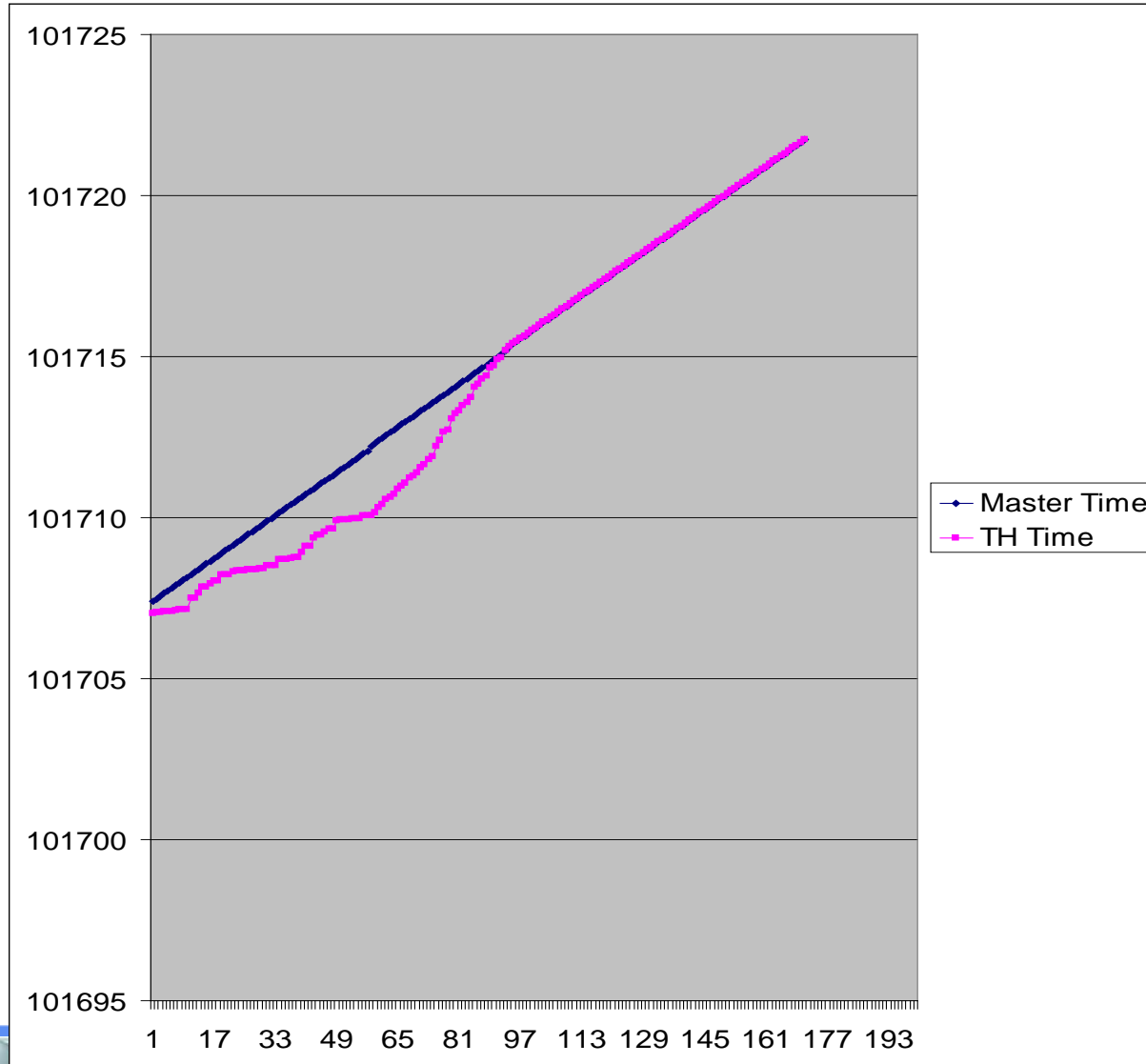


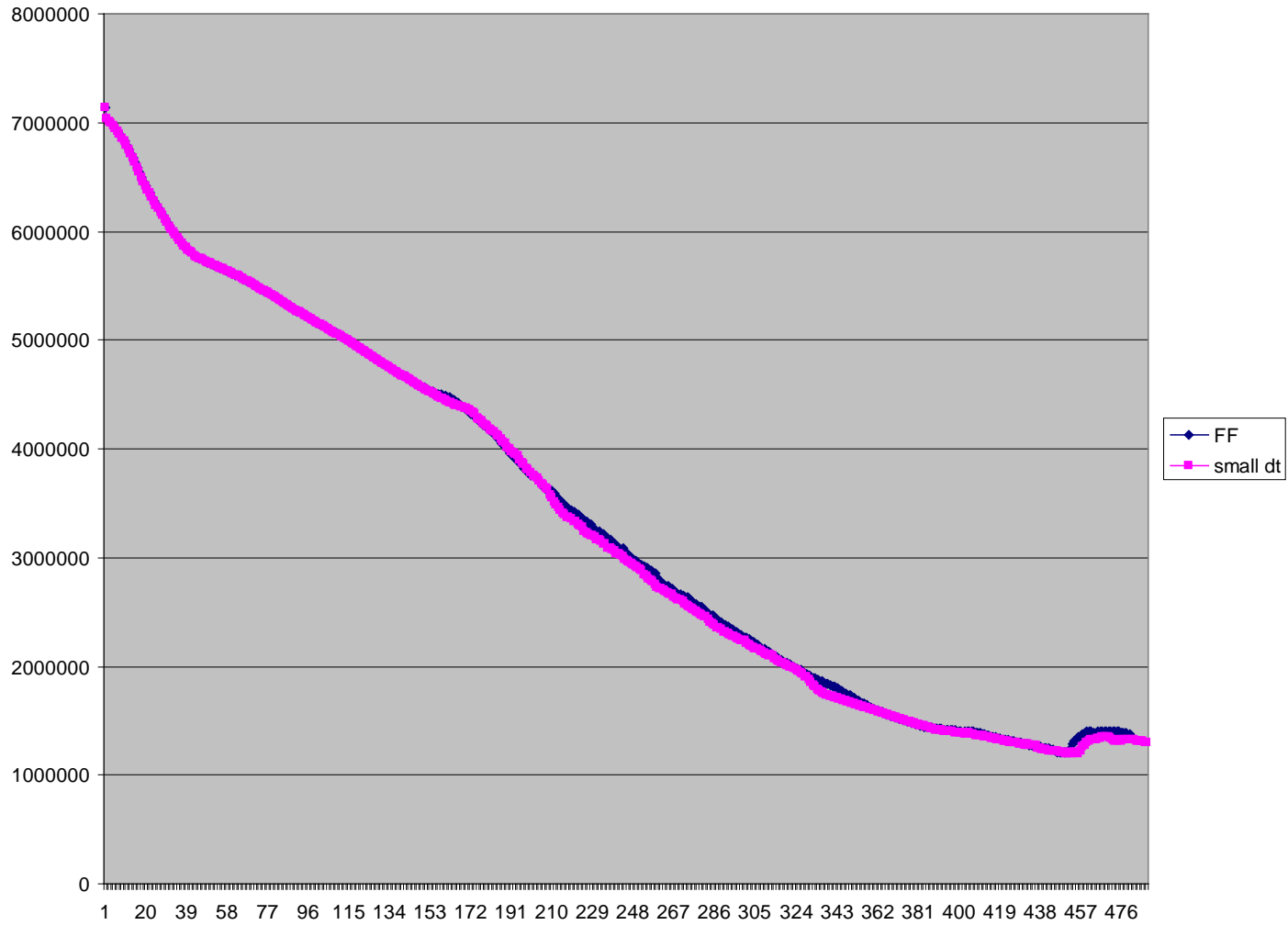
RELAP5 3KEYMASTER Task

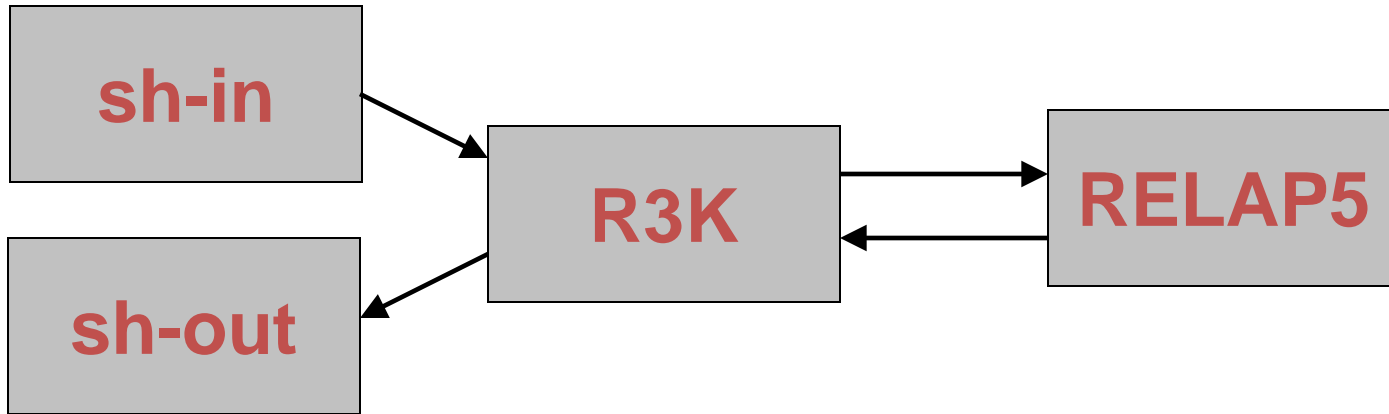


TH	CR	TH	TH	CR	TH	TH	CR	TH	TH	CR	TH
----	----	----	----	----	----	----	----	----	----	----	----









r3k.tdcomp

<name of variable> <component number> <Lag time>

r3k.medit

<name of variable> <component number> <Lag time>



The screenshot displays a simulation software interface with a vertical toolbar on the left containing buttons such as LOADED, RESET, STORE, BACK TRACK, INSTR CONTROLS, LESSON PLAN, EVENT TRIGGER, INSERT OR, CREATE ET, INSERT MP, MONITOR PARAMS, PANEL OVERVIEW, PROC. OVERVIEW, DCC KEYBOARDS, PLANT STATUS, ANNUN, WINDOWS LIST, LOGS, and DIR. The main window, titled 'Panel_2b', shows a 'TURBINE C' control panel and an 'X-Y Plot' window. The plot shows a green curve on a grid with the y-axis ranging from 7.07e-006 to 7.15e-006 and the x-axis from 00:00:00 to 00:07:00. A data point is highlighted as '^p402010000 7.074e+006'. Below the plot is a 'Name Browser' window with a search field containing 'p*', buttons for Select, Table, Collisions, Save As..., and Exit, and checkboxes for Lookup Database Variables, Contacts, Add, and Relap. A table window at the bottom shows the following data:

Object Name	Type	File/Global
p300010000		
p308010000		
p400010000		
p400020000		
p402010000		
p404010000		
p404020000		
p48010000		
p48010000		
p500010000		

Below the Name Browser, a 'Table' window displays:

Parameter	Value
^p402010000	7074040

Engineering Station - Susquehanna.proj (Reset:303, Snap:) <FREEZE>

Project Drawing Edit View Execution IC Presentation Object Instructor Window Help

Feedwater (M-106_1_5_B) Info Reactor Water C...Up (M-144_2_3) Clean-Up Filter...zer (M-145_1_1) Reactor Water C...Up (M-144_1_3) Panel_LP1C276 * Panel_LP1C103 Panel_1C614

Table

Parameter	Value
^cntrlvar111	1.000

Enter New Value

^cntrlvar111
 0.5 [OK] Delay (sec) 5
 Min: Max: [Cancel] Ramp (sec) 10
 Snap Constant

Name Browser

Object / Variable(s) Name or Wildcards
 c*111 [Select] [Table] [Collisions] [Save As...] [Exit]

Name Occurrence Lookup Database Variables Contacts Add Relap

Object Name	Type	File/Global
cntrlvar111		

```
if (*rlp_th_refuel)  
{  
  
    OPENPVLV(cntrlvar645, 0.1);  
  
    double addLevel = (MAXVOID - *voidg670010000)* MAXLEVEL;  
  
    if (addLevel > MAXLEVEL)  
        addLevel = MAXLEVEL;  
  
    *cntrlvar10 = *cntrlvar10 + addLevel;  
}  
else  
    CLOSEPVLV(cntrlvar645, 0.1);
```



- each restart in separate file
- fully compatible with stand alone RELAP5
- possibility to replace RELAP5 components after restart
- possibility to change model time after restart
- backtrack options
 - run in separate thread
 - run on another CPU
 - automatic compress



- Options to develop Control System
 - RELAP5 Input Deck
 - complex when logics involved
 - changes require re-snap ICs
 - 3KEYMASTER task C++ program
 - have to build task
- **Symbolic Calculations and Transfer - SCATER**
 - implemented in YACC
 - invoked on every time step
 - no declarations, simple and handy



```
density[] = {  
    80.0, 1011.838    \  
    100.0, 1005.543  \  
    150.0, 988.4994  \  
    300.0, 922.7115  \  
}
```

```
dp50 = (r5.p052020000 + r5.rho052010000 * 15.93) - r5.p050010000
```

```
dp50lag = lag(dp50, 1.5);
```

```
reftemp = 0.09 * r5.tempg050010000 + r5.cntrlvar6761 * 0.91;
```

```
level50 = density[reftemp] * 25.2 + dp50;
```

```
r5.cntrlvar50 = nconv[level50];
```

```
if (aa > 1.5 || 2.4 < dd) {  
    dd = 1.0;  
}
```



```
vvv = time;
```

```
vvv = dt;
```

```
conv[ ] = {
```

```
    "m-inch", 1011.838 \
```

```
    "cnn",    1005.543 \
```

```
    "cnn",    998.9754 \
```

```
}
```

```
cc = cc * conv["m-inch"];
```

```
bb = bb + (aa + sin(0.5)*3.0 + aa);
```

```
comment-----
```

```
comment-----
```



XML definition in external file

First Version - Validator

<PIPE>

```

<CardNo0001 MaxNumber="0001" option="Required" wno="1" help="pg_0070">
  <W1 name="Vol num" type="int" range="GT 0 AND LT 100" update="var" value="0" N="1" help="pg_0070"/>
</CardNo0001>
<CardNo0003 MaxNumber="0003" option="Optional" wno="5" help="pg_0072">
  <W1 name="Magnetic f str" type="float" range="GE 0" update="var" value="0" help="pg_0072"/>
  <W2 name="Duct wall cond" type="float" range="GE 0" update="var" value="0" help="pg_0072"/>
  <W3 name="Duct wall thickness" type="float" range="GE 0" update="var" value="0" help="pg_0072"/>
  <W4 name="Duct geometry type" type="int" range="EQ 1 AND EQ 2" update="var" value="1" wopt="opt"
    help="pg_0072"/>
  <W5 name="Fringe volume flag" type="int" range="GE -1 AND LE 2" update="var" value="0" wopt="opt"
    help="pg_0072"/>
</CardNo0003>
<CardNo0101 MaxNumber="0199" option="Required" wno="2" help="pg_0073">
  <W1 name="Area X" type="float" range="GE 0" update="var" value="0.0" help="pg_0073"/>
  <W2 name="Vol No" type="int" range="GT 0" update="var" value="1" help="pg_0073"/>
</CardNo0101>

```



Relap Editor

File Options Help

Component No.: Insert Card:

Card No.	Type	W1	W2	W3	W4	W5	W6	W7	W8	W9
	c	name	type							
0480000	r	St-Dom	branch							
	c	Jun num	Init flag							
0480001	r	4	0							
	c	Area X	Lenght X	Volume X	Azim angle	Inclin angle	Elev change	Roughness	H diameter	tlpvbfe
0480101	r	249.99	10.958	0.0	0.0	90.0	10.958	1.5e-4	0.0	0000000
	c	Area Y	Lenght Y	Roughness	H diameter	tlpvbfe	Not used	Not used	Pos change	
	c	#0.0	#0.0	#0.0	#0.0	#0000000	#0.0	#0.0	#0.0	
	c	ebt	Pressure	Liq temp	Vap/gas temp	Vap/gas void ...	Noncond ...			
	c	008	1049.3	545.43						
	c	From	To	Jun flow...	En loss coef	Rev en loss coef	jefvcahs	Vol fr lim	2-ph dis...	SH disch
0481101	r	048010001	400010001	3.01	4.0	4.0	00000000			
0482101	r	048010001	600010001	3.01	4.0	4.0	00000000			
0483101	r	048010001	500010001	3.01	4.0	4.0	00000000			
0484101	r	048010001	700010001	3.01	4.0	4.0	00000000			
	c	Diameter	Flooding	Intercept	Slope					
0481110	r	1.9706	0.0	1.0	1.0					
0482110	r	1.9706	0.0	1.0	1.0					
0483110	r	1.9706	0.0	1.0	1.0					
0484110	r	1.9706	0.0	1.0	1.0					
	c	Init Lig...	Init vap...	Interfac...						
0481201	r	0.0	1001.8325	0.0						

Delete Card

Move Up

Move Down

Instructor Station - FPL_TKP.proj (Reset:9, Snap): <FREEZE> - [RelapNodFPL1]

Project Drawing Edit View Execution IC Presentation Object Instructor Window Help

RelapTmdpvol_in_FB RVF690010000

Parameter	Value	Unit	Description
#boron	0	norm	boron concentration
#h	0	J/kg	enthalpy
input_select	3	integer	Input parameters selector: ; 1 -(p,h,quala); 2 -(p,temp,void=0); 3 -(p,temp,void=1,quala); 4 -(p,quala)
#p	6.06739e+006	Pa	pressure
#quala	0.9	norm	noncondensable mass fraction
#qualan1	1		
#qualan2	0		
#qualan3	0		
#qualan4	0		
#qualan5	0		
#quals	0.999929	norm	static mass quality
#temp	400		sattemp
#tempf	549.429	degK	liquid temperature
#tempg	549.429	degK	vapor/gas temperature
#uf	1.20946e+006	J/kg	Liquid specific internal energy
#ug	2.58985e+006	J/kg	Vapor/gas specific internal energy
#voidg	0.999997	norm	vapor/gas fraction (void fraction)

RelapTmdpjun_in_FB RJF691000000

Parameter	Value	Unit	Description
#area	0.591699		
#delta vg vf	0		
input_select	1	integer	Input parameters selector: ; 1 -(mflowj_total,delta=vg-vf); 2 -(mflowj,mflowgj); 3 -(mflowj_total,area,delta=vg-vf); 4 -(mflowj,mflowgj,area)
#mflowj	421.8	kg/s	liquid mass flow rate
#mflowgj	0	kg/s	vapor/gas mass flow rate
#mflowj_total	421	kg/s	combined liquid and vapor/gas flow rate
velfj	23.9568	m/s	liquid velocity
velgj	23.9568	m/s	vapor/gas velocity

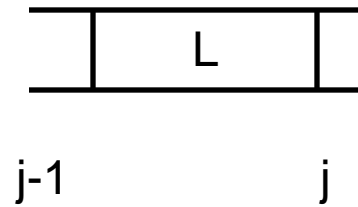
Nodes

Nodes Links Dynamic Types

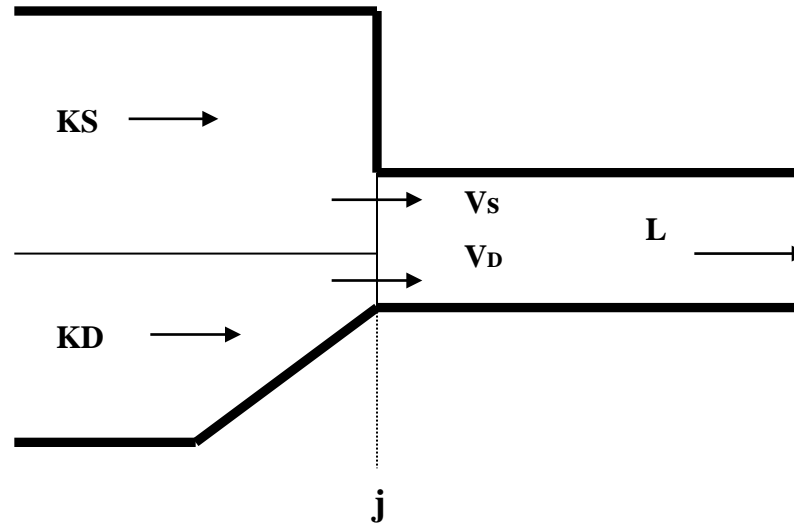
RELAP5-3D Real Time Improvements



Pump Two-Phase Multiplier



$$\alpha_L \leftarrow \frac{1}{2} (\alpha_{j-1} + \alpha_j)$$



$$\left(\frac{\rho_f - \rho_g}{\rho_f \rho_g} \right) (P_L - P_{KS}) + \frac{\alpha_{gS} \rho_{gS} v_{gS} A_S (v_{gL} - v_{gS})}{\alpha_{gL} \rho_{ga} A_L} + \frac{\alpha_{gD} \rho_{gD} v_{gD} A_D (v_{gL} - v_{gD})}{\alpha_{gL} \rho_{ga} A_L} + \frac{1}{2} \frac{\alpha_{gKS} \rho_{gKS} (v_{gS}^2 - v_{gKS}^2)}{\alpha_{gKS} \rho_{ga}} =$$

$$\frac{\alpha_{fS} \rho_{fS} v_{fS} A_S (v_{fL} - v_{fS})}{\alpha_{fL} \rho_{fa} A_L} + \frac{\alpha_{fD} \rho_{fD} v_{fD} A_D (v_{fL} - v_{fD})}{\alpha_{fL} \rho_{fa} A_L} + \frac{1}{2} \frac{\alpha_{fKS} \rho_{fKS} (v_{fS}^2 - v_{fKS}^2)}{\alpha_{fKS} \rho_{fa}}$$

$$\alpha_{gL} \leftarrow \frac{1}{2} (\alpha_{gL} + \alpha_{gj})$$

$$\alpha_{fL} \leftarrow \frac{1}{2} (\alpha_{fL} + \alpha_{fj})$$

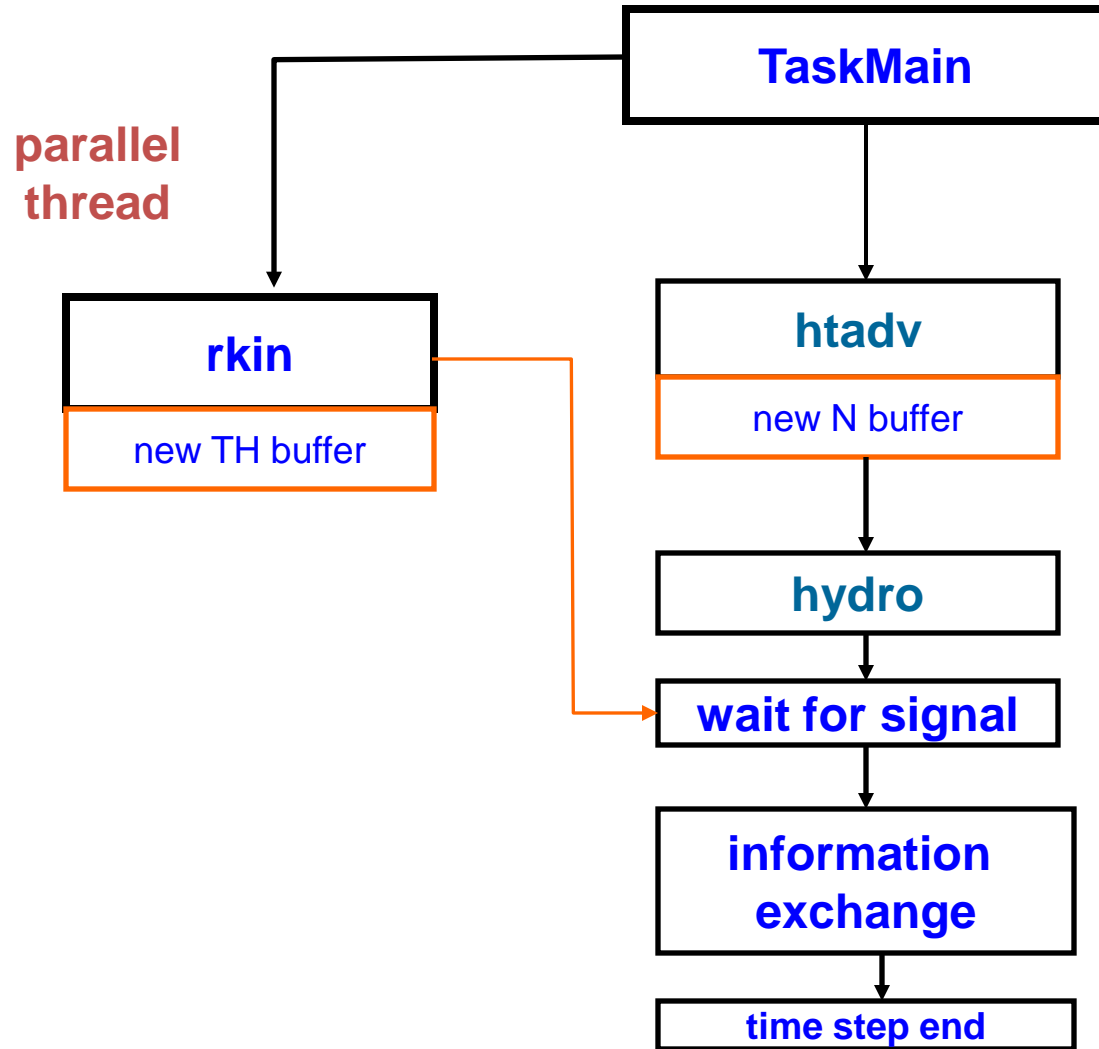


- Dalton-Gibbs Equations Convergence Failure
- Noncondensables First Appearance Criteria
- Velocities Flip-Flop for Selected Junctions



Parallel Threads Execution





Performance Results Comparison

- Sequential execution, TH time step 0.05 sec., N time step 0.2 sec.,
CPU load: 1 – 5%, 2 – 70%
- Sequential execution, TH time step 0.01 sec., N time step 0.1 sec.,
CPU load: 1 – 5%, 2 – 95%
- Parallel execution, TH time step 0.01 sec., N time step 0.1 sec.,
CPU load: 1 – 50%, 2 – 60%



QUESTIONS

