3KEYRELAP5 – Improvements and Applications

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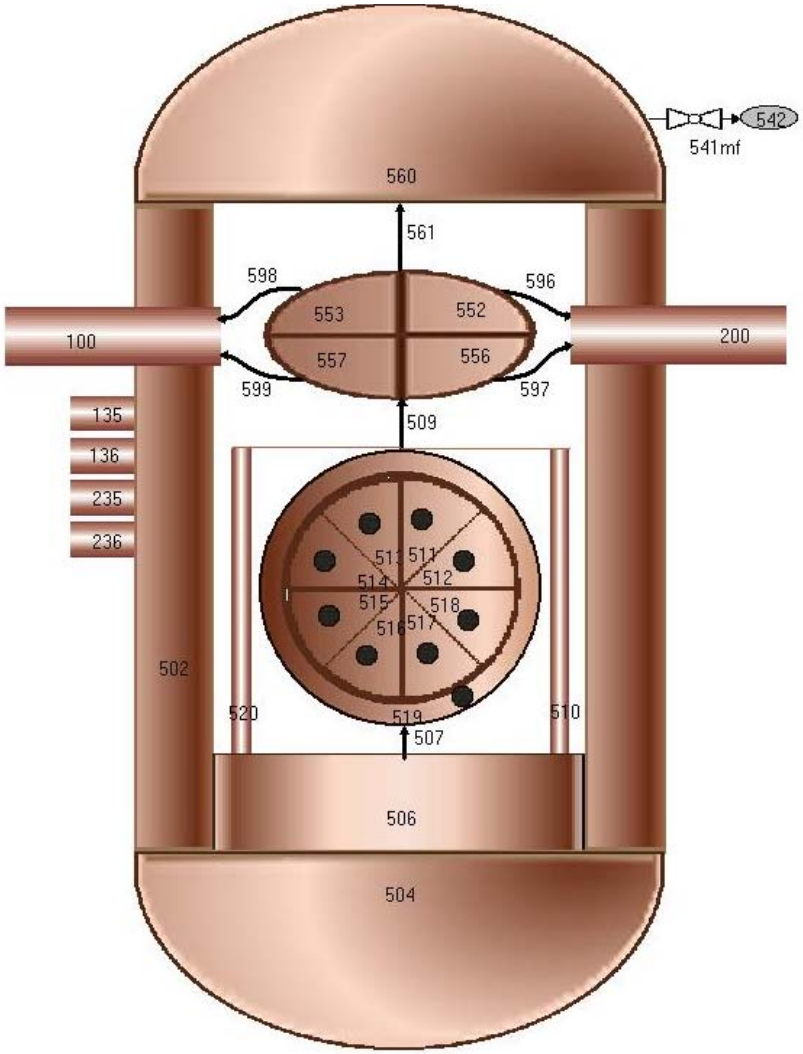
Prepared for IRUG August 2009

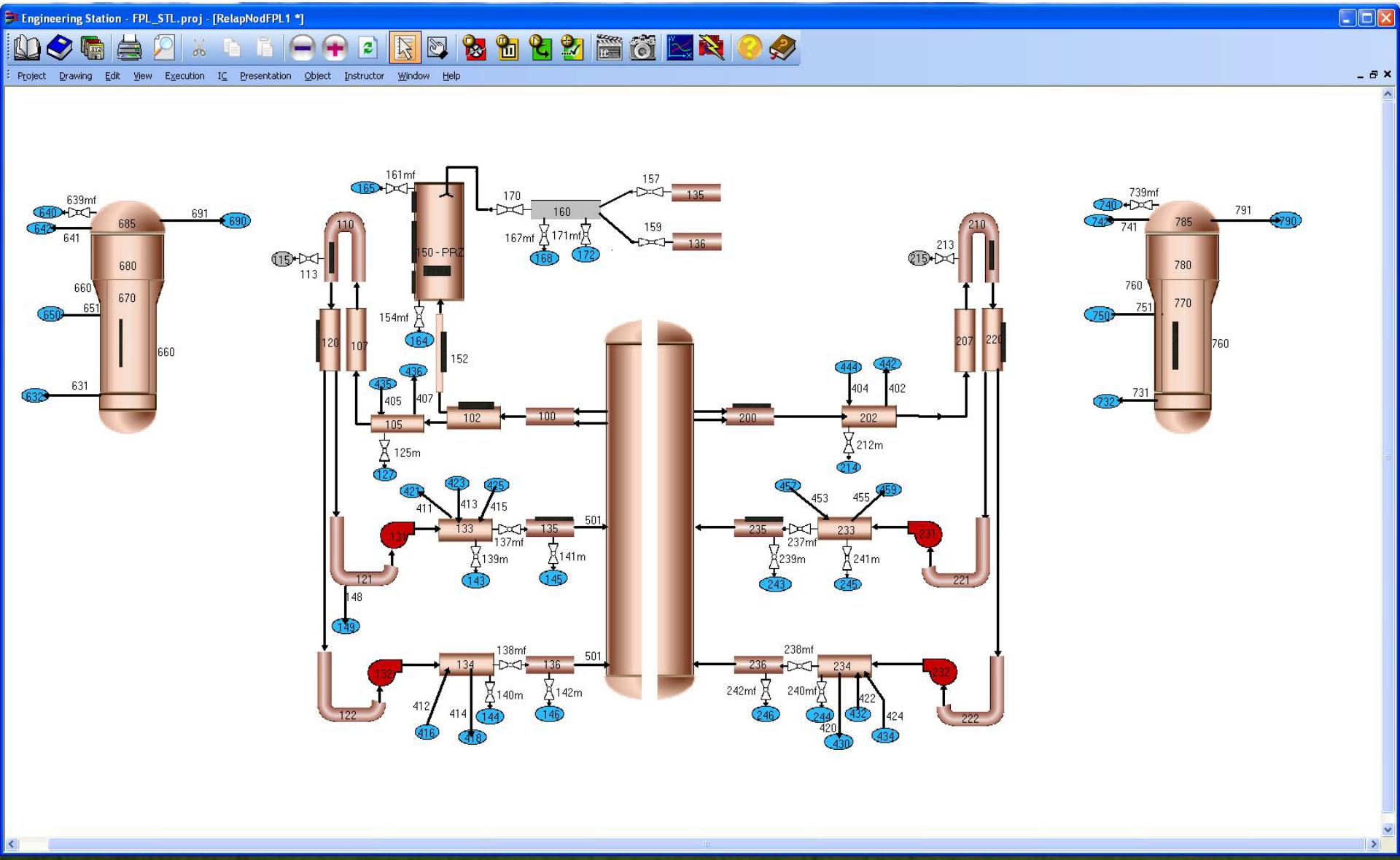
Quick Overview

- 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

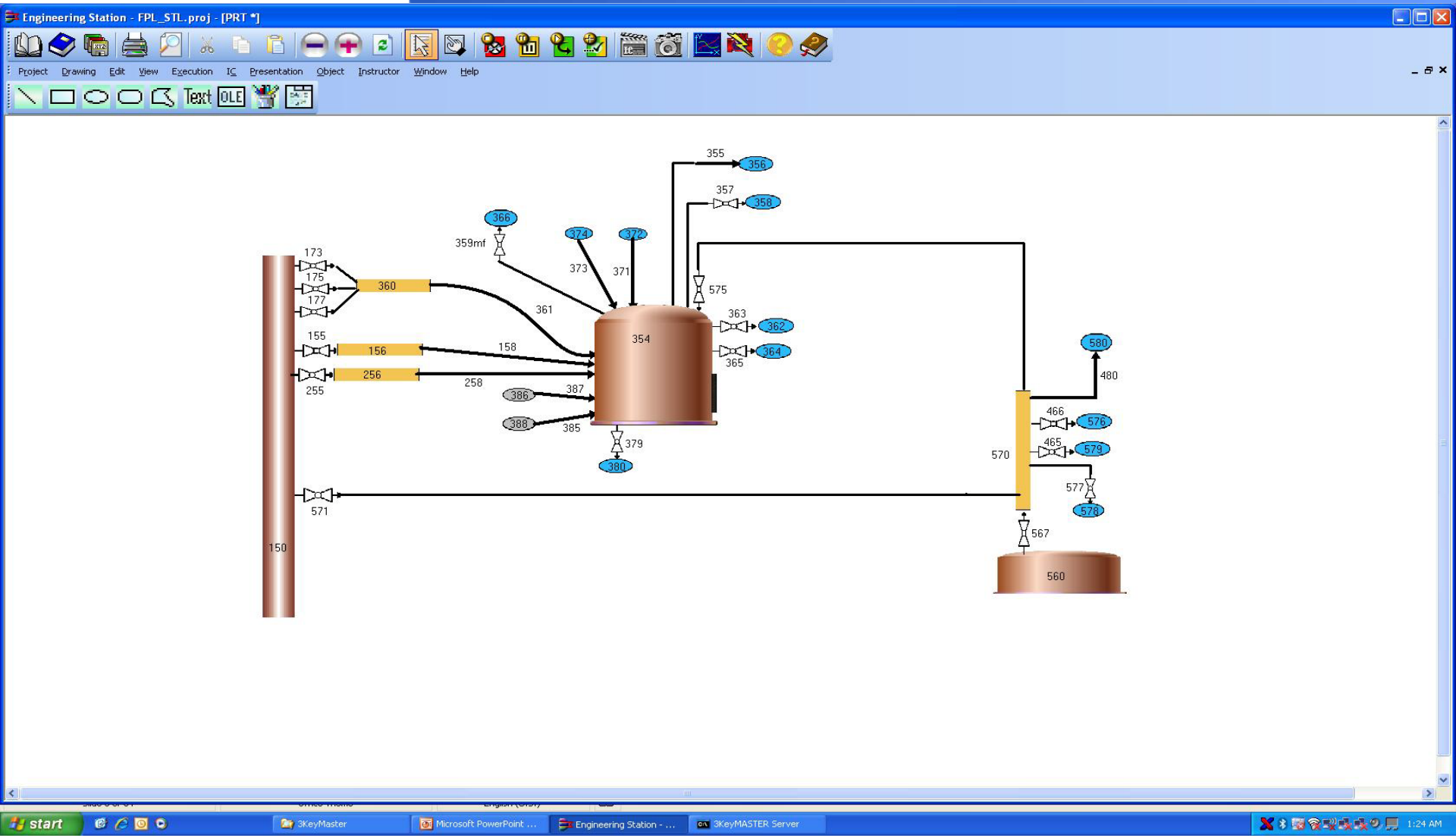
St.Lucie Reactor Vessel



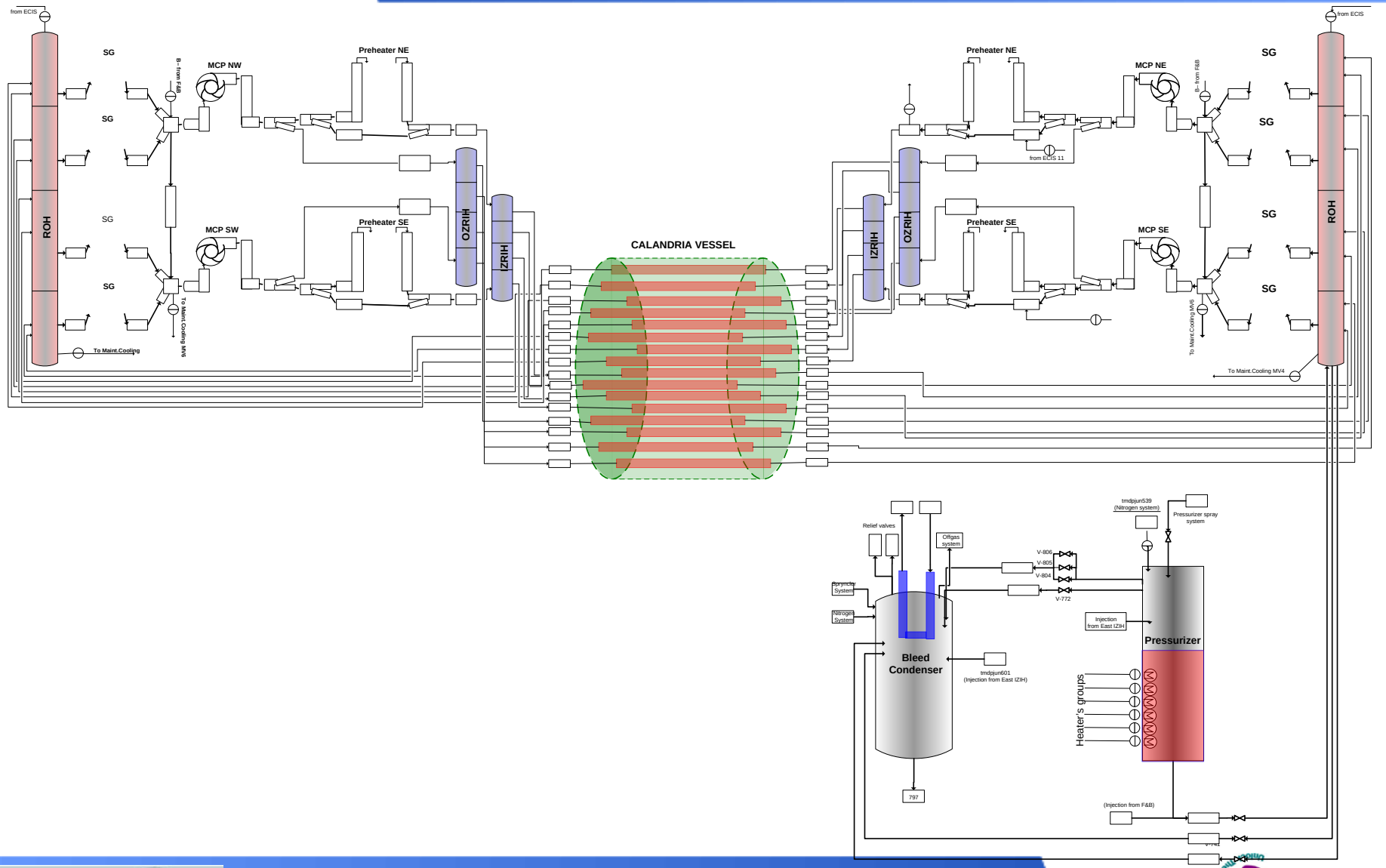
St.Lucie Loops



St.Lucie PRZ & Quench Tank

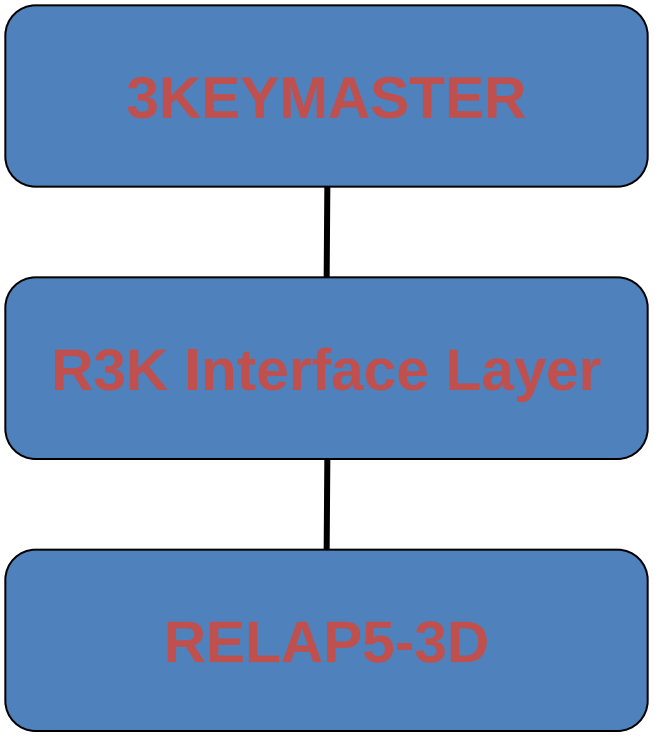


BruceB - Primary Heat Transport System



3KEYRELAP5 Technology

RELAP5 – 3KEYMASTER Interface



- 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

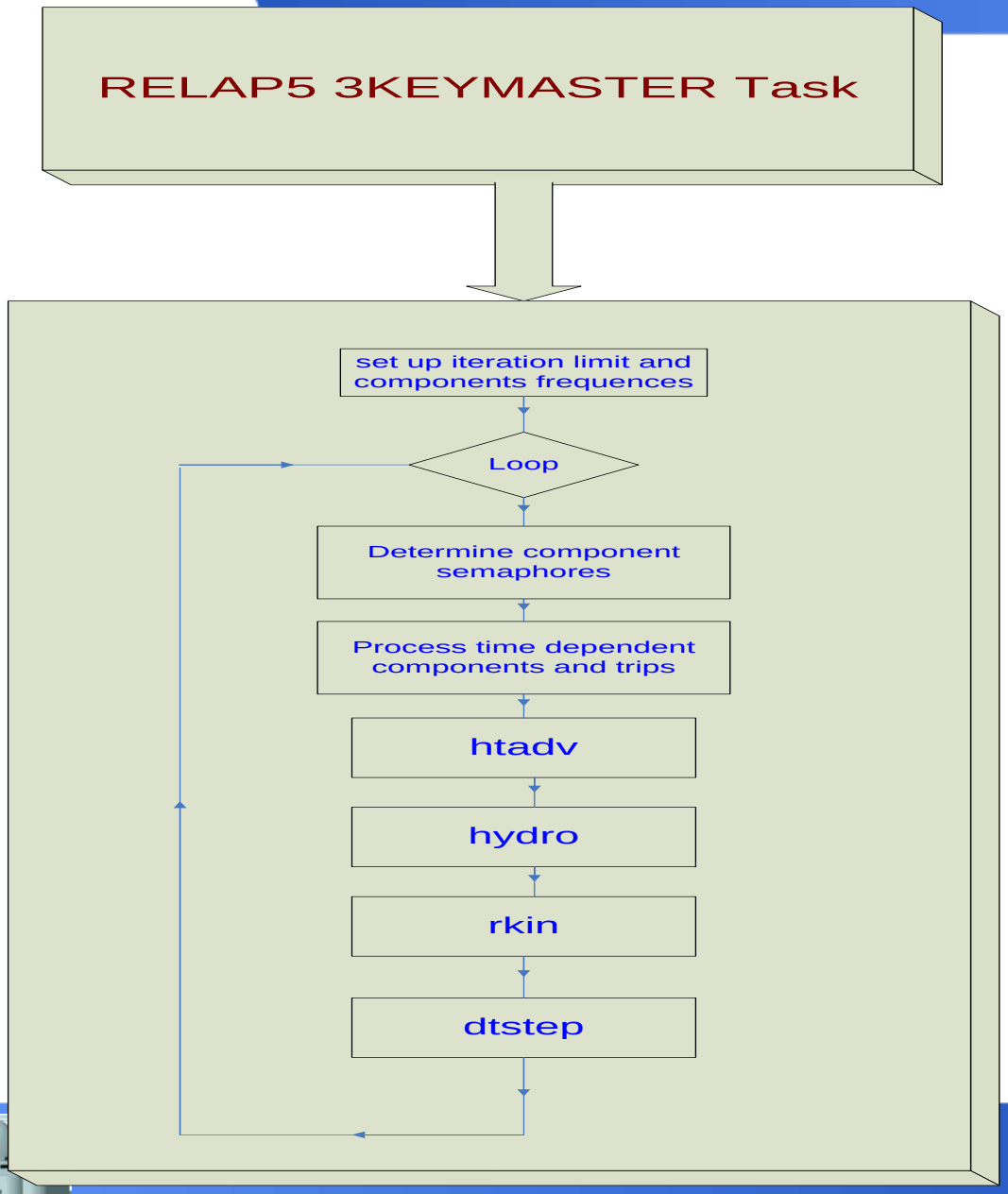
RELAP5 as a 3KEYMASTER Task

- 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

R3K Functional Specification

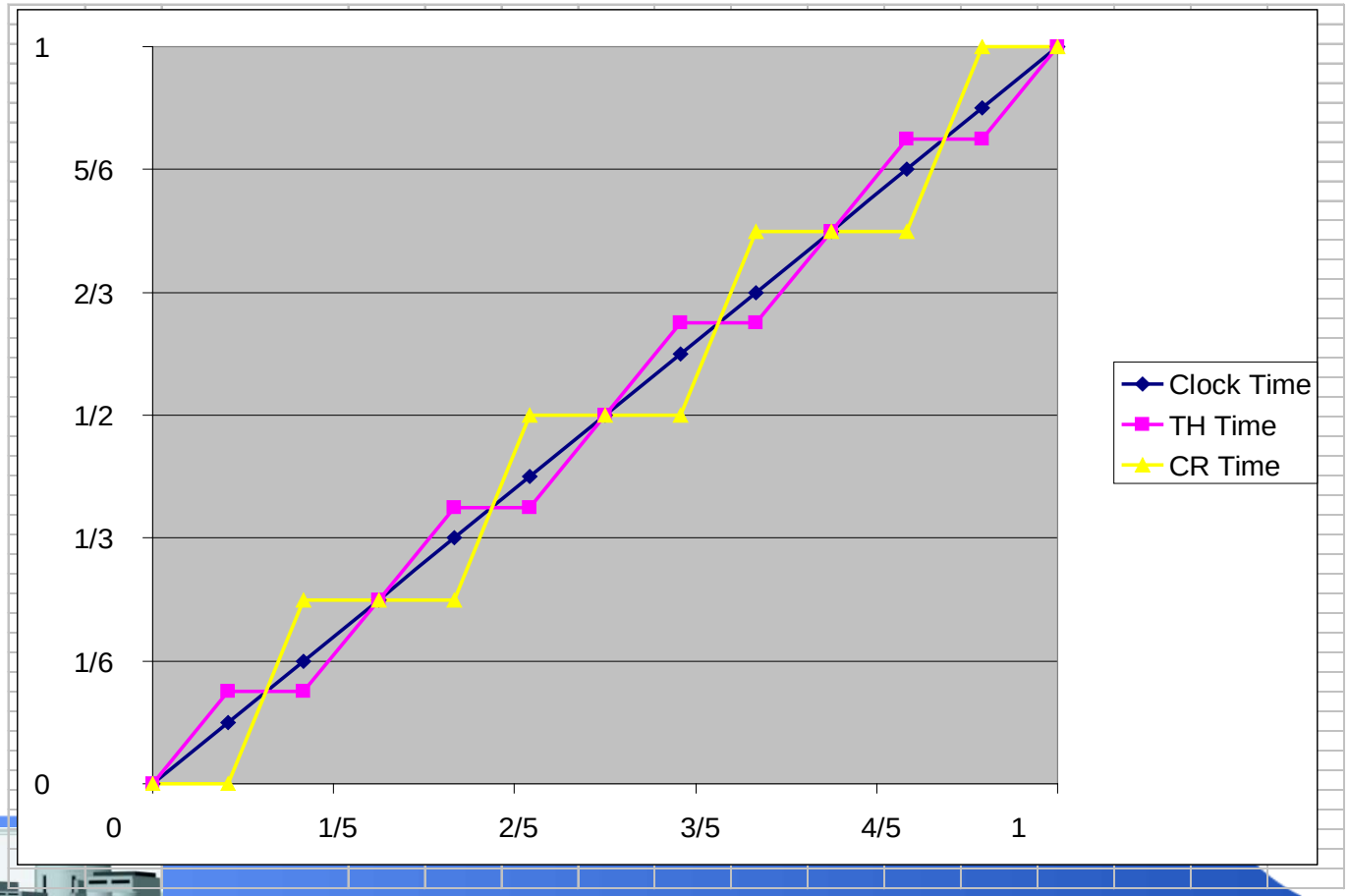
- make time advancement
- write restart file
- read restart file
- setup model time
- setup mode
  - steady-state / transient
  - components to run (hydro, htadv, rkin)
  - print major edit
  - debug mode on/off
- generate list of ME variables
- output specified variables
- input parameters of TDC and 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

R3K – time advancement

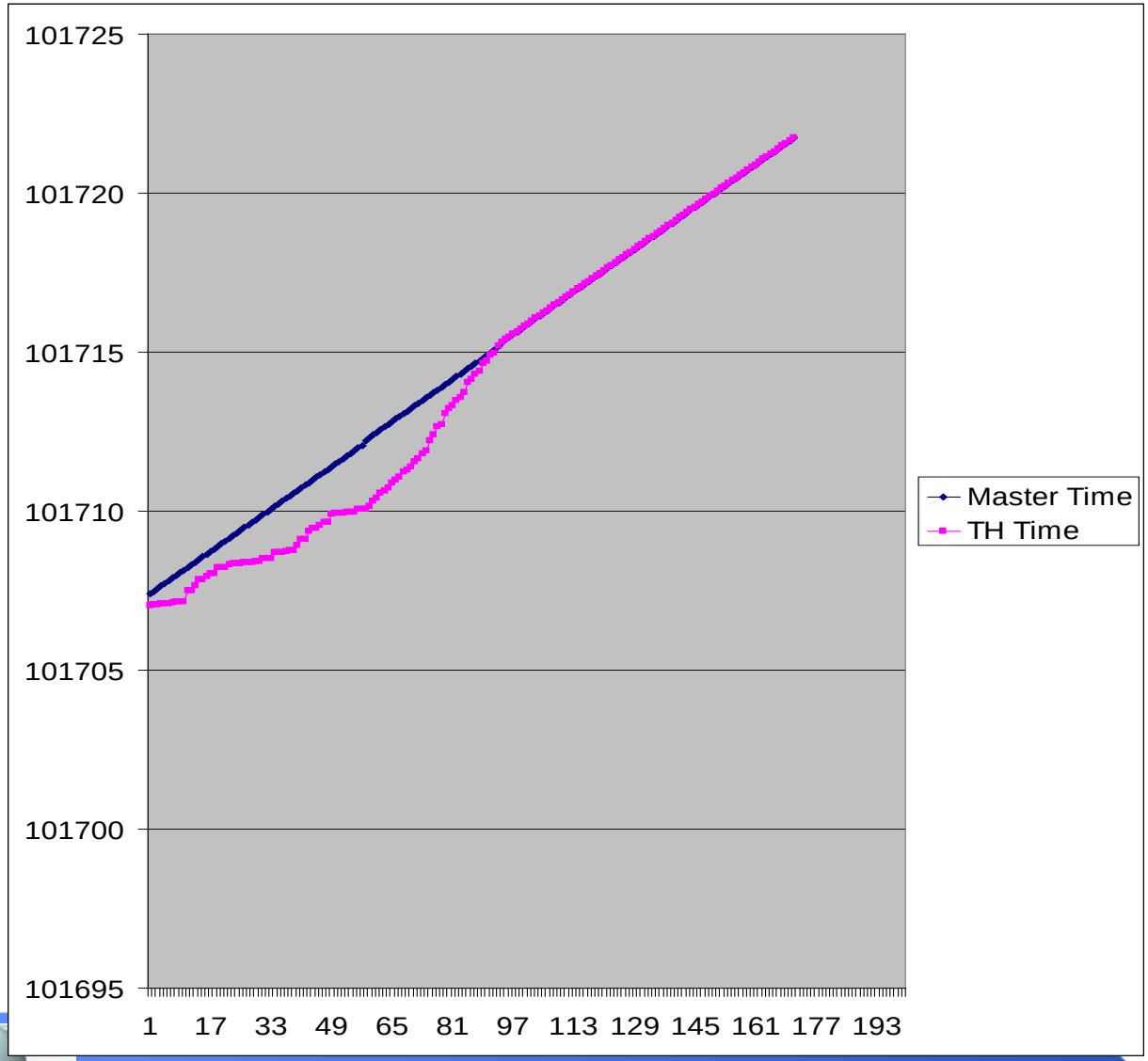


R3K – Fixed Frequencies

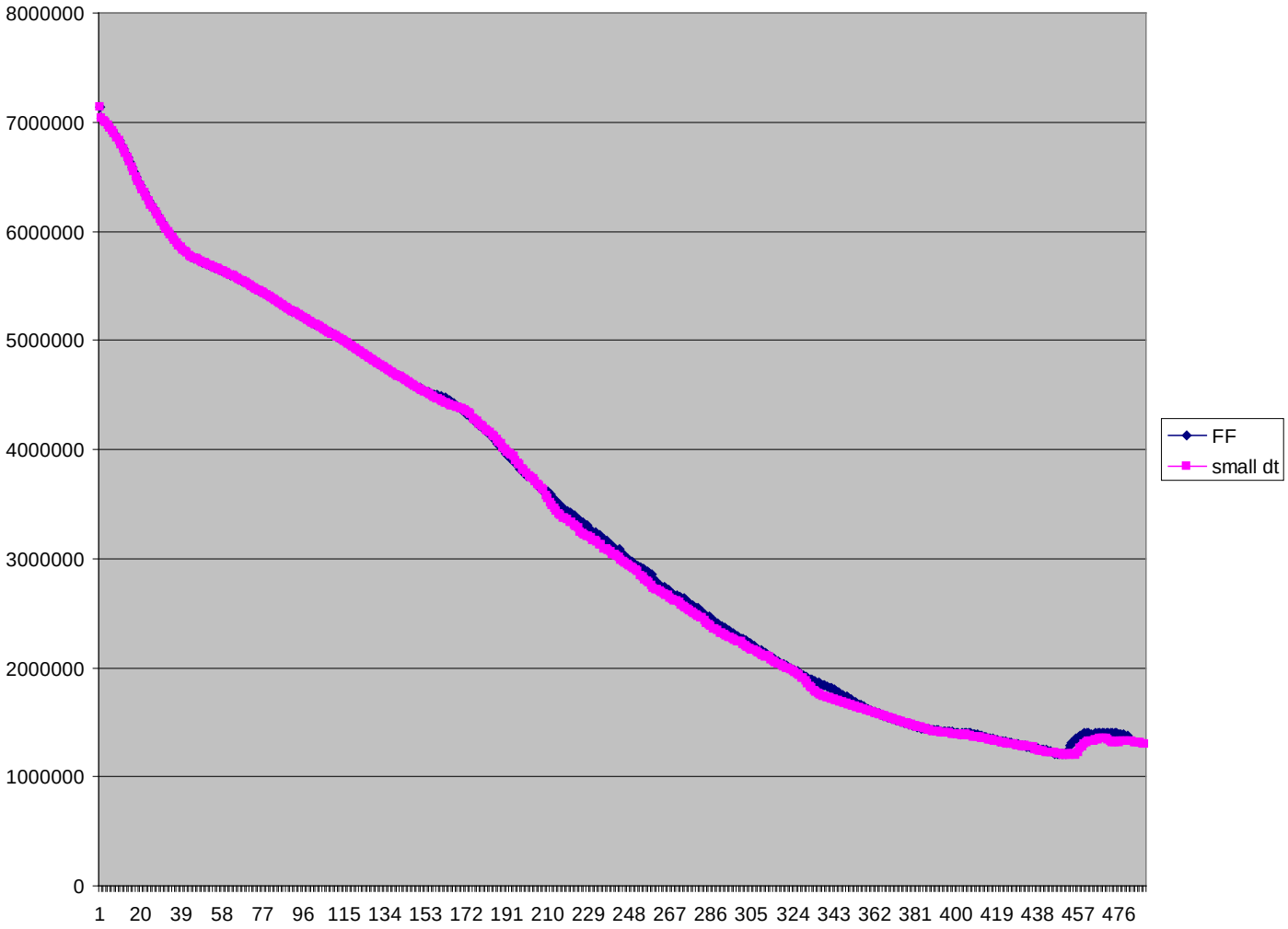
TH	CR	TH	TH	CR	TH	TH	CR	TH	TH	CR	TH



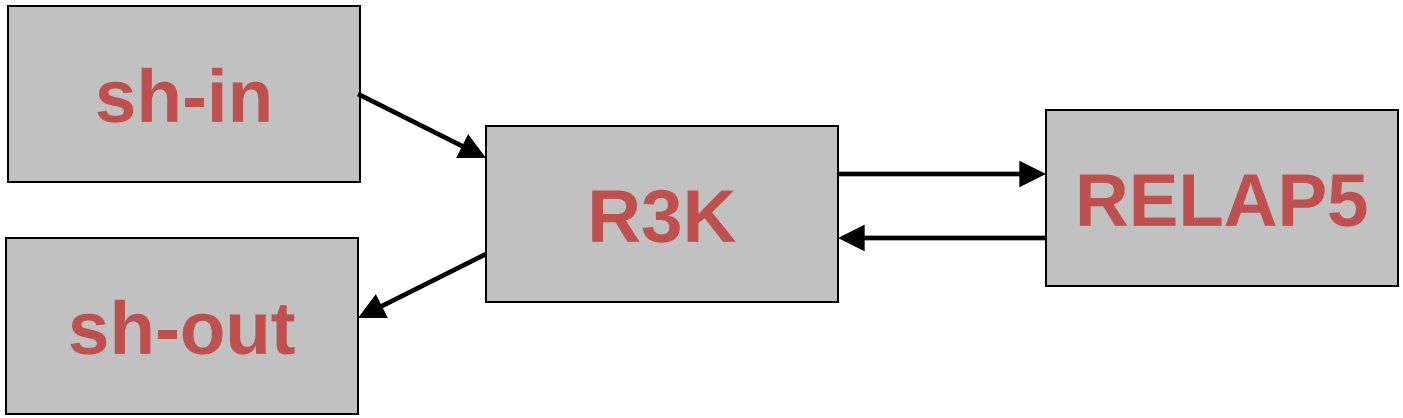
R3K – Floating Frequencies



R3K – Floating Frequencies



R3K- RELAP5 Variables Access



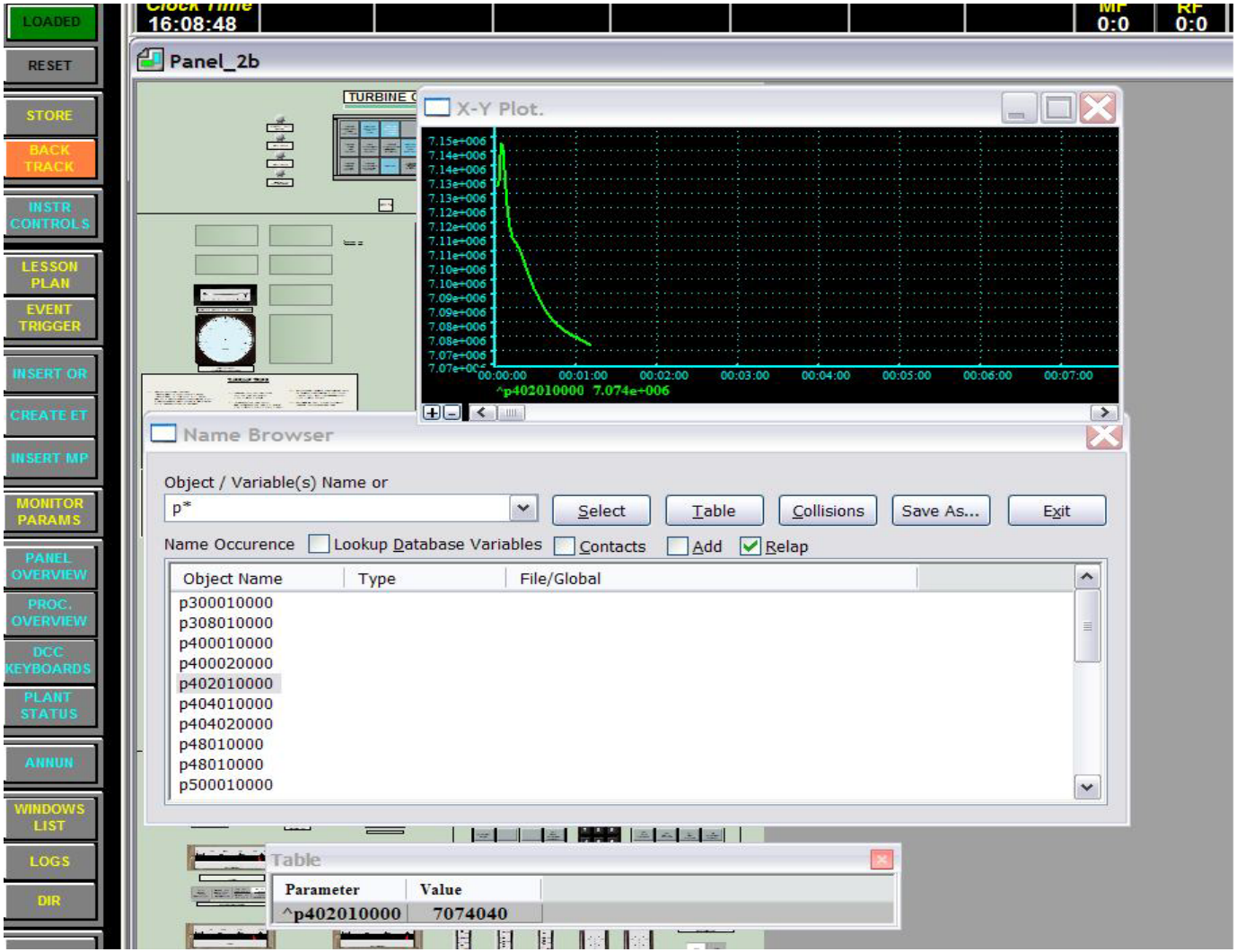
r3k.tdcomp

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

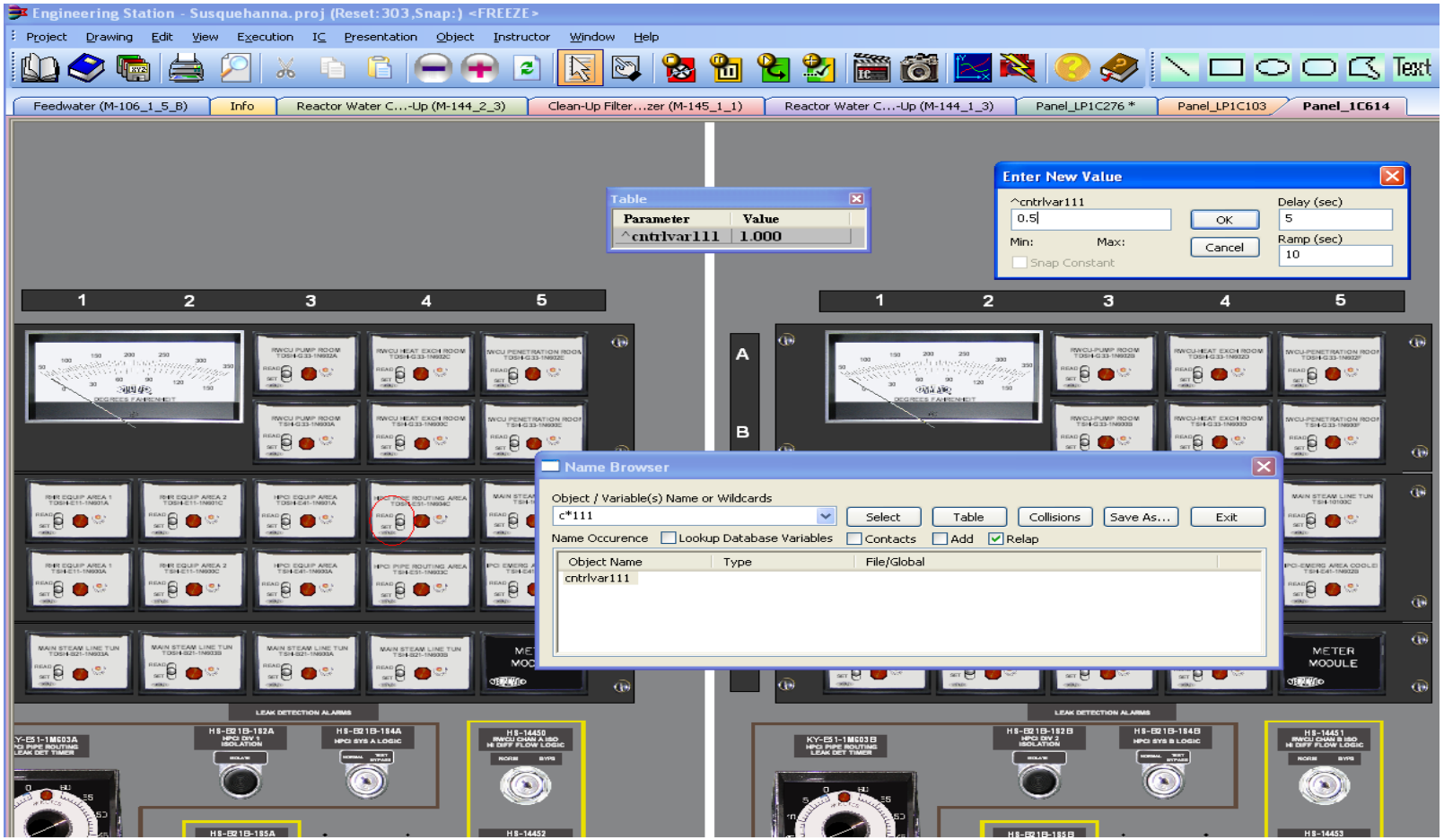
r3k.medit

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

R3K – RELAP5 Variables Access



R3K – RELAP5 Variables Access



R3K – C++ access

```
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);
```

R3K – snap/reset file

- 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

R3K – Control System Interpreter

- 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

R3K – SCATER Example

```
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;
}
```

SCATER – advanced features

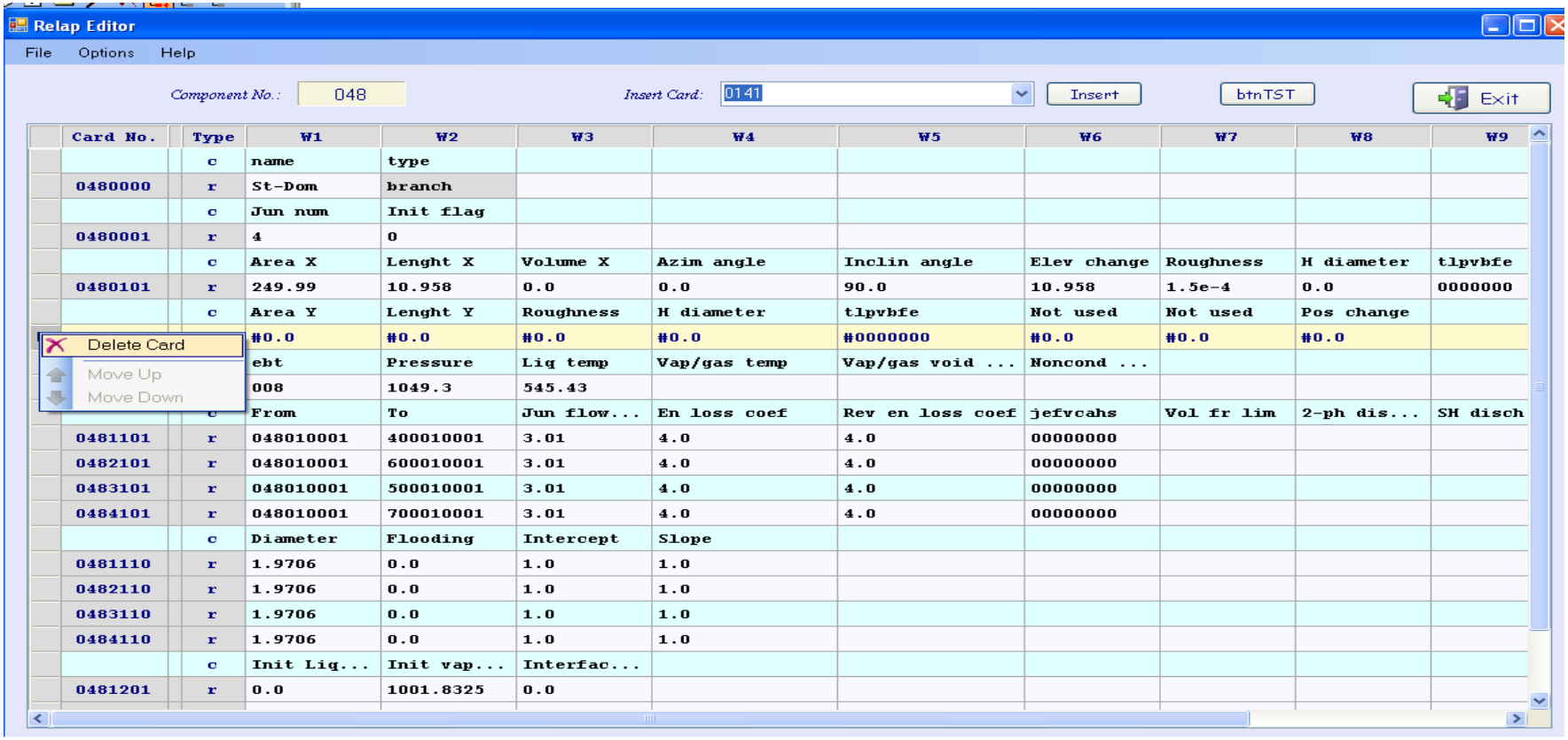
```
vvv  =  time;

vvv  =  dt;

conv[ ] = {                                          comment----------------

 "m-inch",  1011.838   \                            comment----------------
 "cnn",     1005.543   \
 "cnn",     998.9754   \
}

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

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

XML definition in external file

First Version - Validator

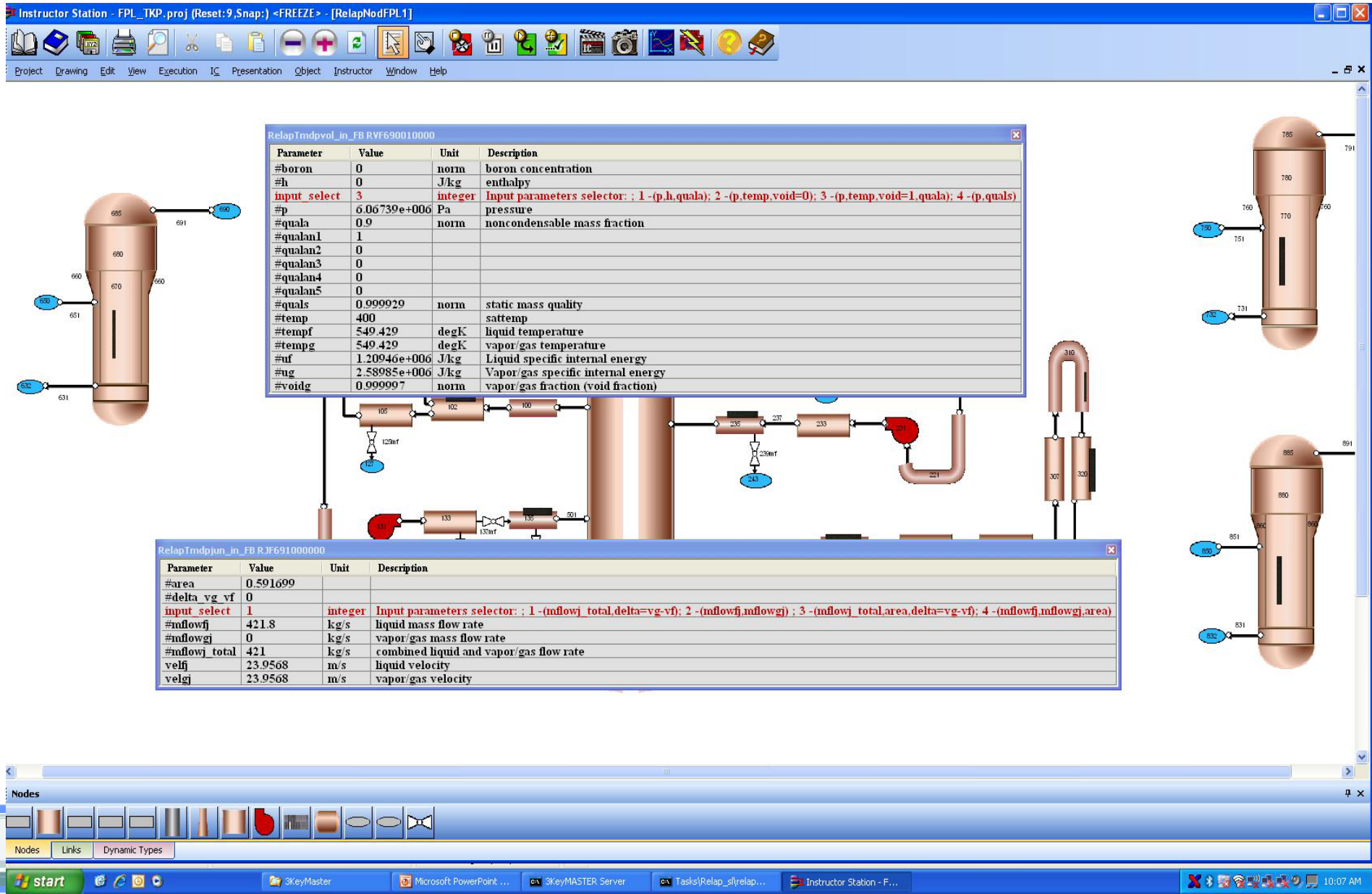
```
<PIPE>
  <CardNo0001 MaxNumber="0001" option="Required" wno="1" help="pg_0070">
    <W1 name="Vol num" type="int" range="GT 0 AND LT 100" update="var" value="0" N="1" help="pg_0070"/>
   </CardNo0001>
   <CardNo0003 MaxNumber="0003" option="Optional" wno="5" help="pg_0072">
    <W1 name="Magnetic 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="Fringle 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>
```

RELAP5 Input Deck Editor



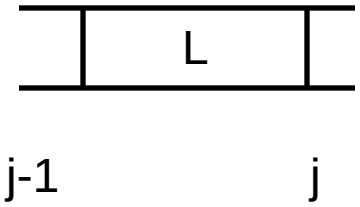
Card No.	Type	W1	W2	W3	W4	W5	W6	W7	W8	W9
	c	name	type							
0480000	r	St-Dom	branch							
	c	Jun num	Init flag							
0480001	r	4	0							
	c	Area X	Lenght X	Volume X	Azim angle	Inclin angle	Elev change	Roughness	H diameter	tlpvbfe
0480101	r	249.99	10.958	0.0	0.0	90.0	10.958	1.5e-4	0.0	0000000
	c	Area Y	Lenght Y	Roughness	H diameter	tlpvbfe	Not used	Not used	Pos change	
		#0.0	#0.0	#0.0	#0.0	#0000000	#0.0	#0.0	#0.0	
		ebt	Pressure	Liq temp	Vap/gas temp	Vap/gas void ...	Noncond ...			
		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 Liq...	Init vap...	Interfac...						
0481201	r	0.0	1001.8325	0.0						

Boundary Checker Task



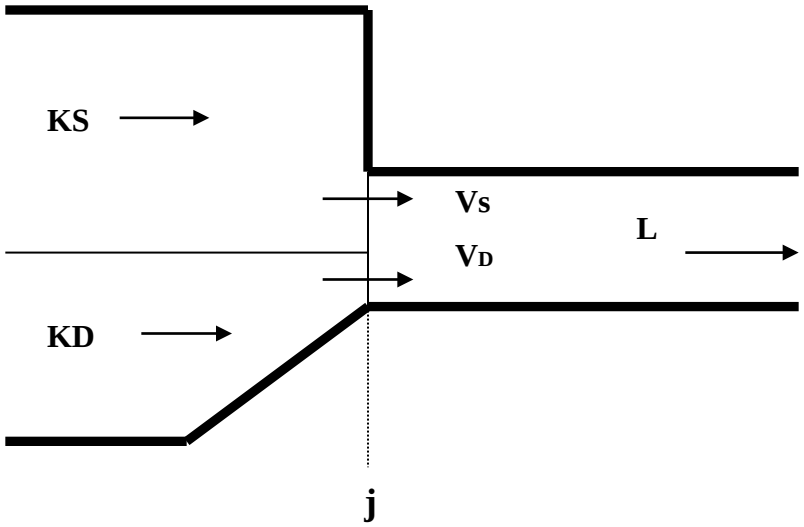
RELAP5-3D Real Time Improvements

Pump Two-Phase Multiplier



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

RELAP5-3D Real Time Improvements



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

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

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

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

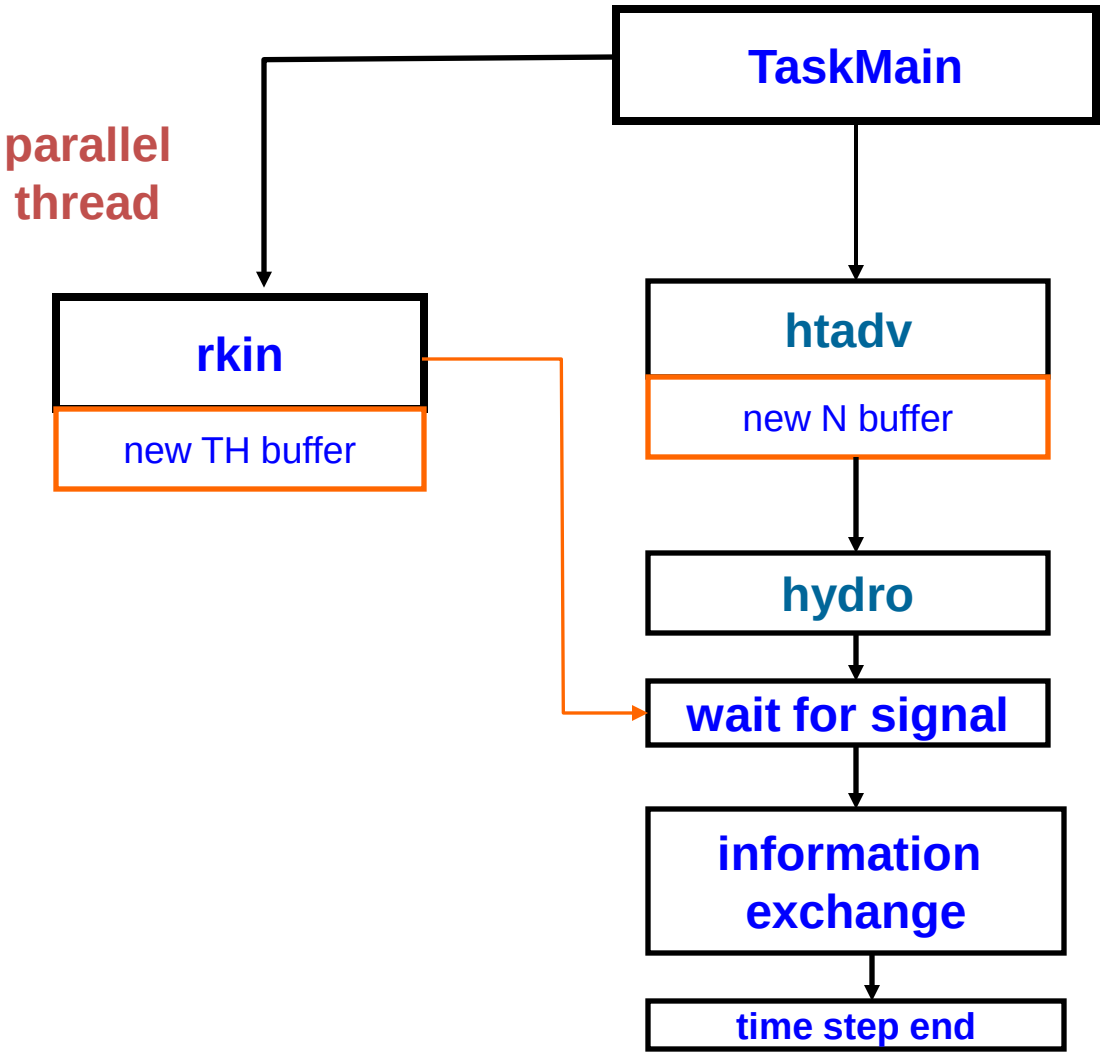
RELAP5 Real Time Improvements

RELAP5 Real Time Improvements

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

Parallel Threads Execution

Parallel Threads



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