INL/CON-24-80339-Revision-1

Presentation for IRUG - Pressurizer controllers

September 2024

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Changing the World's Energy Future

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RELAP5-3D Intermediate Training

Pressurizer controllers.

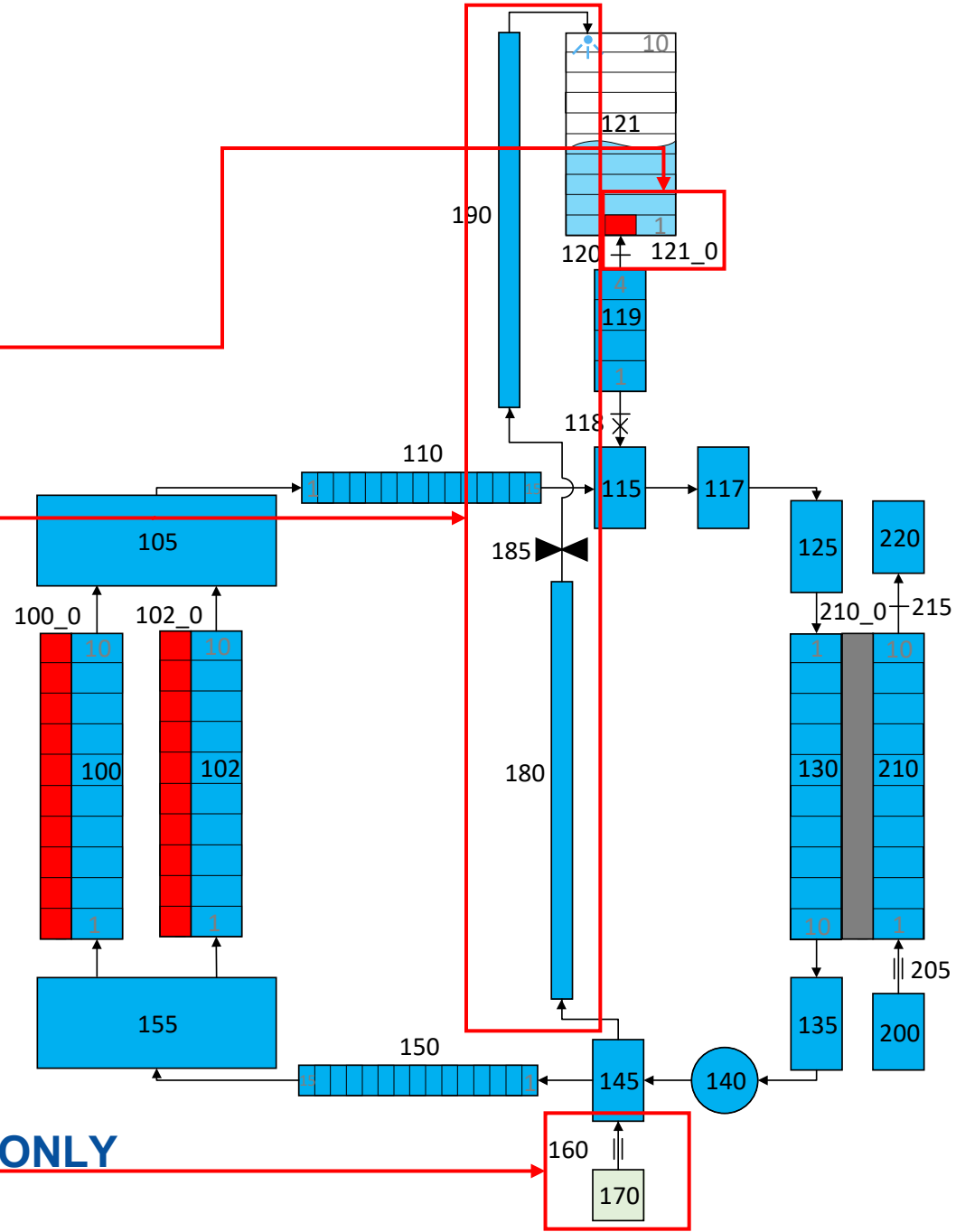
Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy

Idaho National Laboratory

Full Model with Pressurizer Controls

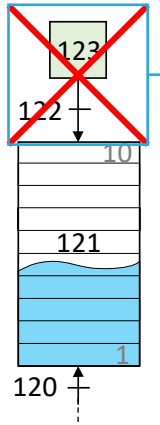
Three additional systems are integrated into the base loop:

1. Pressurizer heater (HS. 121_0) to increase the system pressure when it falls below the setpoint (15.5 MPa).
2. Spray Line (VOL 180, VLV 185, BRANCH 190) to reduce the system pressure when it exceeds the setpoint (15.5 MPa).
3. Makeup tank and pump (TDPV 170, TDJ 160) to maintain the pressurizer level at the desired setpoint (0.75 m);



OFFICIAL USE ONLY

TRIPs modifications and additions



Remove the ideal pressure controller “snj122” & “tdv123”

Include TRIPs to turn ON and OFF the following control systems:

1. Makeup tank and pump activated at 0.0 s and deactivated after 1000.0 s.
2. The pressurizer spray remains active throughout the entire transient.
3. The pressurizer heater remains active throughout the entire transient.

```
**************************************************************************
*                    TRIP INPUT
**************************************************************************
*                        Var.        Param.      Rela.       Var.      Pram.
* Cont'd                 Cosnst.     Latch       Timeof
505                     time        0           gt          null      0
+                       1.00E+06    n           -1.0                  *  Pump motor trip (False = Electricity to the Motor, True = Motor OFF)
506                     time        0           gt          null      0
+                       1.00E+06    n           -1.0                  *  Control the power table (False = Steady State, True = SCRAM)
507                     time        0           lt          null      0
+                       1.00E+06    n           0.0                   *  Makeup volume (True = ON, False = OFF)
508                     time        0           lt          null      0
+                       1.00E+06    n           0.0                   *  Pressurizer spray (True = ON, False = OFF)
509                     time        0           lt          null      0
+                       1.00E+06    n           0.0                   *  Pressurizer heater (True = ON, False = OFF)
510                     time        0           gt          null      0
+                       1.00E+06    n           -1.0                  *  Control the Secondary side MFR (False = Steady State, True = MFR change)
*
**************************************************************************
```

Existing components modifications

```
**************************************************************************
* Branch component (#145)
* Name Type
1450000          brch145          branch
*                Junc. No'           icc
1450001                 2             1
*                    Area       Length       Volume      Hor. Ang.      Ver. Ang.
1450101         5.86E-03          0.5          0.0            0.0            0.0
*                    Elev.         Wall      roughDh         tlpvbfe
1450102             0.0       5.00E-05        0.086        0000000
*                  Area-Y     Length-Y       Wall      roughDh-Y       tlpvbfe-Y
1450181             0.0          0.086        0.0            0.0        0000010
*                     ebt       Pres.        Temp.
1450200               3       1.55E+07       552.6
*                    From         To          Area
1451101         145010000     150000000        0.0
*                      AF         AR         jefvcahs
1451102             0.0          0.0        00000000
*                    From         To          Area
1452101         145010000     180000000        0.0
*                      AF         AR         jefvcahs
1452102             0.0          0.0        00000000
* Init. Co      Liq. Mfl.    Vap. Mfl.      Intf. Vel
1451201          28.442          0.0            0.0
1452201             0.0          0.0            0.0
*
**************************************************************************
```

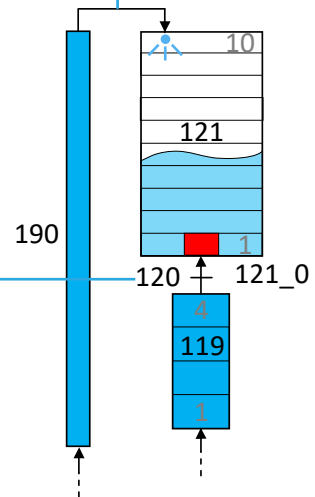
Adding a junction to branch 145, located downstream of the pump, to connect the lower part of the spray line (vol180).

```
* Init.          Coebt          Pres.          Temp.          Qual.          Null
* Cont'd         Null           Vol. No'
1191201          003            1.55E+07       586.0          0.0            0.0
+                0.0            4
*
* Init.          Coebt          Pres.          Temp.          Qual.          Null
* Cont'd         Null           Vol. No'
1211201          003            1.55E+07       586.0          0.0            0.0
+                0.0            5
* Init.          Coebt          Pres.          Qual.          Null           Null
* Cont'd         Null           Vol. No'
1211202          002            1.55E+07       1.0            0.0            0.0
+                0.0            10
```

- Adjusting the initial temperatures of the surge line (pipe119) and the pressurizer (pipe121) to match the hot leg to which they are connected.
- Although the temperatures of these components will eventually equalize with the hot leg, this process occurs very slowly due to the stagnant fluid within them, as they are not part of the main flow path.
- This modification is intended to accelerate the temperature equalization.

Existing components modifications

```
************************************************************************
* Pressurizer component (#121) - Pressurizer
*                Name            Type
1210000          prz121          prizer
* Geometry      No'vols.        surgjN          intfhxl         intfhxv         multl
*                Cont'd          multv           droplsiz        sprayjN         mixcoeff.
1210001          10              120000000       0.0             0.0             0
+                0               0.0             190010000       0.0
* Geometry      Area            Vol. No'
1210101          3.24E-02        10
* Geometry      Length          Vol. No'
1210301          0.15            10
* Geometry      Ver. Ang.       Vol. No'
1210601          90.0            10
* Geometry      Elevation       Vol. No'
1210701          0.15            10
```



- Change the component type from “pipe” to “prizer” this will require additional words on card 1210001

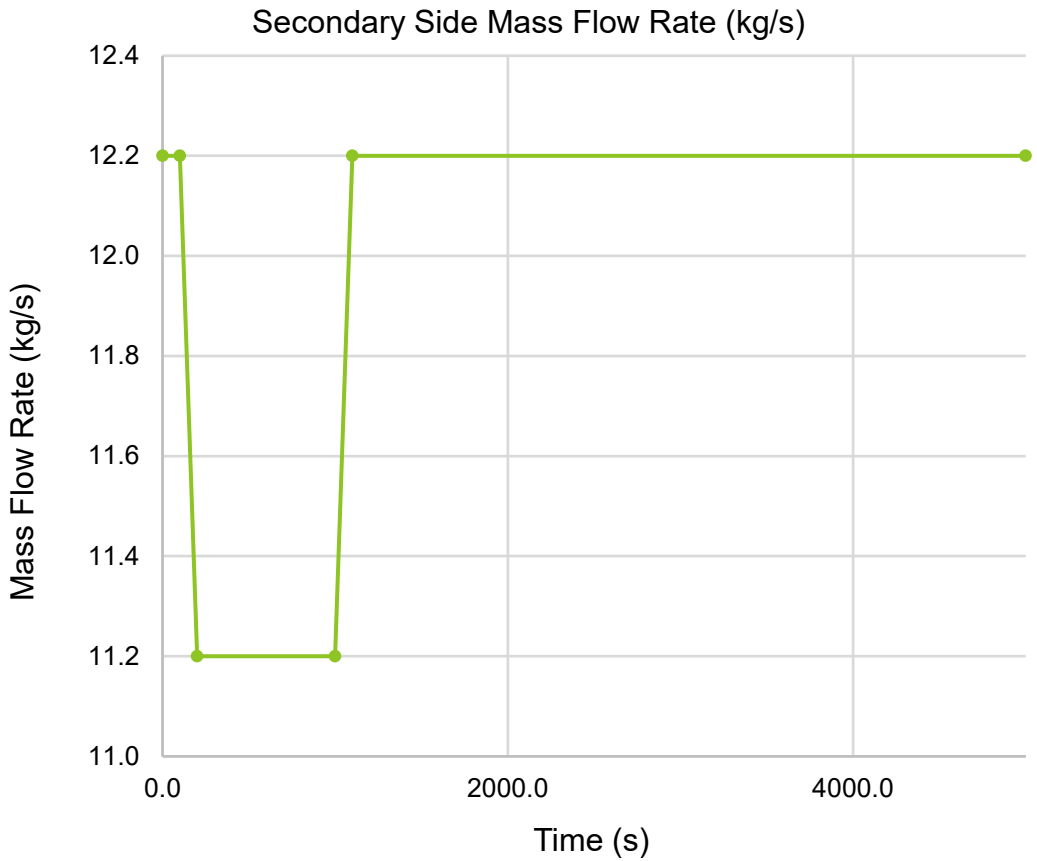
- The "prizer" component needs to know which junction belongs to the surge line (junction 120000000) and which one belongs to the spray line (junction 190010000).
- The rest of the parameters are needed to control the mixing of the droplets and the droplets size, default parameters will be used.

Existing components modifications

```
************************************************************************
* Time dependent junction (#205) - 2nd side Flow B.C.
*                    Name          Type
2050000            tdj205        tmdpjun
* Geometry          From          To          Area
2050101            200010000     210000000   0
* Data control      Option        Trip no'
2050200            1             510
* Data              Time          Liq. Vel.   Vap. Vel.  Interface vel.
2050201            -1.0          12.2        0.0        0.0
2050202            0.0           12.2        0.0        0.0
2050203            100.0         12.2        0.0        0.0
2050204            200.0         11.2        0.0        0.0
2050205            1000.0        11.2        0.0        0.0
2050206            1100.0        12.2        0.0        0.0
2050207            1.0E+06       12.2        0.0        0.0
*
************************************************************************
```

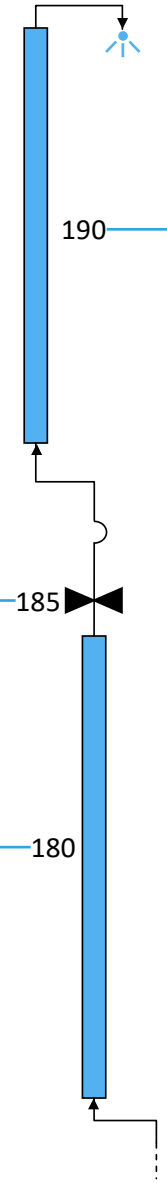
Set up the secondary-side time-dependent junction (tdj205) for the secondary-side upset:

1. The mass flow rate will decrease by 1 kg/s over 100s, starting at 100.0s.
2. The mass flow rate will return to its original value over 100s starting at 1000.0s.



Spray Line

```
**********************************************************************
* Volume component (#180) - Lower part of the spray line
*                    Name            Type
1800000            vol180          snglvol
*                    Area          Length          Volume       Hor. Ang.       Ver. Ang.
1800101            3.14E-04             6.0             0.0             0.0            90.0
*                    Elev.       Wall rough              Dh          tlpvbfe
1800102                6.0        5.00E-05             0.0          0000000
*                     ebt            Pres.            Temp.
1800200               003         1.55E+07           552.6
**********************************************************************
* Valve component (#185) - Spray valve
*                    Name            Type
1850000            vlv185           valve
* Geometry          From              To            Area              AF              AR
*                  Cont'd        jefvcahs
1850101         180010000        190000000        3.14E-04             9.0             9.0
+               00000100
* Init. Co         Option         Liq. Vel.        Vap. Vel.       Intf.Vel
1850201                1             0.0              0.0             0.0
*                 VLV Type
1850300            srvvlv
*               CntrlVar No'
1850301               73
**********************************************************************
```

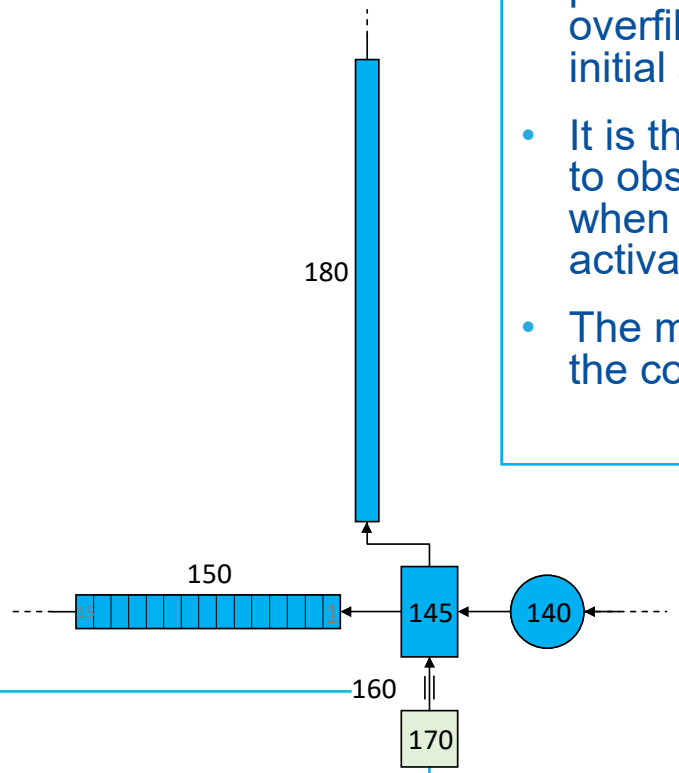


- A 2 cm diameter pipe is modeled with 2 volumes, covering a total length of 6.9431817 meters.
- This length corresponds to the height from the pump follower (BRANCH145) to the top of the 10th volume of the pressurizer (PIPE121).
- Servo valve used to simulate the spray valve opening and closing based on the signal from control variable 73

```
**********************************************************************
* Branch component (#190) - Upper part of the spray line
*                    Name            Type
1900000            brch190          branch
*                  Junc. No'           icc
1900001                1             1
*                    Area          Length          Volume       Hor. Ang.       Ver. Ang.
1900101            3.14E-04       0.9431817             0.0             0.0            90.0
*                    Elev.            Wall         roughDh          tlpvbfe
1900102          0.9431817        5.0E-05             0.0          0000000
*                     ebt            Pres.            Temp.
1900200               003         1.55E+07           552.6
*                    From              To            Area
1901101         190010000        121010000             0.0
*                      AF              AR        jefvcahs
1901102               0.0             0.0        00000100
* Init. Co       Liq. Mfl.       Vap. Mfl.       Intf.Vel
1901201           28.442             0.0             0.0
*
**********************************************************************
```

Makeup Tank and Pump

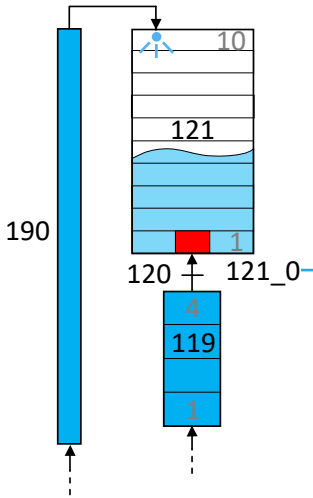
```
*******************************************************************************
* Time dependent junction (#160) - Makeup pump
*                    Name          Type
1600000             tdj160        tmdpjun
* Geometry           From          To            Area
1600101             170000000     145000000     0.04
* Data control       Option        Trip no'      CntrlV Nm     CntrlV no'
1600200             0             0             cntrlvar      83
*
* Data               Time          Liq. Vel.     Vap. Vel.     Interface vel.
1600201             -10.0         -10.0         0.0           0.0
1600202             10.0          10.0          0.0           0.0
*
*******************************************************************************
* Time dependent volume (#170) - Makeup tank
*                    Name          Type
1700000             tdv170        tmdpvol
* Geometry           Area          Length        Volume        Hor. Ang.     Ver. Ang.
* cont'd             Elev. Chg.    Wall rough.   Hydro. D.     tlpvbfe
1700101             10.0          1.0           0.0           0.0           90.0
1700102             1.0           0.0           0.0           0
* Data control       ebt           Trip no'
1700200             3             0
* Data               Time          Pres.         Temp.
1700201             0             1.55E+07      552.6
*
*******************************************************************************
```



- The time-dependent junction (TDJ160) adds or removes cold water from the TDV170 at 552.6 K into the pump follower volume (BRANCH145).
- This system is initially used to prevent the pressurizer from overfilling or drying out during the initial stabilization period.
- It is then deactivated after 1000s to observe how the level changes when the spray or the heater is activated.
- The mass flow rate is controlled by the control variable 83

Pressurizer Heaters

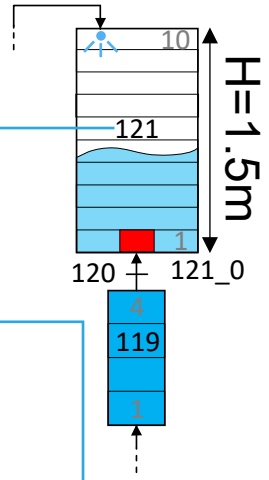
- The heater in the pressurizer is simulated using the heat structure HS121_0
- HS121_0 represent 20 metallic rods with 5cm radius
- HS121_0 is coupled on the right side with the volume 1 of the pressurizer (PIPE121)
- The power source is controlled by the control variable 76




```
**********************************************************************
* Pressurizer proportional heater (HS #121_0)
*                Axial vols     Radial vols          Type      S-S init.     Left coor.
11210000                1               5             2               0            0.0
* HS mesh          Location          Format
11210100                0               1
                 No' interv     Right coor.
11210101                4            0.05
* HS mater        Mat. No'     No' interval
11210201                1               4
* HS heat          Source     No' interval
11210301               1.0               4
* Init. Te         Option
11210400                0
* Init. Te          Temp.     Radial vols.
11210401            552.6               5
* Left        B-Cdefinition     Increment      HT type     Area type     Area data
* Cont'd           HS No'
11210501                0               0             0             1           3.0
+                       1
* Right       B-Cdefinition     Increment      HT type     Area type     Area data
* Cont'd           HS No'
11210601        121010000               0             1             1           3.0
+                       1
* Heat src      Source typ     Source coe     Left mod.    Right mod.       HS No'
11210701             10076             1.0           0.0           0.0             1
*                Hydro. D.     For. Lengt    Rev. Lengt     For. Grid  Rev. Grid L.
* Cont'd          For. Grid     Rev. Grid     Loc. Boili       HS No'
11210901               0.0             1.0           1.0           0.0           0.0
+                      0.0             0.0           1.0             1
*
**********************************************************************
```

Makeup Tank and Pump controllers

```
**************************************************************************
* Pressurizer level error (setpoint 0.75m out of 1.5m)
20500800          lvlset          sum          -1.0          0.0          0
20500801           -0.75          1.0        przlvl           121
*
* Presurizer makeup pump mass flow rate (min -10.0 m/s, Max 10.0 m/s)
20500810          lvlprint        prop-int     1.0           0.0          0
+                    3            -10.0        10.0
20500811          1.0E-01         5.0E-05      cntrlvar      80
*
* Presurizer makeup pump switch
20500820          mmswitch        tripunit     1.0           1.0          0
20500821           507
*
* Presurizer makeup pump mass flow rate
20500830          pzrpres         mult         1.0           0..0         0
20500831          cntrlvar        81
20500832          cntrlvar        82
*
**************************************************************************
```



$$L_f(t) = \int_0^H \alpha_f(t)dh \approx \sum_{n=1}^{10} 0.15 \cdot \alpha_f^n(t)$$

α_f = volume liquid fraction

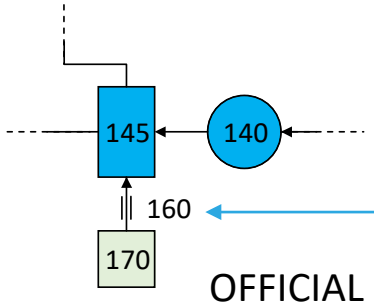
H = pressurizer height

$$err(t) = L_f(t) - 0.75$$

$$s(t) = 1.0e{-}1 \cdot err(t) + 5.0e{-}5 \cdot \int_0^t err(t)\,dt$$

$$[-10.0 < s(t) < 10.0]$$

$$mfr(t) = s(t) \cdot TRIP507(t)$$



Spray line controllers

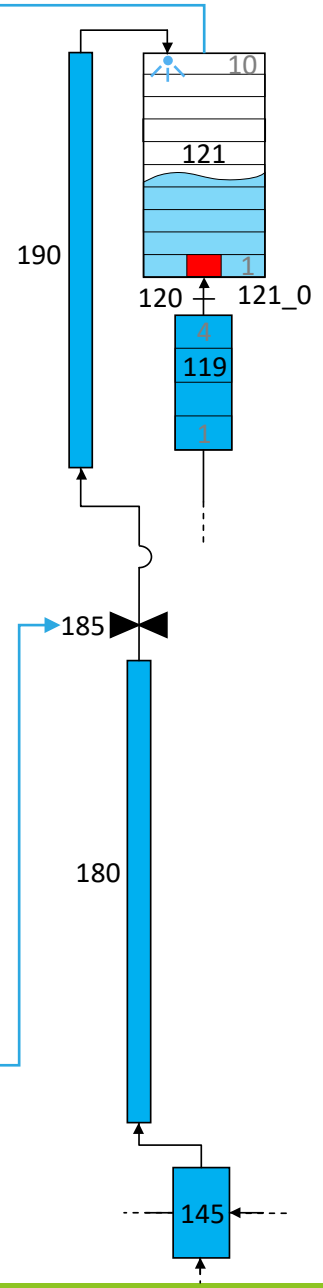
```
*******************************************************************
* Pressurizer pressure error
20500700          prsset          sum          1.0          0.0          0
20500701       -1.55E+07            p    121100000
*
* Pressurizer spray line valve norm area (min 0.0, Max 1.0)
20500710        prsprint      prop-int         -1.0          0.0          0
+                      3           0.0          1.0
20500711       1.0E-06       1.0E-13       cntrlvar           70
*
* Pressurizer spray line switch
20500720       mmswitch      tripunit          1.0          1.0          0
20500721            508
*
* Pressurizer spray line valve norm area
20500730         pzrpres          mult          1.0          0.0          0
20500731         cntrlvar            71
20500732         cntrlvar            73
*
*******************************************************************
```

$$err(t) = P(t) - 15.5e{+}07$$

$$s(t) = 1.0e{-}6 \cdot err(t) + 5.0e{-}13 \cdot \int_0^t err(t)\, dt$$

$$[0.0 < s(t) < 1.0]$$

$$area(t) = s(t) \cdot TRIP508(t)$$



Pressurizer heaters controllers

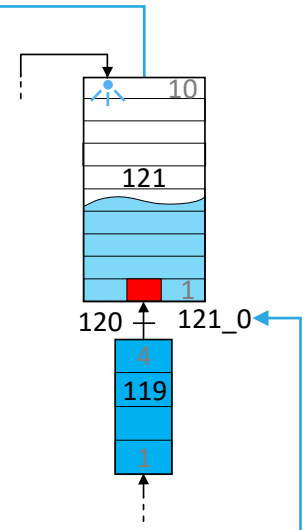
```
**************************************************************************
* Pressurizer pressure error
20500700          prsset          sum          1.0          0.0          0
20500701       -1.55E+07          1.0            p    121100000
*
* Pressurizer power (min 0.0 W, Max 2.0kW)
20500710          prsprint        prop-int     1.0          0.0          0
+                 3               0.0          2000.0
20500711          1.0E-02         5.0E-12      cntrlvar     70
*
* Pressurizer heater switch
20500720          mmswitch        tripunit     1.0          1.0          0
20500721          509
*
* Pressurizer heat
20500730          pzrpres         mult         1.0          0.0          0
20500731          cntrlvar        74
20500732          cntrlvar        75
*
**************************************************************************
```

$$err(t) = P(t) - 15.5e{+}07$$

$$s(t) = 1.0e{-}2 \cdot err(t) + 5.0e{-}12 \cdot \int_0^t err(t)\, dt$$

$$[0.0 < s(t) < 2.0e + 03]$$

$$area(t) = s(t) \cdot TRIP509(t)$$



Steady state simulations suggested comparison plot list

Variable Name	Variable Number	Description
p	121100000	Pressure at the top of the pressurizer (Pa)
tempf	115010000	Main loop temperature at the surge line connection (K)
pmpvel	140	Pump velocity (rad/s)
mflowfj	145010000	Main loop liquid mass flow rate (kg/s)

Transient Simulations with ACTIVE controllers

```
**********************************************************************
*                TRIP INPUT
**********************************************************************
*                        Var.        Param.        Rela.        Var.        Pram.
* Cont'd                 Cosnst.      Latch       Timeof
505                        time           0           gt        null           0
+                      1.00E+06           n         -1.0                       *  Pump motor trip (False = Electricity to the Motor, True = Motor OFF)
506                        time           0           gt        null           0
+                      1.00E+06           n         -1.0                       *  Control the power table (False = Steady State, True = SCRAM)
507                        time           0           lt        null           0
+                           0.0           n         -1.0                       *  Makeup volume (True = ON, False = OFF)
508                        time           0           lt        null           0
+                      1.00E+06           n          0.0                       *  Pressurizer spray (True = ON, False = OFF)
509                        time           0           lt        null           0
+                      1.00E+06           n          0.0                       *  Pressurizer heater (True = ON, False = OFF)
510                        time           0           gt        null           0
+                           0.0           n          0.0                       *  Control the Secondary side MFR (False = Steady State, True = MFR change)
*
**********************************************************************
```

Start the transient on the secondary side at time 0.0s

Turn OFF the makeup volume at time 0.0s, not needed for the transient.

Transient Simulations with controller DISABLED

```
*************************************************************************
*                TRIP INPUT
*************************************************************************
*                        Var.        Param.       Rela.        Var.        Pram.
* Cont'd                 Cosnst.      Latch       Timeof
505                      time          0           gt          null          0
+                      1.00E+06        n          -1.0                       *  Pump motor trip (False = Electricity to the Motor, True = Motor OFF)
506                      time          0           gt          null          0
+                      1.00E+06        n          -1.0                       *  Control the power table (False = Steady State, True = SCRAM)
507                      time          0           lt          null          0
+                        0.0           n          -1.0                       *  Makeup volume (True = ON, False = OFF)
508                      time          0           lt          null          0
+                        0.0           n          -1.0                       *  Pressurizer spray (True = ON, False = OFF)
509                      time          0           lt          null          0
+                        0.0           n          -1.0                       *  Pressurizer heater (True = ON, False = OFF)
510                      time          0           gt          null          0
+                        0.0           n          0.0                        *  Control the Secondary side MFR (False = Steady State, True = MFR change)
*
*************************************************************************
```

Turn OFF the pressurizer spray at time 0.0s

Turn OFF the pressurizer heater at time 0.0s

Transient simulations suggested comparison plot list

Variable Name	Variable Number	Description
p	121100000	Pressure at the top of the pressurizer (Pa)
przlvl	121	Pressurizer level, max 1.5m (m)
cntrlvar	73	Spray valve normalized area (//)
mflowfj	185000000	Spray valve liquid mass flow rate (kg/s)
cntrlvar	76	Power in the pressurizer heaters (W)
httemp	121000101	Heater's centerline temperature (K)
tempf	115010000	Main loop temperature at the surge line connection (K)

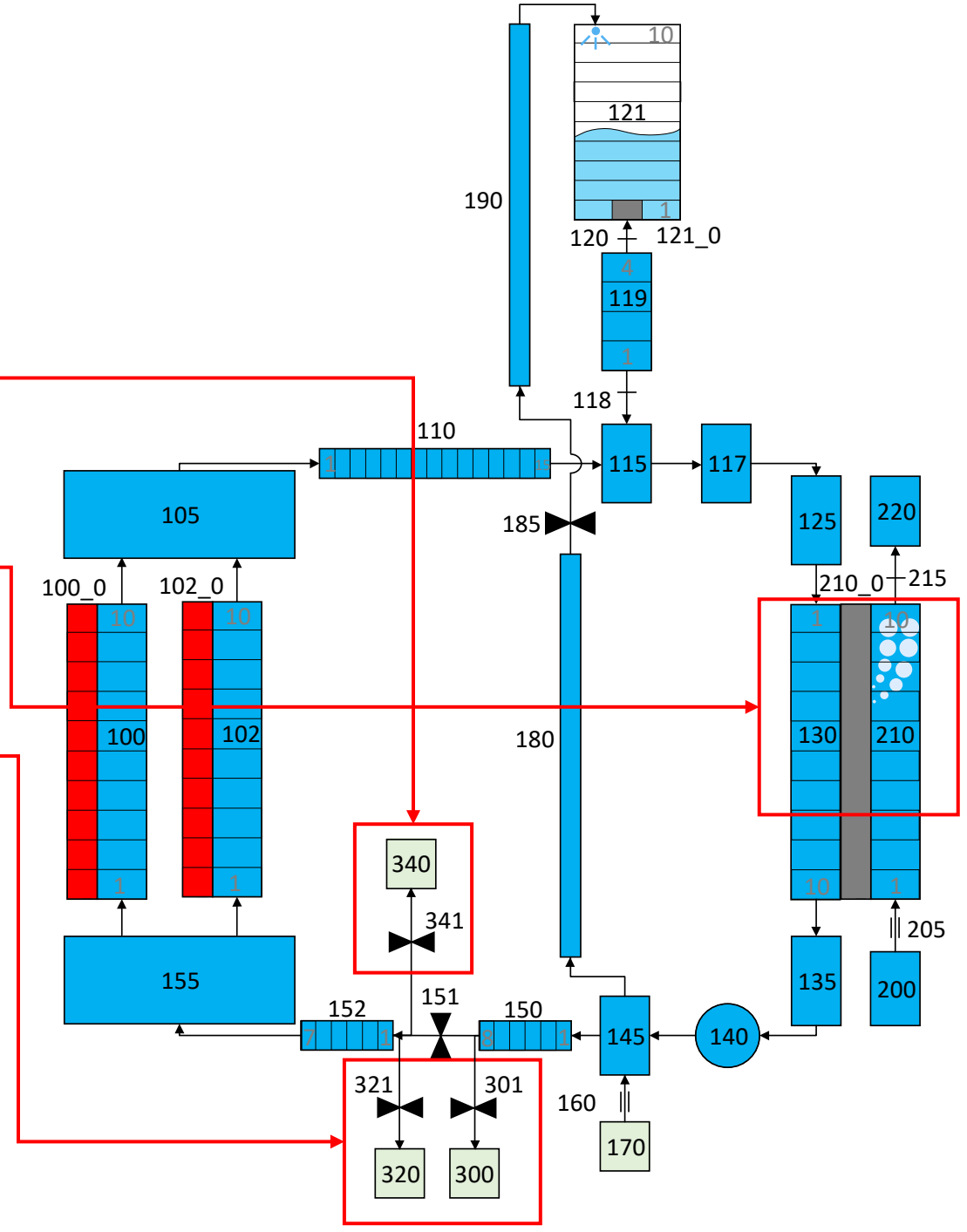
Full Model with LOCA breaks

Additional valves and time dependent volumes to simulate the breaks:

3. One trip valve with a 1cm diameter flow area and a time dependent volume are added to simulate the small break.

2. The secondary side now operates as a boiling system, with reduced pressure and mass flow rate ensuring that the fluid reaches its boiling point before exiting the secondary side.

3. Three trip valves and two time dependent volumes are added to simulate the double guillotine break.



TRIPs modifications and additions

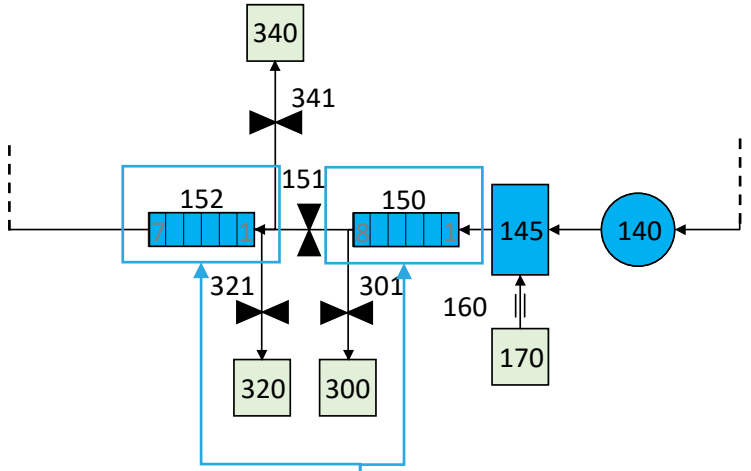
```
**************************************************************************
*       EXPANDED PLOT VARIABLES
**************************************************************************
*                    VarNam        VarNum
20800001             htpowg       1000001*   Heat structure power source
20800002             pmpmt            140*   Pump motor torque
**************************************************************************
*                TRIP INPUT
**************************************************************************
*                      Var.       Param.       Rela.        Var.       Pram.
* Cont'd             Cosnst.      Latch      Timeof
505                    time           0          gt        null          0
+                  1.00E+06           n        -1.0                       *  Pump motor trip (False = Electricity to the Motor, True = Motor OFF)
506                    time           0          gt        null          0
+                  1.00E+06           n        -1.0                       *  Control the power table (False = Steady State, True = SCRAM)
507                    time           0          lt        null          0
+                  1.00E+06           n         0.0                       *  Makeup volume (True = ON, False = OFF)
508                    time           0          lt        null          0
+                  1.00E+06           n         0.0                       *  Pressurizer spray (True = ON, False = OFF)
509                    time           0          lt        null          0
+                  1.00E+06           n         0.0                       *  Pressurizer heater (True = ON, False = OFF)
510                    time           0          gt        null          0
+                  1.00E+06           n        -1.0                       *  Control the Secondary side MFR (False = Steady State, True = MFR change)
511                    time           0          gt        null          0
+                  1.00E+06           n        -1.0                       *  Loss of flow accident, small break (True = ON, False = OFF)
512                    time           0          gt        null          0
+                  1.00E+06           n        -1.0                       *  Loss of flow accident, double guillotine break (True = ON, False = OFF)
*
**************************************************************************
*                    Trip          Op.        Trip       Latch      Timeof
605                  -505         and        -505           n         0.0*  Pump regulation trip, True when Pump motor trip 505 is False
612                  -512         and        -512           n         0.0*  Loss of flow accident, double guillotine break
**************************************************************************
```

Add the expanded plot variables to plot the pump motor torque and the power in the heaters.

Include TRIPs to open and close the trip valves to simulate the two different LOCA.

Existing components modifications

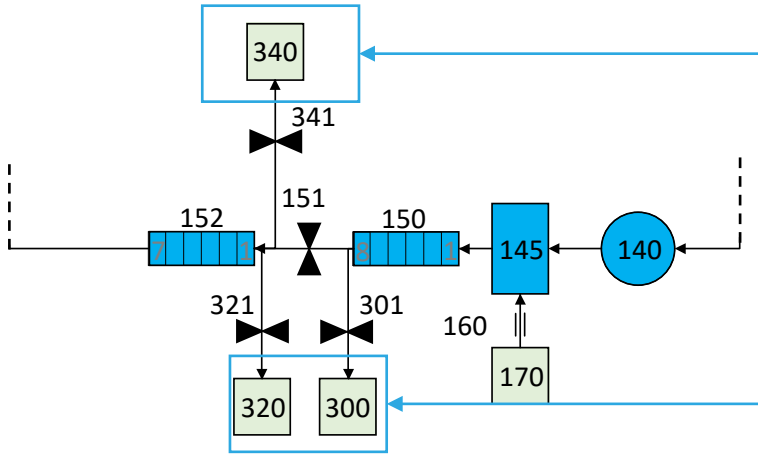
```
*************************************************************************
* Pipe component (#150)
*                          Name          Type
1500000                  pipe150          pipe
* Geometry              No' vols.
1500001                        8
* Geometry                  Area       Vol. No'
1500101                5.858E-03              8
* Geometry                Length       Vol. No'
1500301                   0.667               8
* Geometry               Ver. Ang.       Vol. No'
1500601                     0.0               8
* Geometry               Elevation       Vol. No'
1500701                     0.0               8
* Geometry              Wall rough      Hydro. D.       Vol. No'
1500801                5.00E-05           0.086              8
* Init. Co                    ebt           Pres.          Temp.          Null          Null
* Cont'd Null Vol. No'
1501201                     003        1.55E+07          552.6           0.0           0.0
+                           0.0               8
* Jct. con                Option
1501300                      1
* Jct. dat             Liq. Mfl.      Vap. Mfl.      Int.face V       Jct. No'
1501301                 28.442             0.0             0.0              7
*
*************************************************************************
```



- Reduce the number of volumes from 15 to 8 and the number of junctions from 14 to 7. The rest of the options are unchanged.
- To model the rest of the cold leg a new component with number 152 instead of 150 and 7 volumes instead of 8 and 6 junctions instead of 7 will be added to the model.

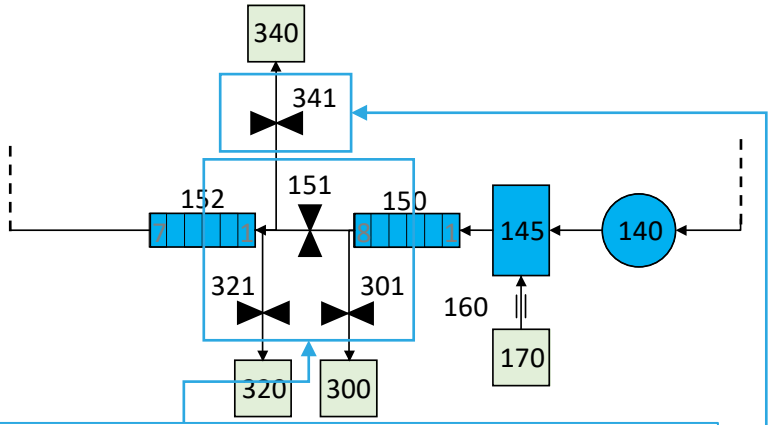
Time dependent volumes to simulate the containement

```
**************************************************************************
* Time dependent volume (#300)
*                      Name          Type
3000000              tdv300        tmdpvol
* Geometry             Area        Length        Volume     Hor. Ang.     Ver. Ang.
* cont'd           Elev. Chg.   Wall rough.    Hydro. D.     tlpvbfe
3000101                10.0           1.0           0.0           0.0          90.0
3000102                 1.0           0.0           0.0             0
* Data control          ebt        Trip no'                                  H516
3000200                   2           512
* Data                 Time          Pres.         Quals.
3000201                -1.0   1.01325E+05           1.0
3000202                 0.0   1.01325E+05           1.0
3000203                 2.0   2.01325E+05           1.0
3000204                 4.0   3.01325E+05           1.0
*
**************************************************************************
* Time dependent volume (#340)
*                      Name          Type
4300000              tdv340        tmdpvol
* Geometry             Area        Length        Volume     Hor. Ang.     Ver. Ang.
* cont'd           Elev. Chg.   Wall rough.    Hydro. D.     tlpvbfe
3400101                10.0           1.0           0.0           0.0          90.0
3400102                 1.0           0.0           0.0             0
* Data control          ebt        Trip no'
3400200                   3             0
* Data                 Time          Pres.         Quals.
3400201                -1.0   1.01325E+05           1.0
3400202                 0.0   1.01325E+05           1.0
3400203             1.00E+06  1.01325E+05           1.0
*
**************************************************************************
```



- Two time dependent volumes to simulate the containment pressurization during double guillotine break LOCA.
- Time dependent volume at atmospheric pressure to simulate small break LOCA.

Valves that open to simulate the breaks




```
**************************************************************************
* Valve component (#151)
*                      Name          Type
1510000              vlv151         valve
* Geometry            From          To          Area          AF          AR
*                     Cont'd        jefvcahs
1510101         150010000          152000000   5.86E-03      1.0         1.0
+                    00000100
* Init. Co           Option        Liq. Vel.   Vap. Vel.     Intf.Vel
1510201                 1          28.442        0.0           0.0
*                    VLV Type
1510300             trpvlv
*                    Trip No'
1510301               612
**************************************************************************
```

```
**************************************************************************
* Valve component (#301)
*                      Name          Type
3010000              vlv301         valve
* Geometry            From          To          Area          AF          AR
*                     Cont'd        jefvcahs
3010101         150010000          300000000   5.86E-03      1.0         1.0
+                    00000100
* Init. Co           Option        Liq. Vel.   Vap. Vel.     Intf.Vel
3010201                 1          0.0           0.0           0.0
*                    VLV Type
3010300             trpvlv
*                    Trip No'
3010301               512
**************************************************************************
```

- Three trip valves to simulate the double guillotine break. Two opens thanks to when TRIP 512 is True and one close following the complement TRIP 612
- One trip valve to simulate the small break LOCA that open when TRIP 511 is True.

```
**************************************************************************
* Valve component (#341)
*                      Name          Type
3410000              vlv301         valve
* Geometry            From          To          Area          AF          AR
*                     Cont'd        jefvcahs
3410101         152000000          340000000   5.86E-03      1.0         1.0
+                    00000100
* Init. Co           Option        Liq. Vel.   Vap. Vel.     Intf.Vel
3410201                 1          0.0           0.0           0.0
*                    VLV Type
3410300             trpvlv
*                    Trip No'
3410301               511
**************************************************************************
```

Steady state simulation suggested plot list

Variable Name	Variable Number	Description
p	121100000	Pressure at the top of the pressurizer (Pa)
tempf	115010000	Main loop temperature at the surge line connection (K)
pmpvel	140	Pump velocity (rad/s)
mflowfj	145010000	Main loop liquid mass flow rate (kg/s)
voidg	210100000	Secondary Side outlet Void fraction (//)
przlvl	121	Pressurizer level, max 1.5m (m)

Small break LOCA transient simulation

```
**********************************************************************
*                TRIP INPUT
**********************************************************************
*                          Var.      Param.      Rela.       Var.      Pram.
* Cont'd                  Cosnst.     Latch     Timeof
505                         time         0         gt       null         0
+                       1.00E+01         n       -1.0                    *  Pump motor trip (False = Electricity to the Motor, True = Motor OFF)
506                         time         0         gt       null         0
+                       1.00E+01         n       -1.0                    *  Control the power table (False = Steady State, True = SCRAM)
507                         time         0         lt       null         0
+                             0.0        n        0.0                    *  Makeup volume (True = ON, False = OFF)
508                         time         0         lt       null         0
+                             0.0        n        0.0                    *  Pressurizer spray (True = ON, False = OFF)
509                         time         0         lt       null         0
+                             0.0        n        0.0                    *  Pressurizer heater (True = ON, False = OFF)
510                         time         0         gt       null         0
+                       1.00E+06         n       -1.0                    *  Control the Secondary side MFR (False = Steady State, True = MFR change)
511                         time         0         gt       null         0
+                       1.00E+01         n       -1.0                    *  Loss of flow accident, small break (True = ON, False = OFF)
512                         time         0         gt       null         0
+                       1.00E+06         n       -1.0                    *  Loss of flow accident, double guillotine break (True = ON, False = OFF)
*
**********************************************************************
*                          Trip        Op.       Trip      Latch     Timeof
605                        -505       and       -505          n        0.0*  Pump regulation trip, True when Pump motor trip 505 is False
612                        -512       and       -512          n        0.0*  Loss of flow accident, double guillotine break
**********************************************************************
```

Shut down the pump motor and SCRAM the power after 10s

Turn off the pressurizer pressure and level control system

Open the valves to simulate the small break LOCA after 10s.

Large break LOCA transient simulation

```
**********************************************************************
*                TRIP INPUT
**********************************************************************
*                          Var.      Param.      Rela.       Var.      Pram.
* Cont'd                  Cosnst.     Latch     Timeof
505                         time         0         gt       null         0
+                       1.00E+01         n       -1.0                    *  Pump motor trip (False = Electricity to the Motor, True = Motor OFF)
506                         time         0         gt       null         0
+                       1.00E+01         n       -1.0                    *  Control the power table (False = Steady State, True = SCRAM)
507                         time         0         lt       null         0
+                            0.0         n        0.0                    *  Makeup volume (True = ON, False = OFF)
508                         time         0         lt       null         0
+                            0.0         n        0.0                    *  Pressurizer spray (True = ON, False = OFF)
509                         time         0         lt       null         0
+                            0.0         n        0.0                    *  Pressurizer heater (True = ON, False = OFF)
510                         time         0         gt       null         0
+                       1.00E+06         n       -1.0                    *  Control the Secondary side MFR (False = Steady State, True = MFR change)
511                         time         0         gt       null         0
+                       1.00E+06         n       -1.0                    *  Loss of flow accident, small break (True = ON, False = OFF)
512                         time         0         gt       null         0
+                       1.00E+01         n       -1.0                    *  Loss of flow accident, double guillotine break (True = ON, False = OFF)
*
**********************************************************************
*                          Trip        Op.       Trip      Latch     Timeof
605                        -505       and       -505          n        0.0*  Pump regulation trip, True when Pump motor trip 505 is False
612                        -512       and       -512          n        0.0*  Loss of flow accident, double guillotine break
**********************************************************************
```

Shut down the pump motor and SCRAM the power after 10s

Turn off the pressurizer pressure and level control system

Open the valves to simulate the large break LOCA after 10s

Transient simulations suggested comparison plot list

Variable Name	Variable Number	Description
p	121100000	Pressure at the top of the pressurizer (Pa)
tempf	115010000	Main loop temperature at the surge line connection (K)
voidg	210100000	Secondary Side outlet Void fraction (//)
pmpmt	140	Pump motor torque (N/m)
htpowg	1000001	Power on the heating rods (W)
mflowj	151000000	Primary loop mass flow rate (kg/s)
mflowj	301000000	Large break right side mass flow rate (kg/s)
mflowj	321000000	Large break left side mass flow rate (kg/s)
mflowj	341000000	Small break mass flow rate (kg/s)
vlvarea	151	Primary loop valve normalized area (//)
vlvarea	301	Large break right side valve normalized area (//)
vlvarea	321	Large break left side valve normalized area (//)
vlvarea	341	Small break valve normalized area (//)
cntrlvar	73	Spray valve normalized area (//)
cntrlvar	76	Power in the pressurizer heaters (W)
przlvl	121	Pressurizer level, max 1.5m (m)

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