Development of an input deck for Fukushima accident

Tools and lessons learned

Marco Sangiorgi - ENEA

EMUG 2012 – hosted by GRS
KOELN 16/17 April 2012

FUKUSHIMA PLANT DATA

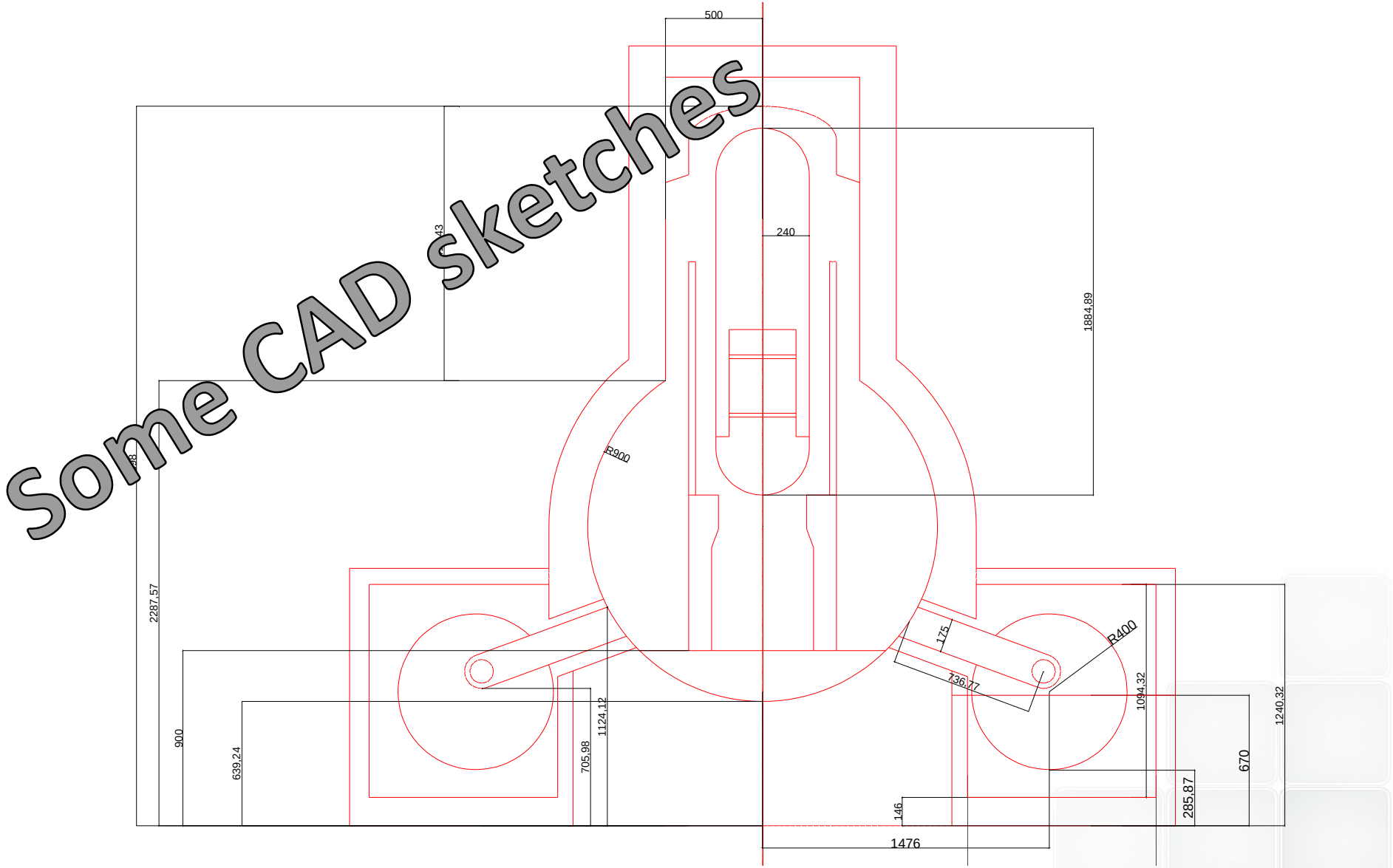
- Three different units belonging to the same *family*
- Not much available information and quite scattered

Unit	Type	Containment	Start construction	First criticality	Commercial operation	Electric power	Reactor supplier	Architecture	Construction	Fuel
Fukushima I – 1	BWR-3	Mark I	July 25, 1967	October 10, 1970	March 26, 1971	460 MW	General Electric	Ebasco	Kajima	LEU
Fukushima I – 2	BWR-4	Mark I	June 9, 1969	May 10, 1973	July 18, 1974	784 MW	General Electric	Ebasco	Kajima	LEU
Fukushima I – 3	BWR-4	Mark I	December 28, 1970	September 6, 1974	March 27, 1976	784 MW	Toshiba	Toshiba	Kajima	LEU/MOX

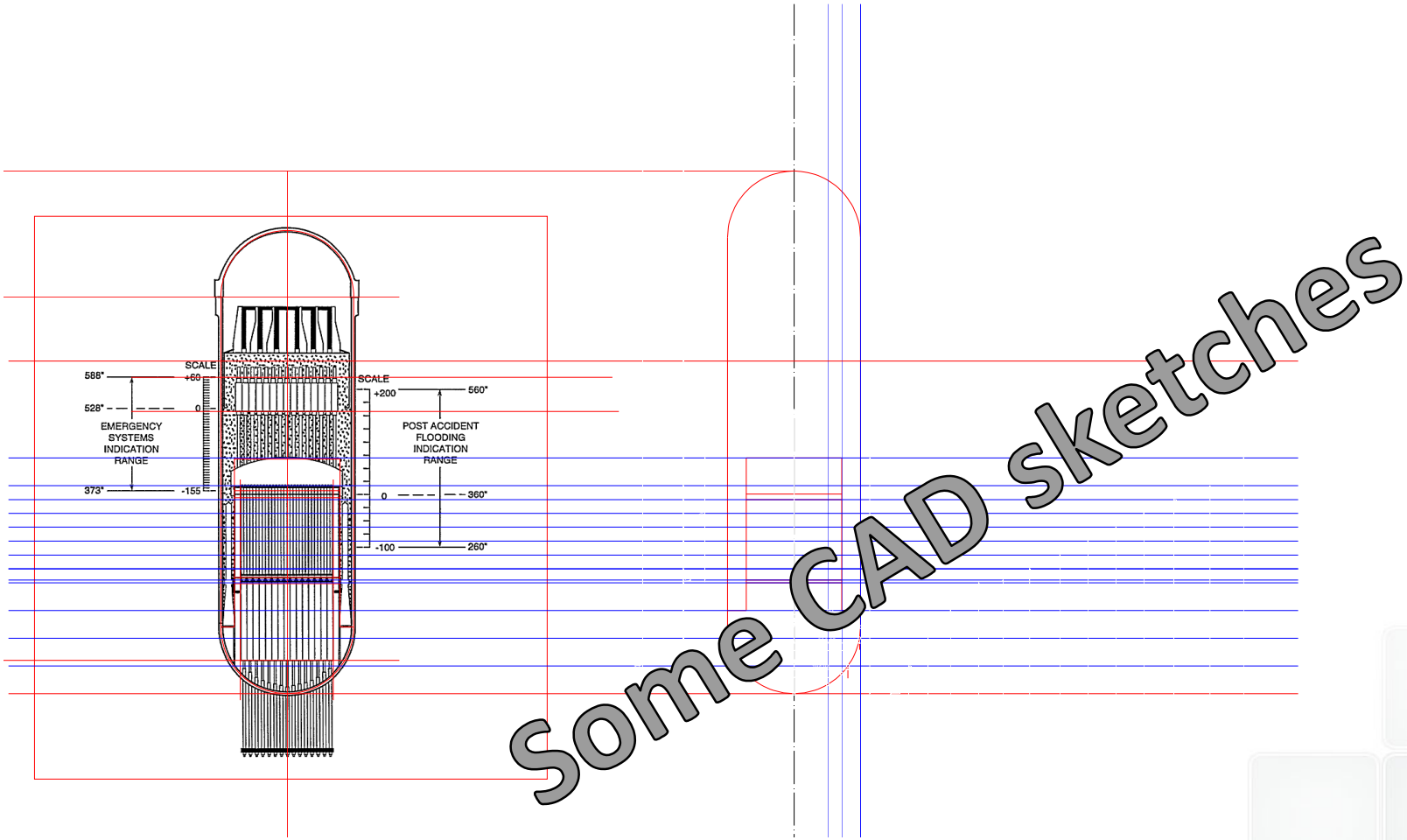
FUKUSHIMA PLANT DATA

- Started collecting free data on the web, open literature, similar plants…
- Created a folder with useful data for creating a MELCOR input deck
- Draw some sketch in CAD
- Created a Dropbox folder that can be shared on request

FUKUSHIMA PLANT DATA



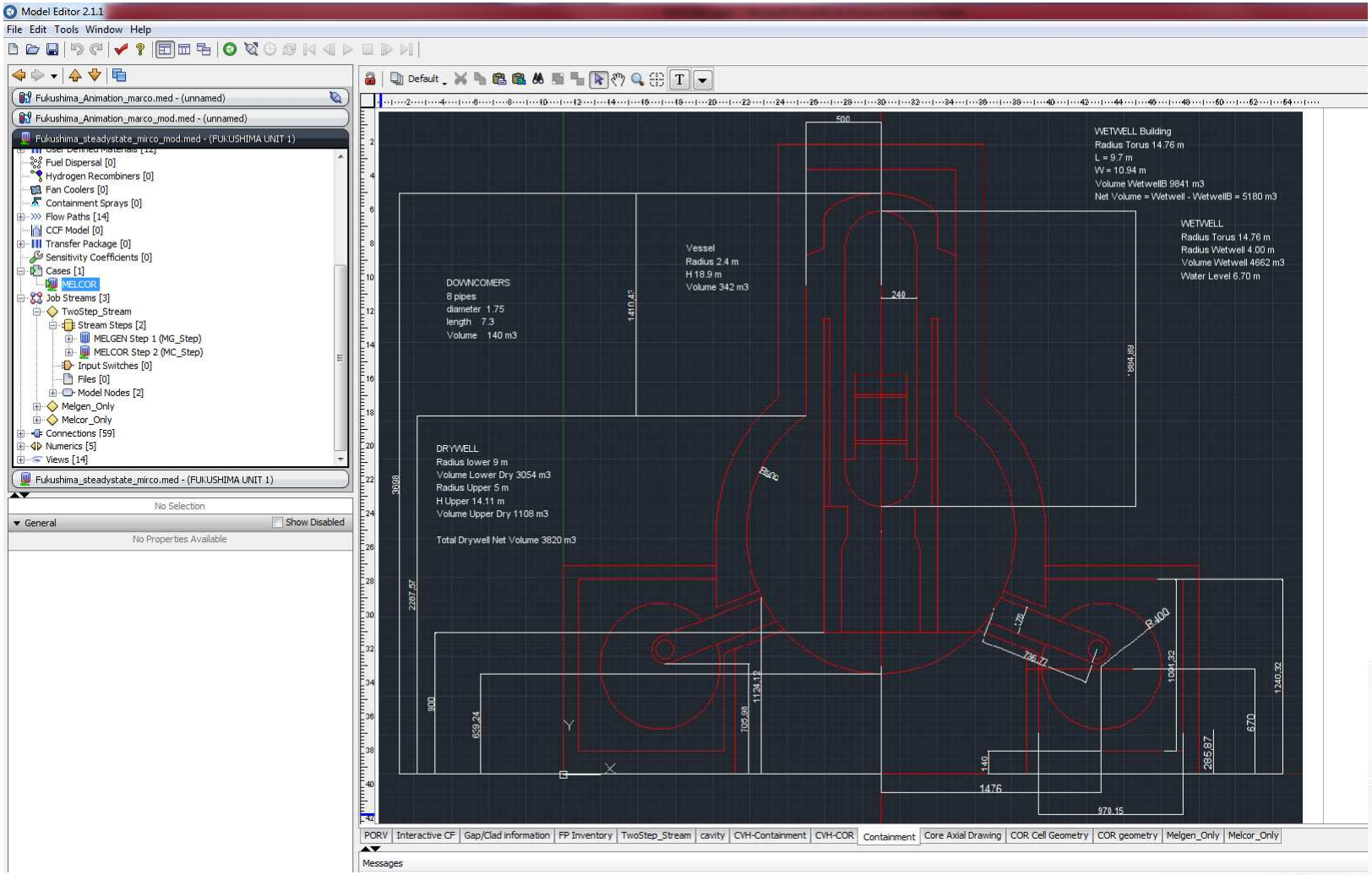
FUKUSHIMA PLANT DATA



Some CAD sketches

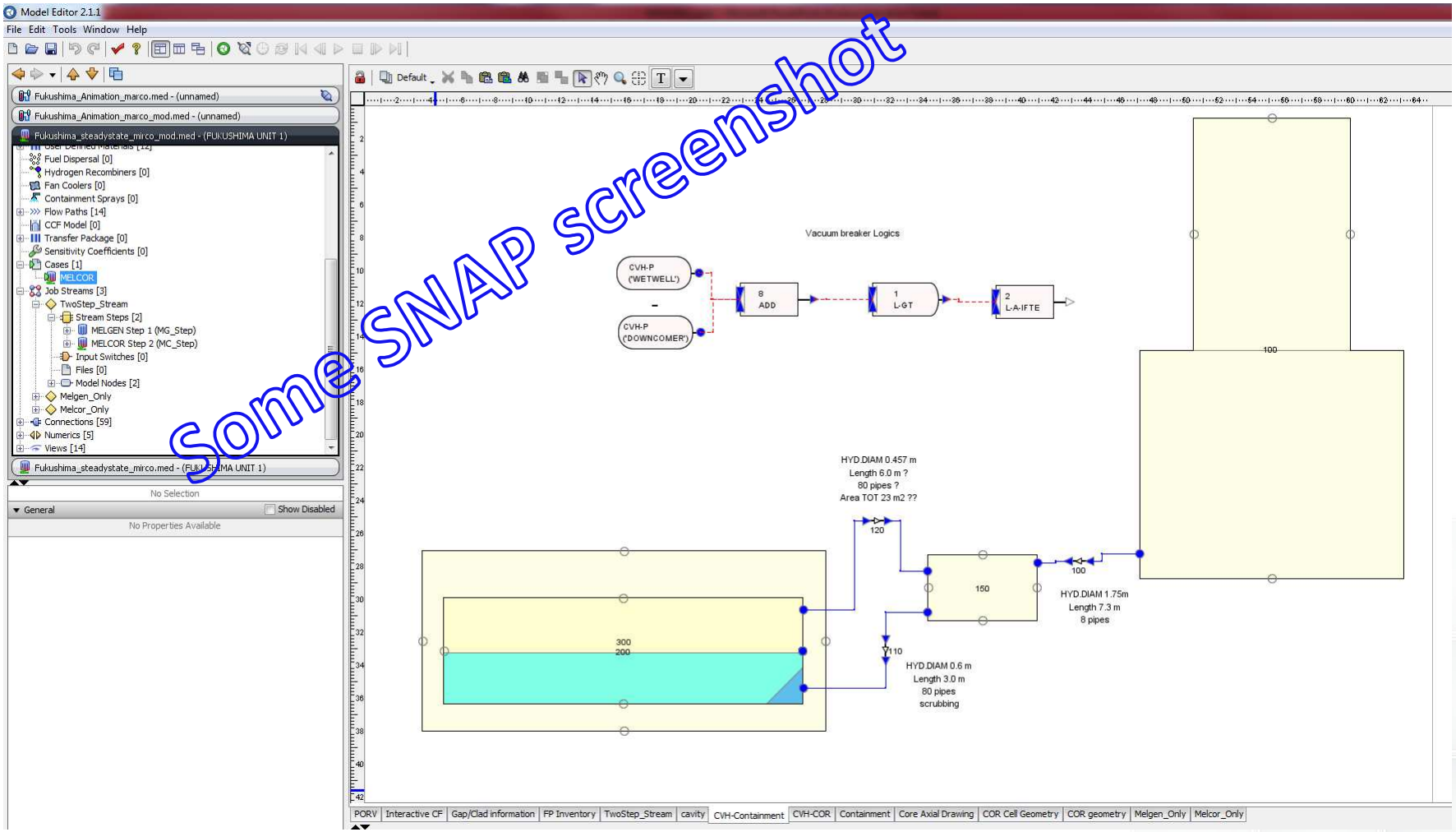
FUKUSHIMA PLANT DATA

Decided to use SNAP to create the input deck in order to better explain the nodalization



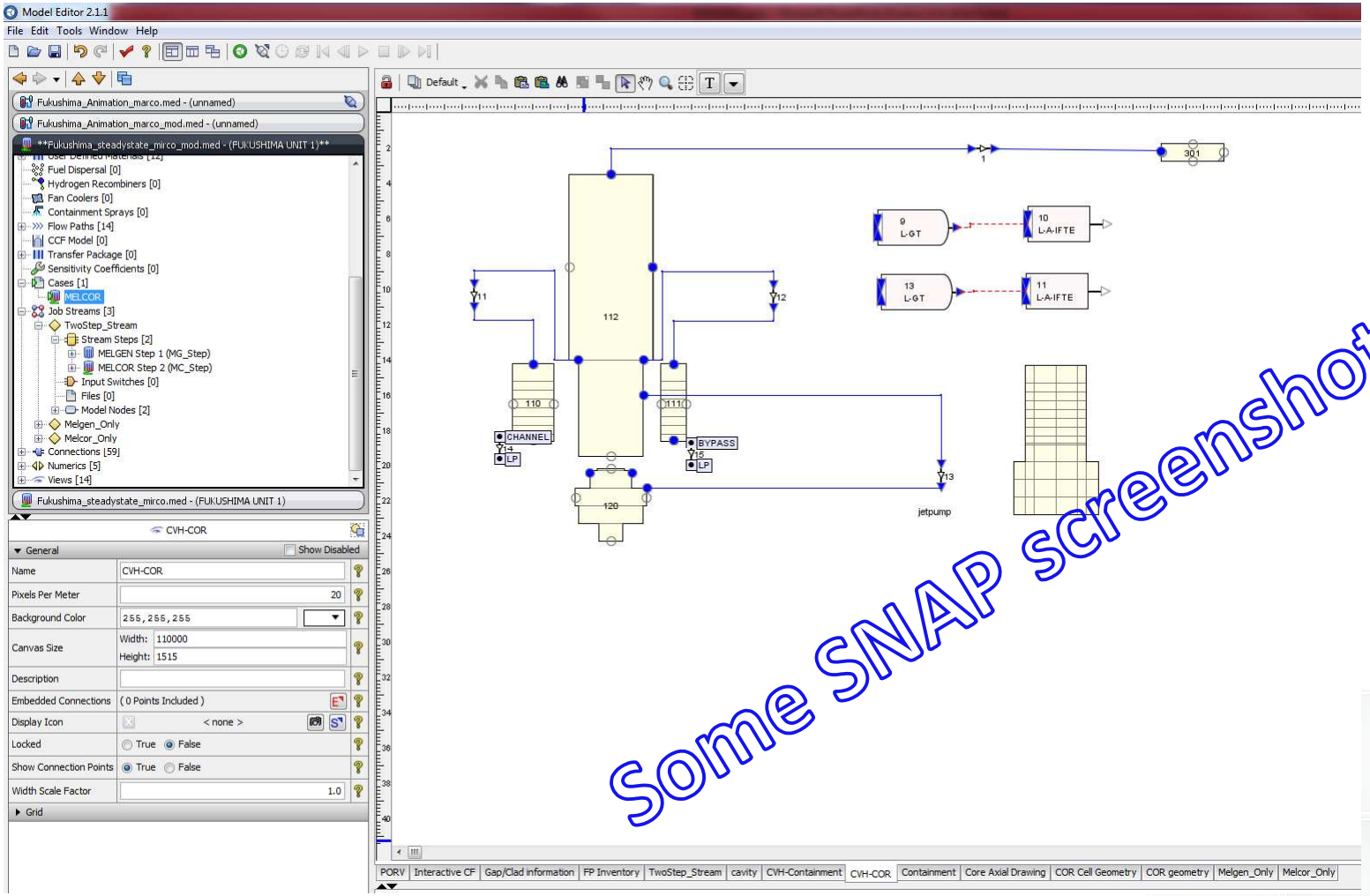
FUKUSHIMA PLANT DATA

Decided to use SNAP to create the input deck in order to better explain the nodalization



FUKUSHIMA PLANT DATA

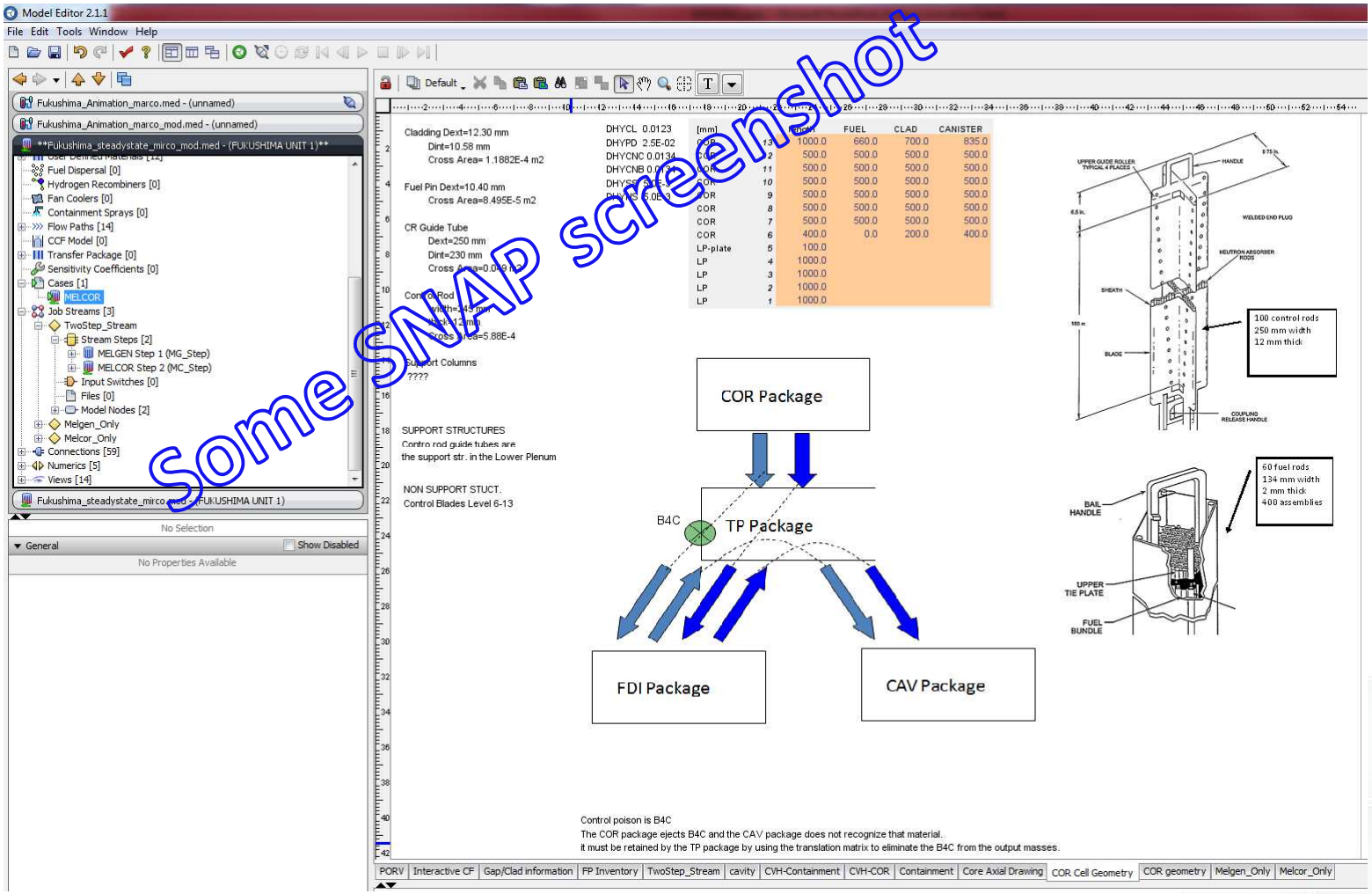
Decided to use SNAP to create the input deck in order to better explain the nodalization



Some SNAP screenshot

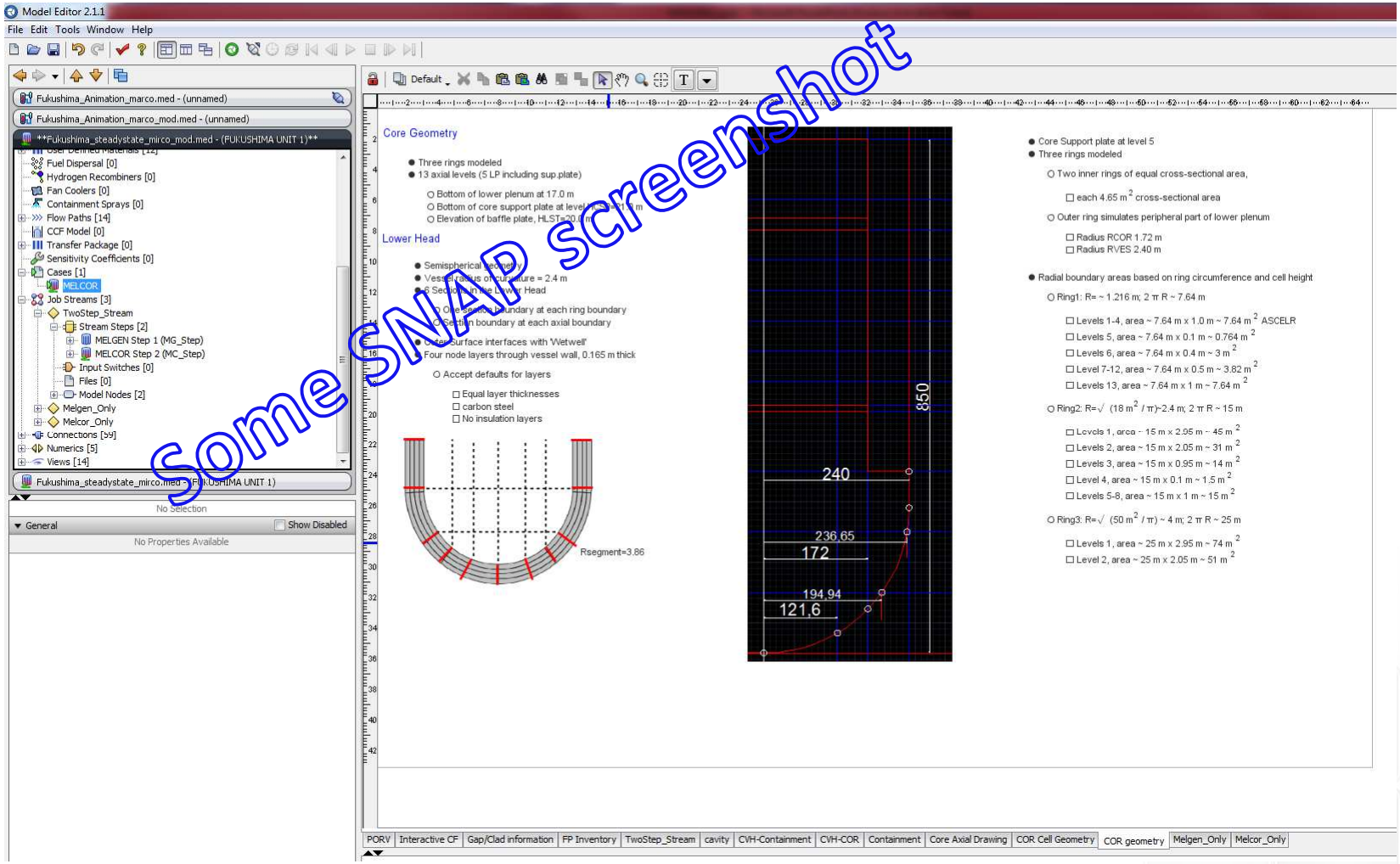
FUKUSHIMA PLANT DATA

Decided to use SNAP to create the input deck in order to better explain the nodalization



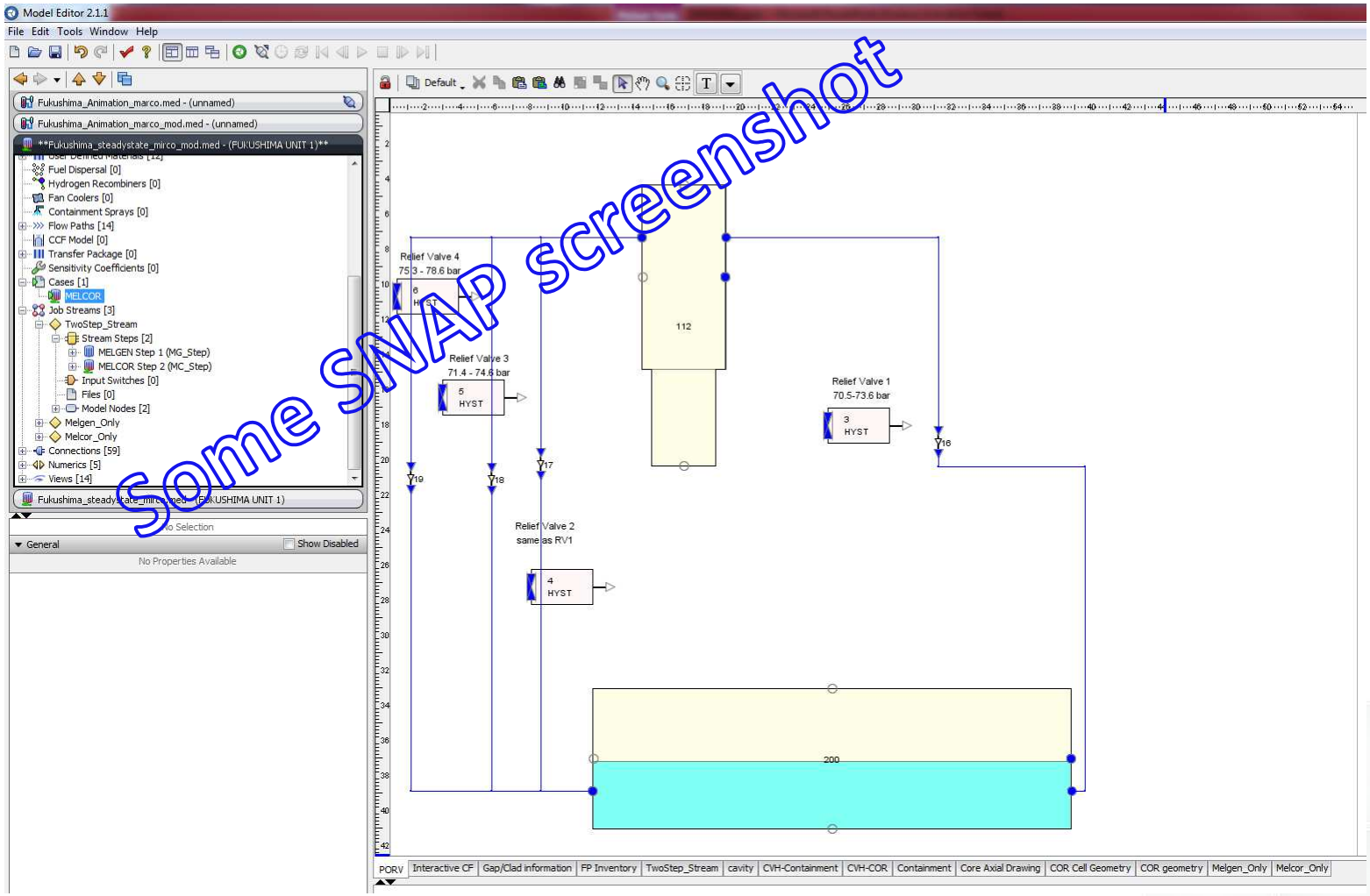
FUKUSHIMA PLANT DATA

Decided to use SNAP to create the input deck in order to better explain the nodalization



FUKUSHIMA PLANT DATA

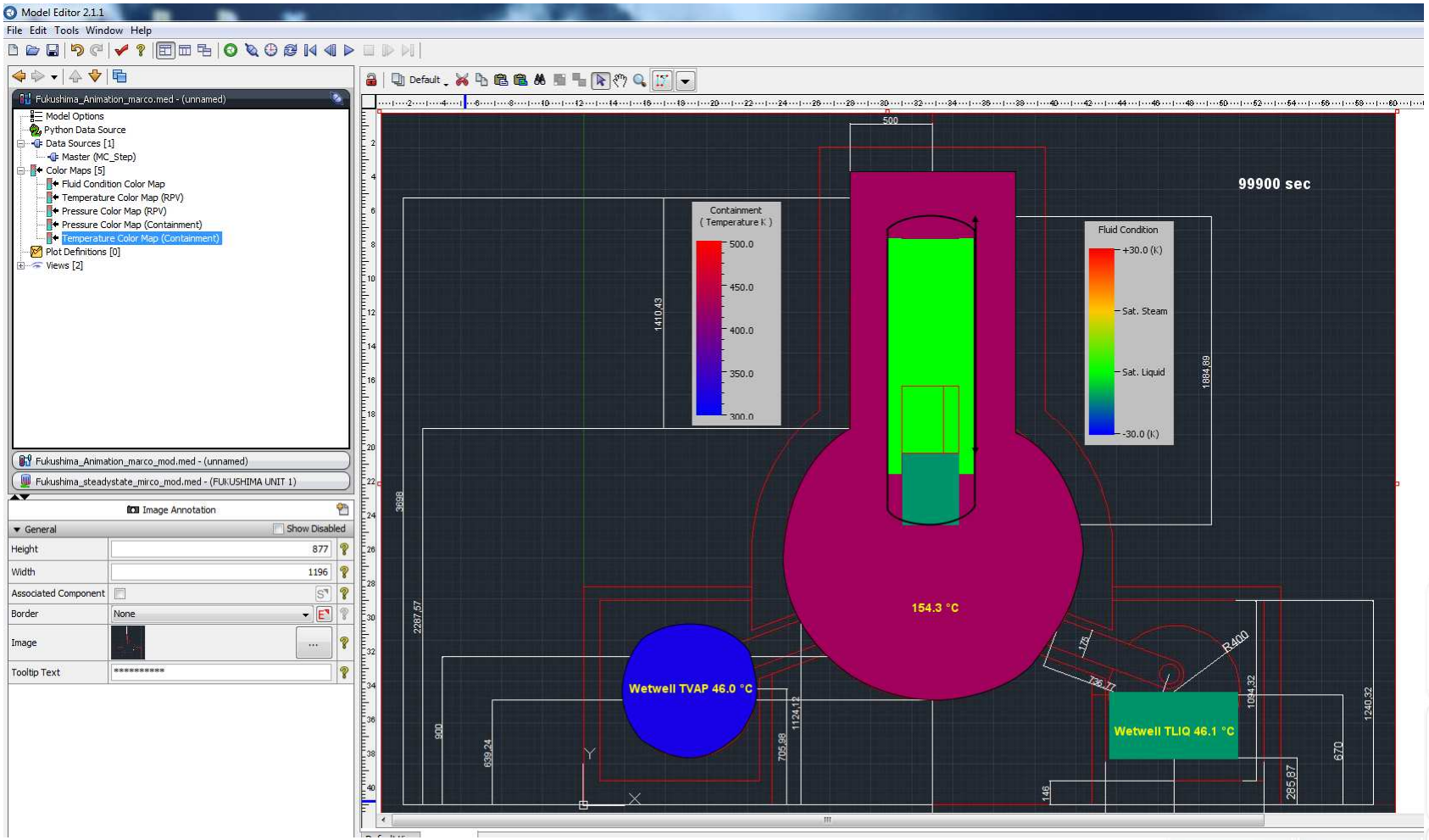
Decided to use SNAP to create the input deck in order to better explain the nodalization



Some SNAP screenshot

FUKUSHIMA PLANT DATA

Simple animation to visualize the results



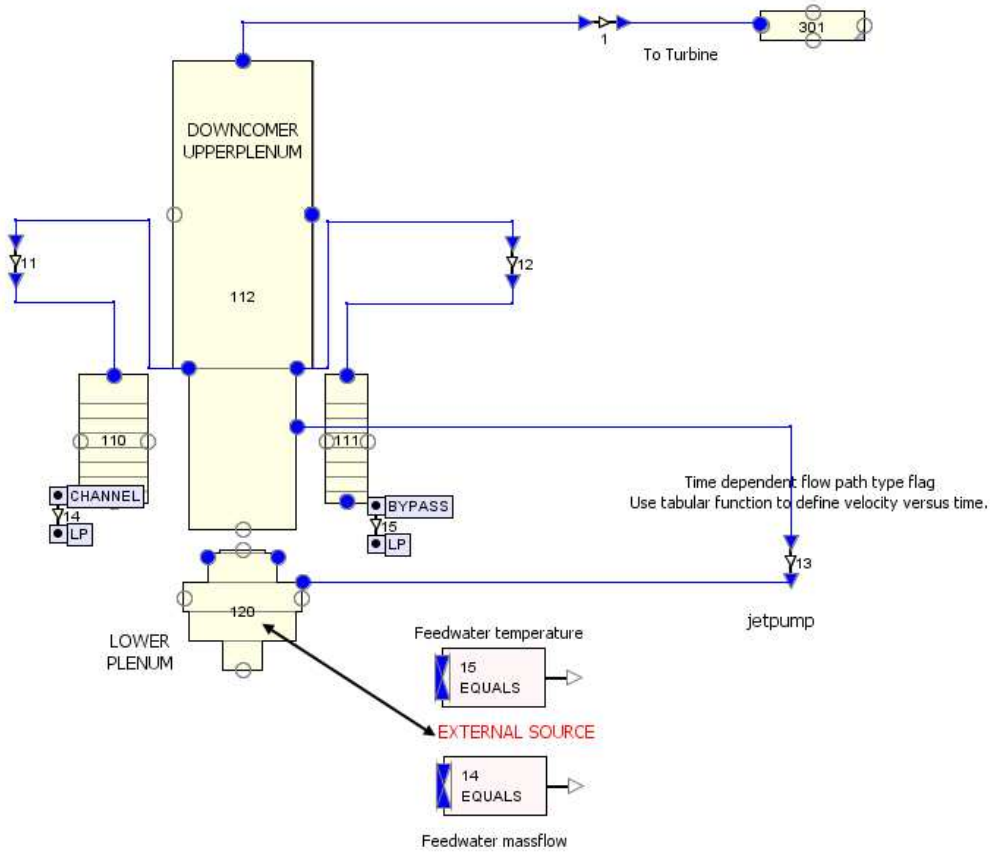
STEADY STATE

- No operating parameters available for Fukushima Daiichi Unit 1
- Model Validation performed using public data from Santa Maria de Garoña NPP (Spain)
  - Similar unit: BWR-3, Mark I, 1380 MWth

PARAMETER	Plant parameter
Core Thermal Power (W)	1.38E+09
RPV dome pressure (MPa)	6.98
Total mass flow (Kg/s)	5622
Bypass flow (Kg/s)	--
Recirculation line mass flow (kg/s)	1308
Steam Lines total mass flow (Kg/s)	685.7
Reactor Level (m above the TAF)	4.109
FW mass flow (Kg/s)	677.5
FW Temperature (°K)	452

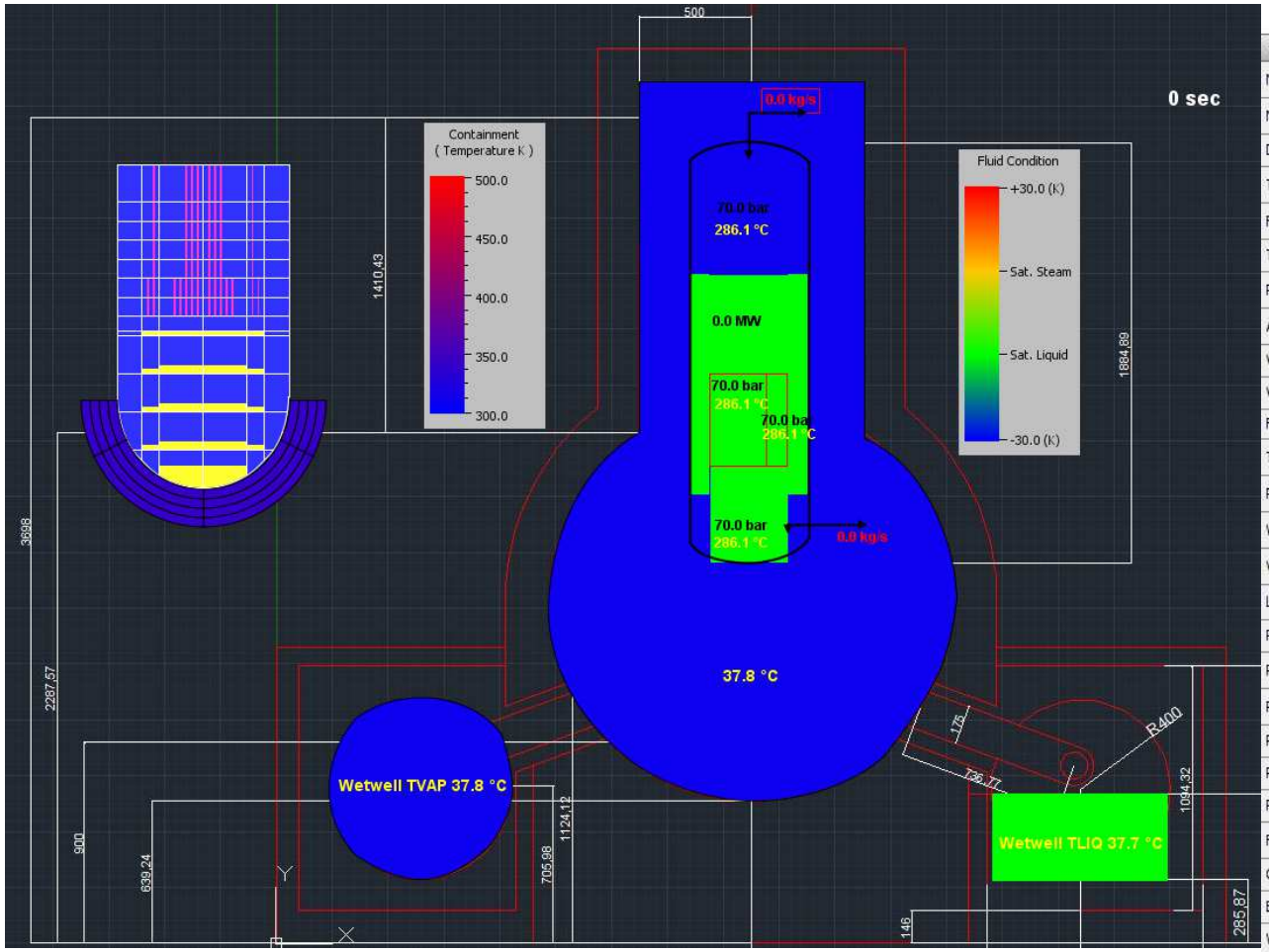
STEADY STATE

How to reach a steady state?
Best way to initialize all variables?



STEADY STATE

Attempt #1
Start with all operating steady conditions

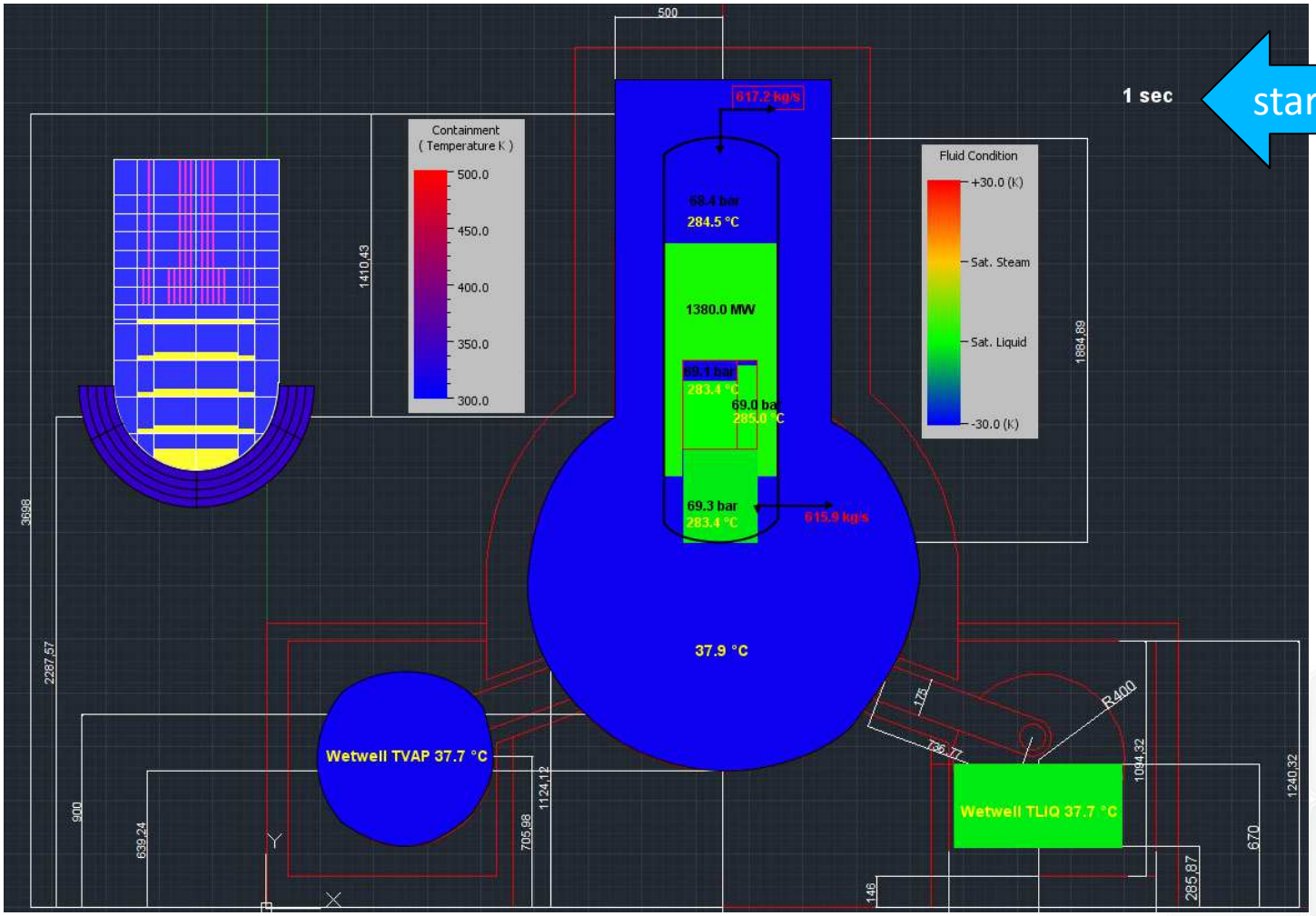


CV 112 (DC)

General	Show Di
Name	DC
Number	112
Description	<none>
Themodyn. Switch	[2] Non-Equilibrium
Flow Flag	[0] Not Defined
Type	< Inactive >
Pool, Fog Switch	[0] Pool, fog allowed
Active/Inactive	[0] Active
Vel. of Atmos.	0.0 (m/s)
Velocity of Pool	0.0 (m/s)
Flow Area	Default
Thermodynamic Input	[3] Pool and Atmosphere
Pool Flag	[3] Both
Water State	[0] Saturated
Vapor State	[0] Saturated
Legacy IC Format	True / False
Pool Pressure	7.0E6 (Pa)
Partial Pressure Flag	< Inactive >
Pool Option	Define Pool Elevation
Pool Elevation	30.0 (m)
Pool Void Fraction	0.0 (-)
Relative Humidity	1.0 (-)
Fog Flag	< Inactive >
Geometry	Rows: 3 [20.0,0.0],[25.5,58.6],[36.0,248.6]
External Sources	[0] Sources Defined
Water Source	[0] Water Sources

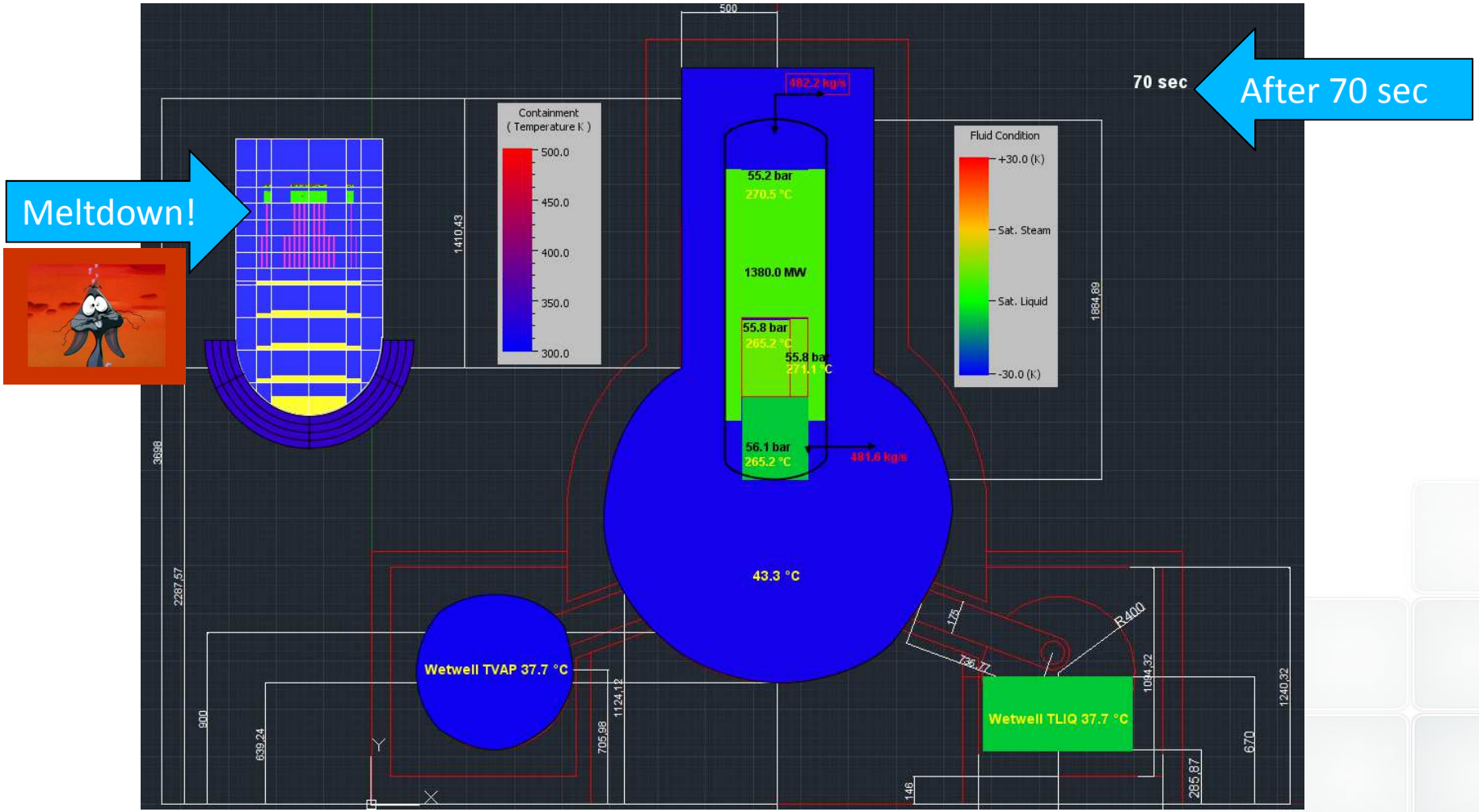
STEADY STATE

Attempt #1
Start with all operating steady conditions



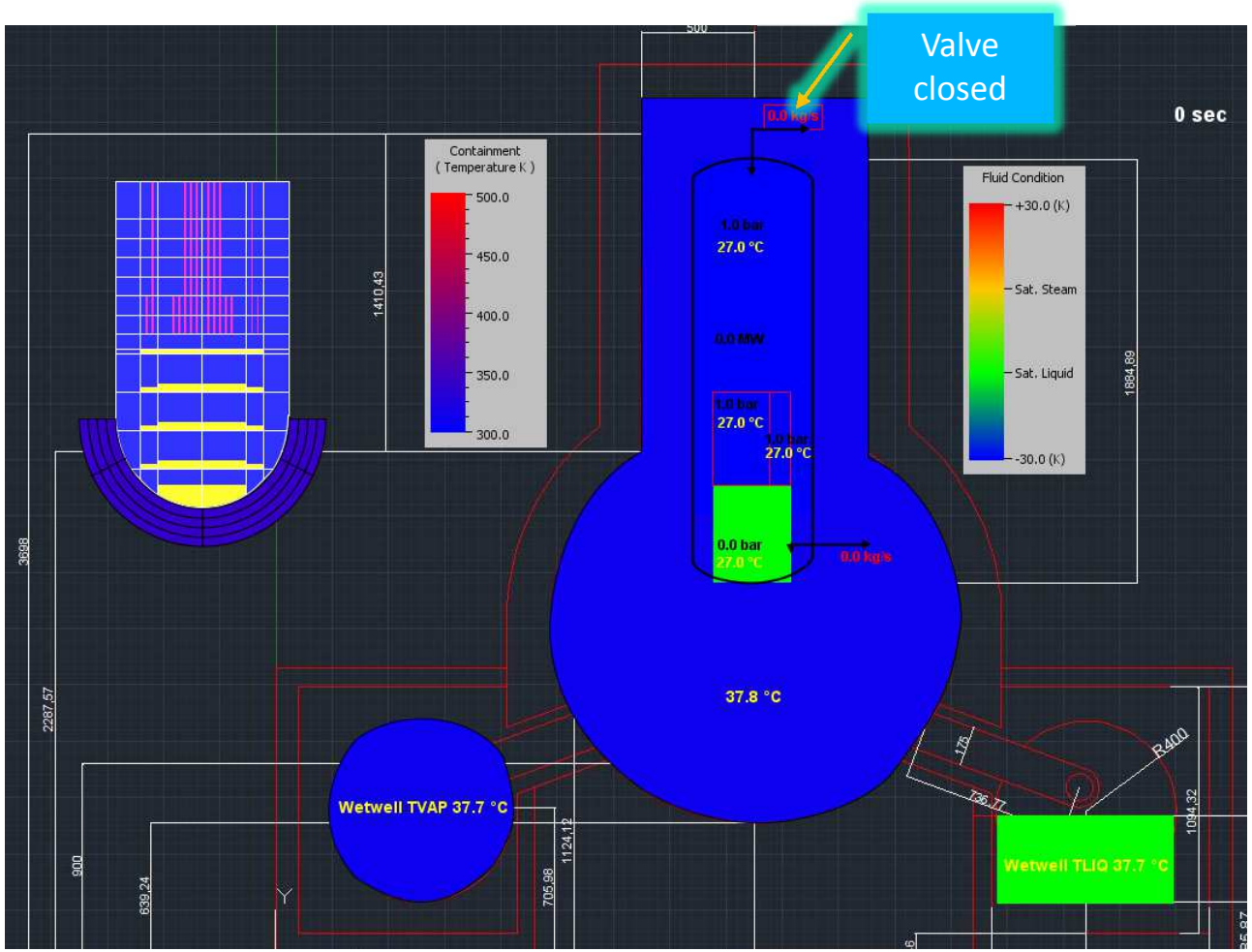
STEADY STATE

Attempt #1
Start with all operating steady conditions



STEADY STATE

Attempt #2
Start with no power, vessel full

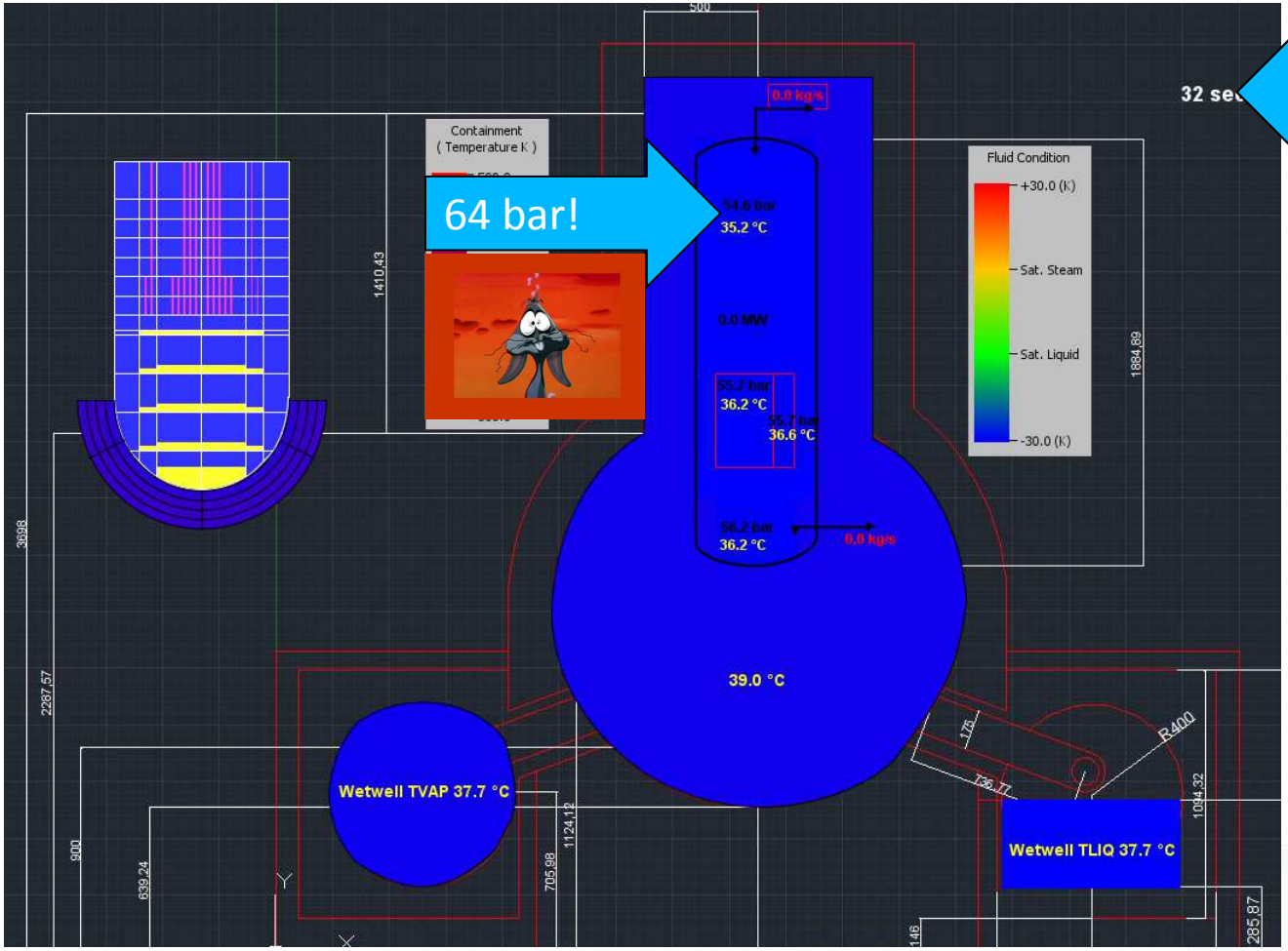


CV 112 (DC)

General	Show Dis
Name	DC
Number	112
Description	<none>
Themodyn. Switch	[1] Equilibrium
Flow Flag	[0] Not Defined
Type	< Inactive >
Pool, Fog Switch	[0] Pool, fog allowed
Active/Inactive	[0] Active
Vel. of Atmos.	0.0 (m/s)
Velocity of Pool	0.0 (m/s)
Flow Area	Default
Thermodynamic Input	[3] Pool and Atmosphere
Pool Flag	[1] Only Pool
Water State	[1] Subcooled
Legacy IC Format	True / False
Pool Pressure	1.0E5 (Pa)
Pool Temperature	300.0 (K)
Partial Pressure Flag	< Inactive >
Pool Option	Define Pool Elevation
Pool Elevation	Unknown (m)
Pool Void Fraction	0.0 (-)
Fog Flag	< Inactive >
Geometry	Rows: 3 [20.0,0.0],[25.5,58.6],[36.0,248.6]
External Sources	[0] Sources Defined
Water Source	[0] Water Sources

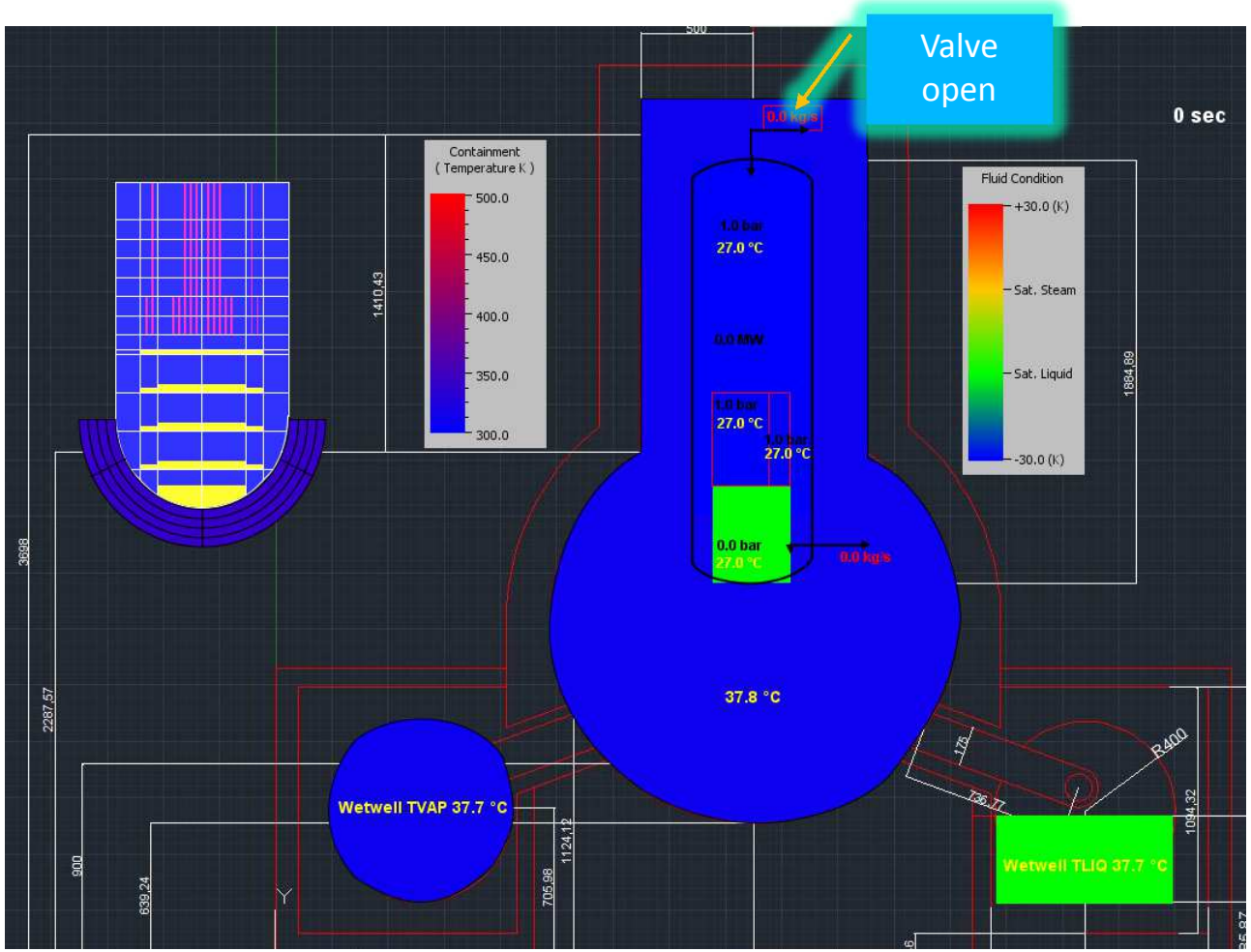
STEADY STATE

Attempt #2
Start with no power, vessel full



STEADY STATE

Attempt #2 bis
Start with no power, vessel full

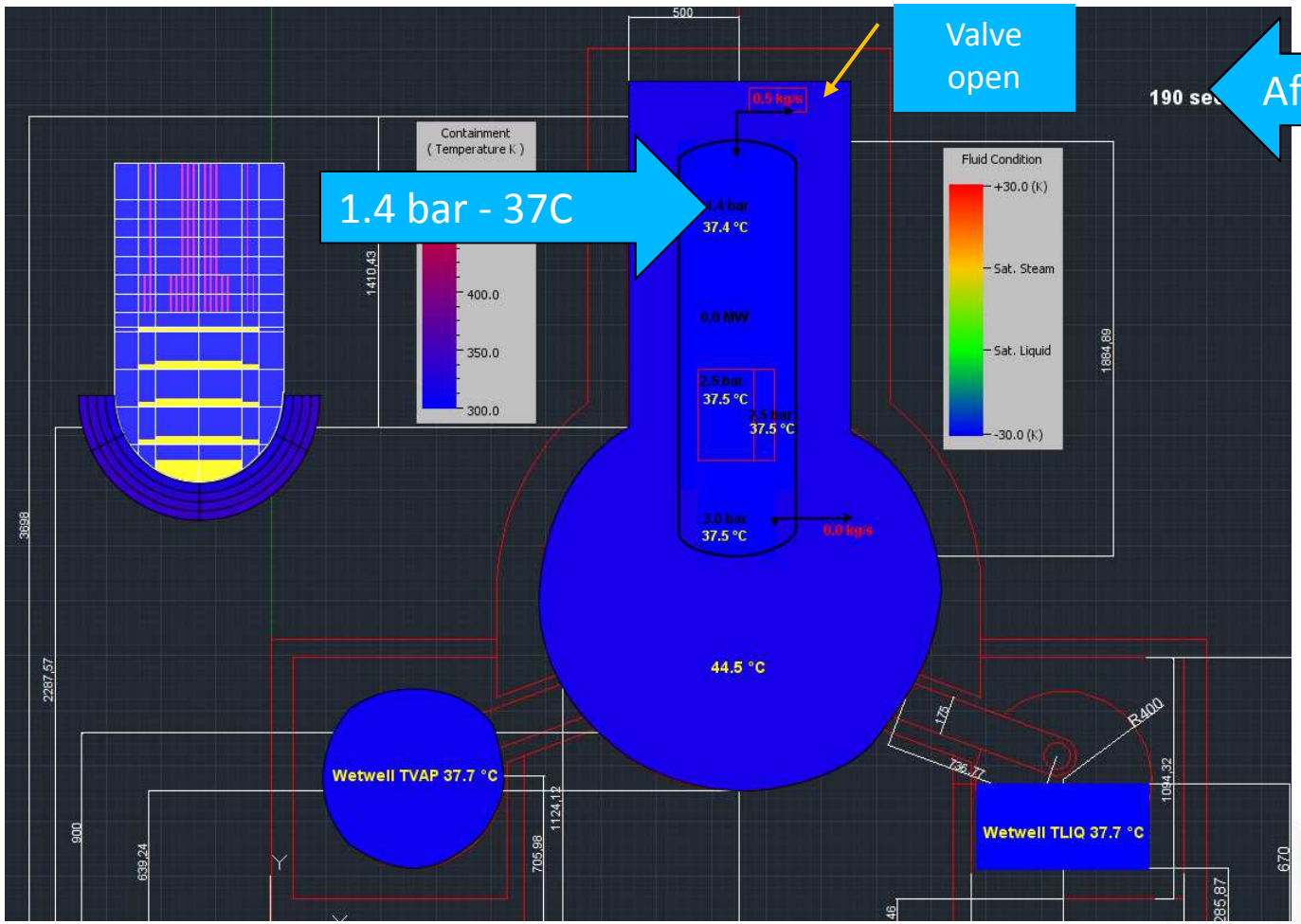


CV 112 (DC)

General	Show Dis
Name	DC
Number	112
Description	<none>
Themodyn. Switch	[1] Equilibrium
Flow Flag	[0] Not Defined
Type	< Inactive >
Pool, Fog Switch	[0] Pool, fog allowed
Active/Inactive	[0] Active
Vel. of Atmos.	0.0 (m/s)
Velocity of Pool	0.0 (m/s)
Flow Area	Default
Thermodynamic Input	[3] Pool and Atmosphere
Pool Flag	[1] Only Pool
Water State	[1] Subcooled
Legacy IC Format	True / False
Pool Pressure	1.0E5 (Pa)
Pool Temperature	300.0 (K)
Partial Pressure Flag	< Inactive >
Pool Option	Define Pool Elevation
Pool Elevation	Unknown (m)
Pool Void Fraction	0.0 (-)
Fog Flag	< Inactive >
Geometry	Rows: 3 [20.0,0.0],[25.5,58.6],[36.0,248.6]
External Sources	[0] Sources Defined
Water Source	[0] Water Sources

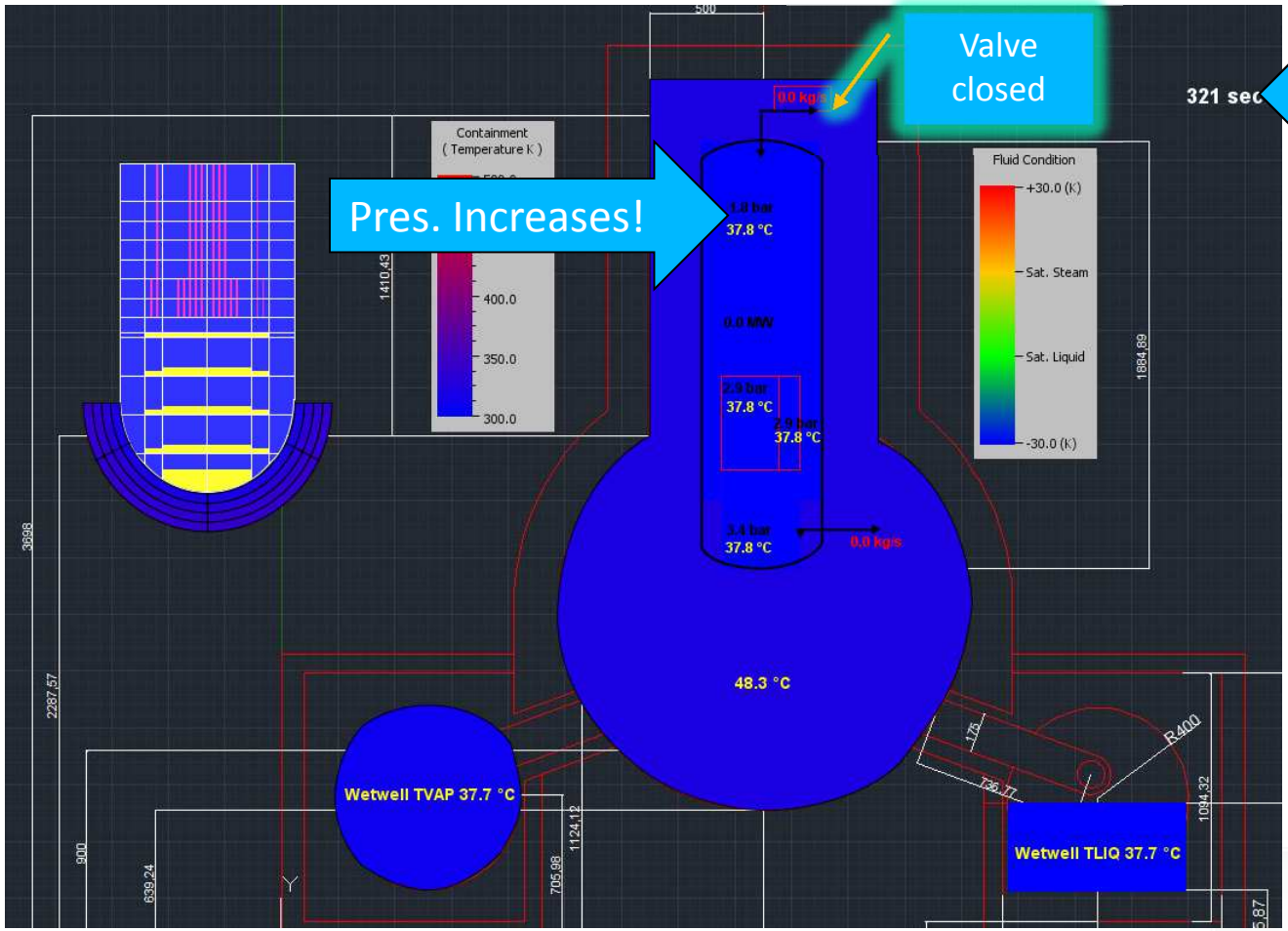
STEADY STATE

Attempt #2 bis
Start with no power, vessel full



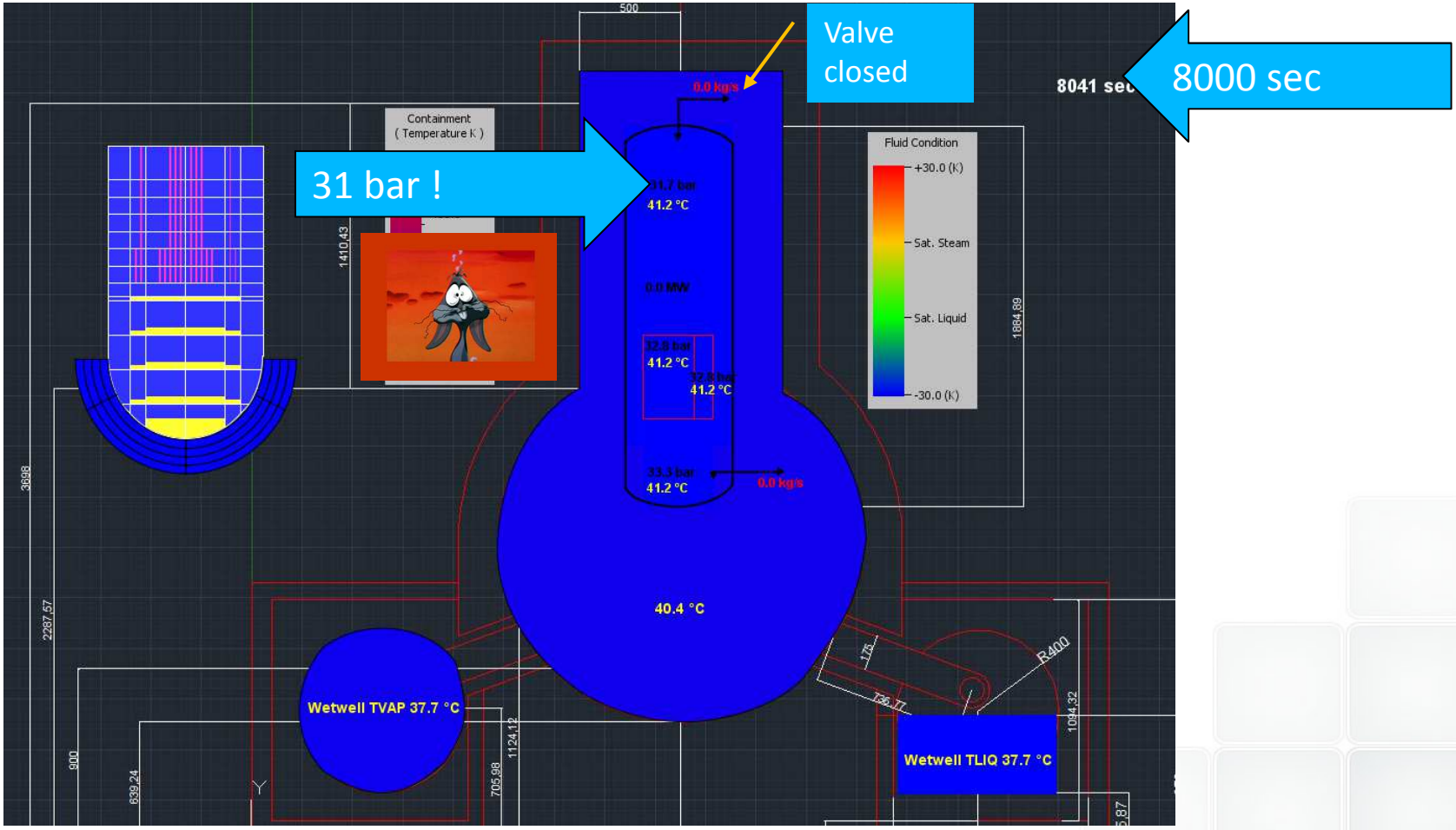
STEADY STATE

Attempt #2 bis
Start with no power, vessel full



STEADY STATE

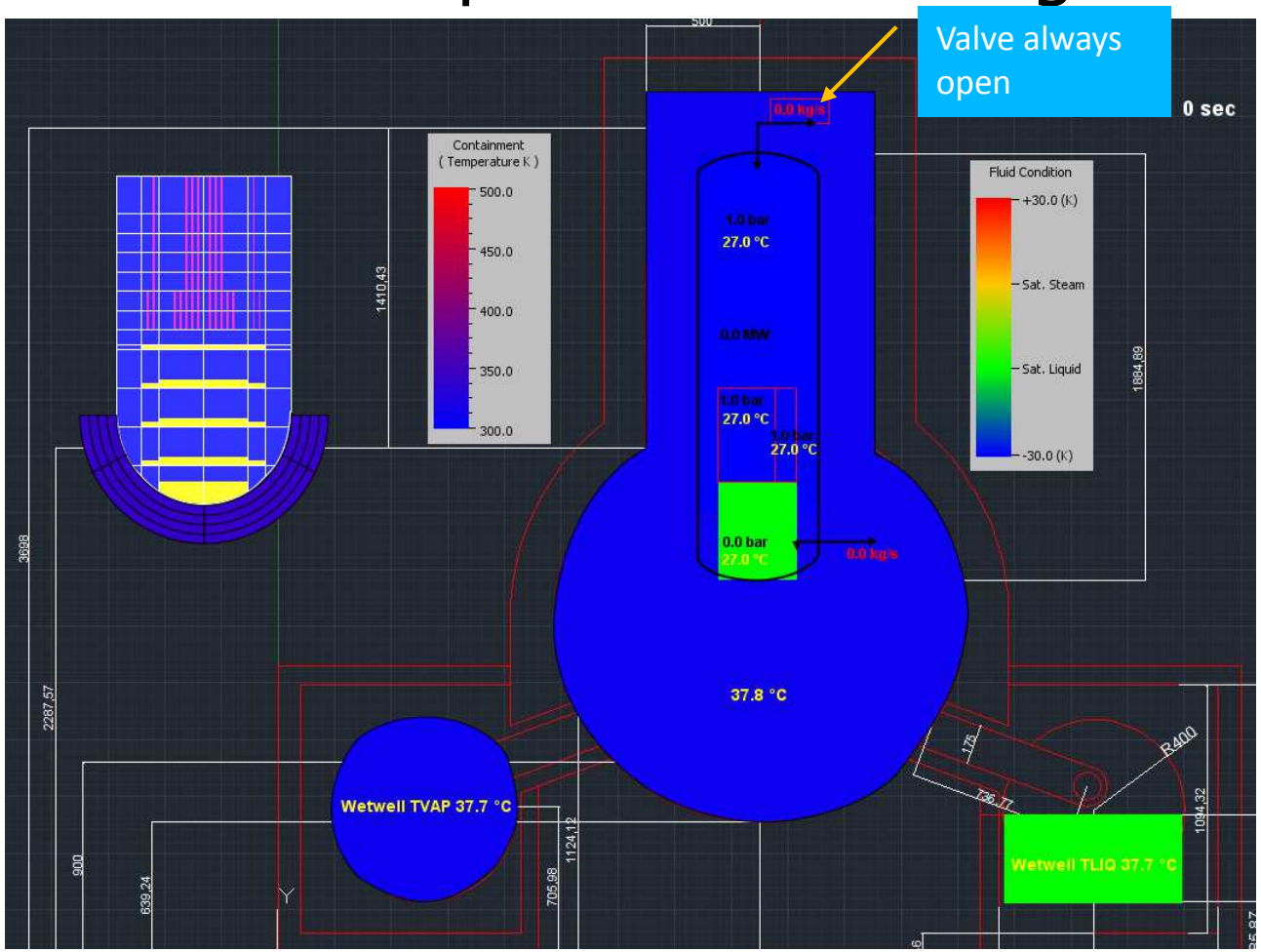
Attempt #2 bis
Start with no power, vessel full

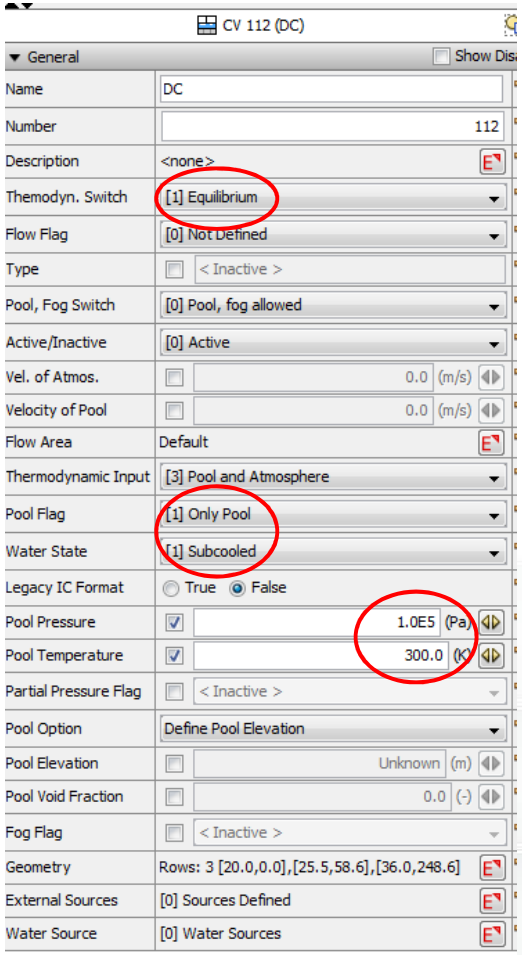


STEADY STATE

Attempt #3

Start with no power, vessel full, valve open, power increasing slowly

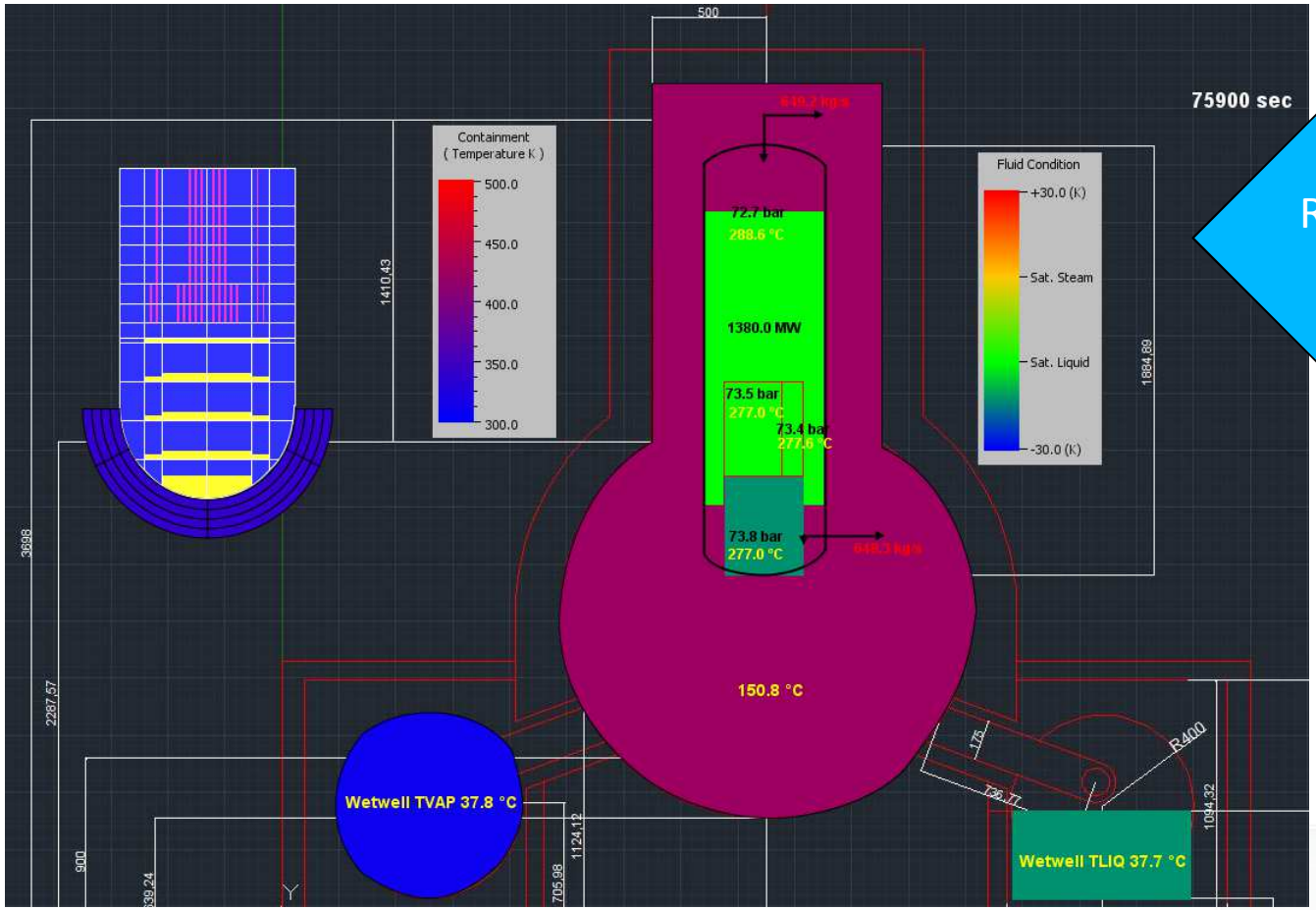




STEADY STATE

Attempt #3

Start with no power, vessel full, valve open, power increasing slowly

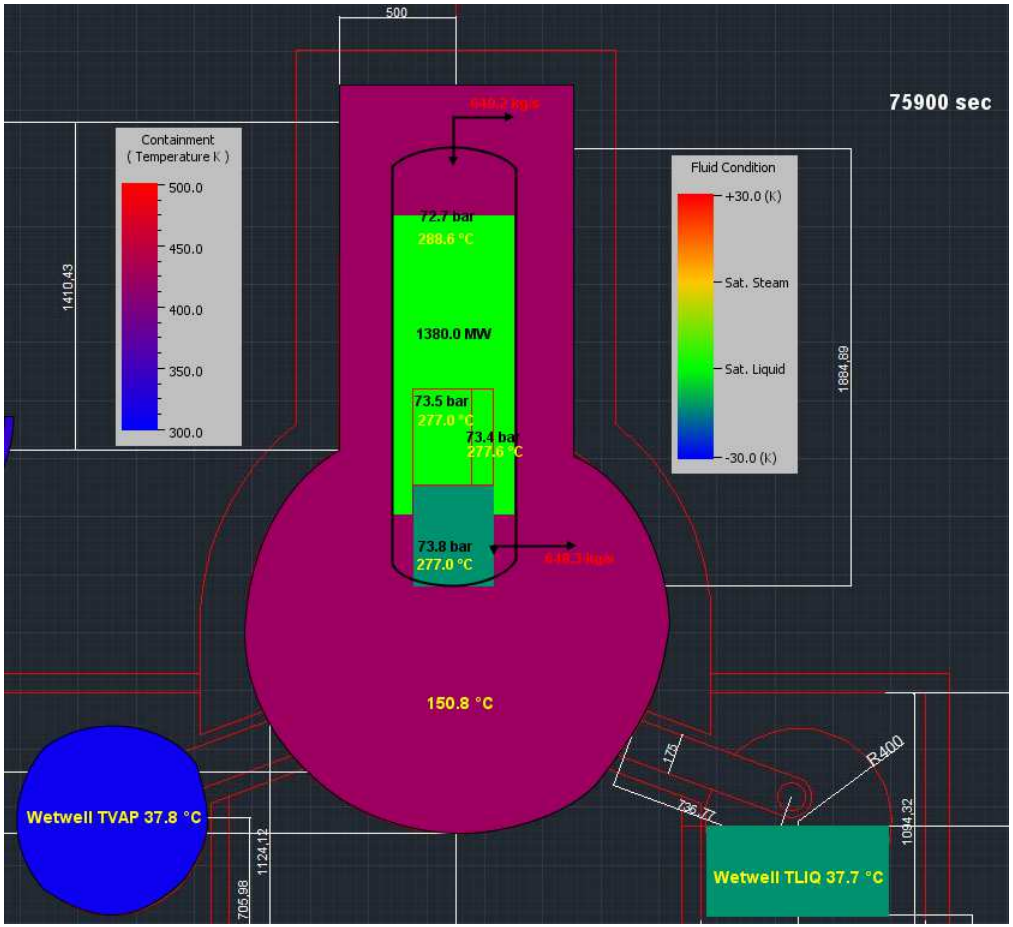


Reasonable values

STEADY STATE

Attempt #3

How to fine-tune the steady conditions?



PARAMETER	Plant parameter
Core Thermal Power (W)	1.38E+09
RPV dome pressure (MPa)	6.98
Total mass flow (Kg/s)	5622
Bypass flow (Kg/s)	--
Recirculation line mass flow (kg/s)	1308
Steam Lines total mass flow (Kg/s)	685.7
Reactor Level (m above the TAF)	4.109
FW mass flow (Kg/s)	677.5
FW Temperature (°K)	452

Defining interactive variables

Interactive Variable:
Channel set to CFVALU_17
Variable set to "feedwtrcntrl"

1.0

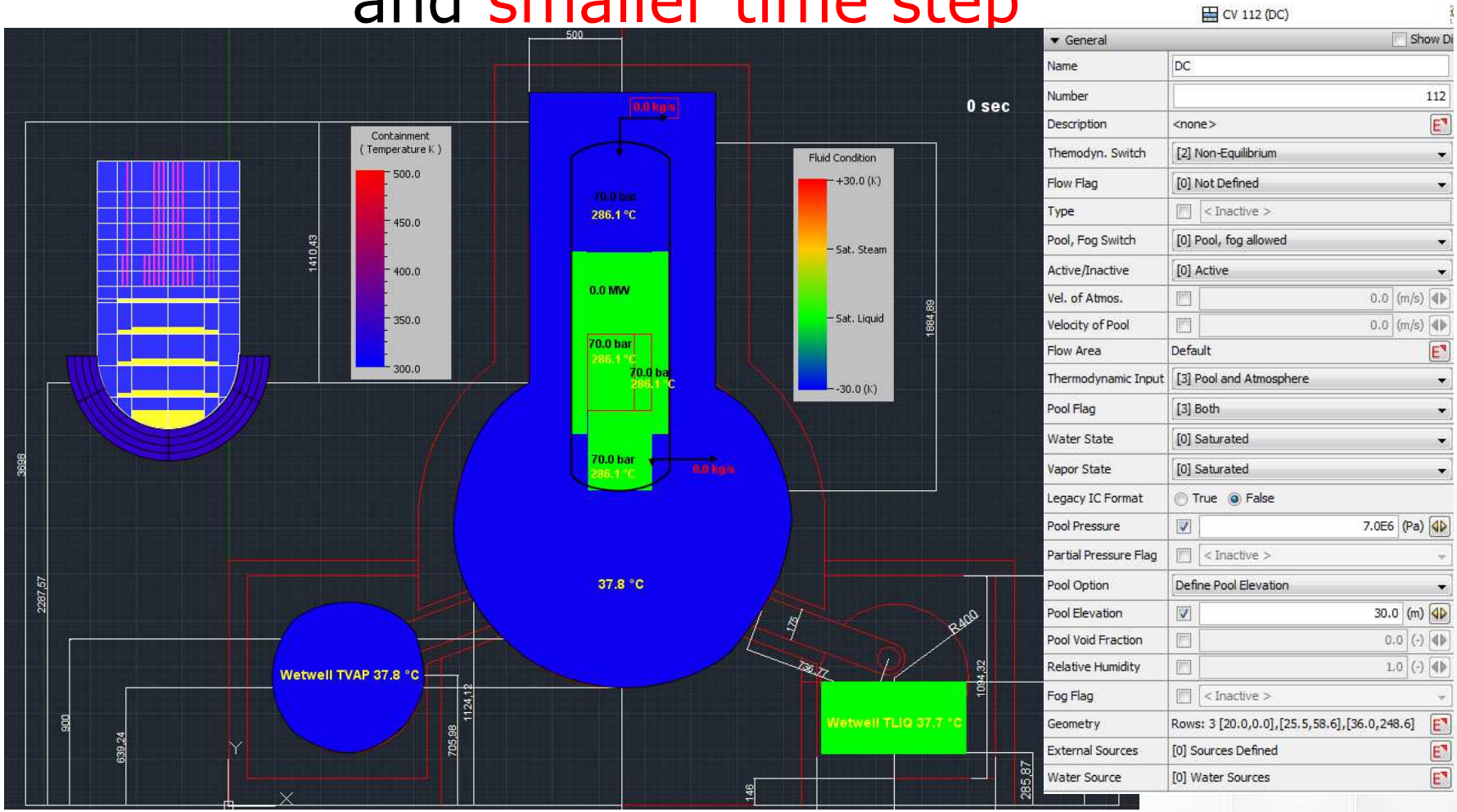
H2O MFLOW FP2 = 649

Result: CF16 = 648

STEADY STATE

Attempt #4

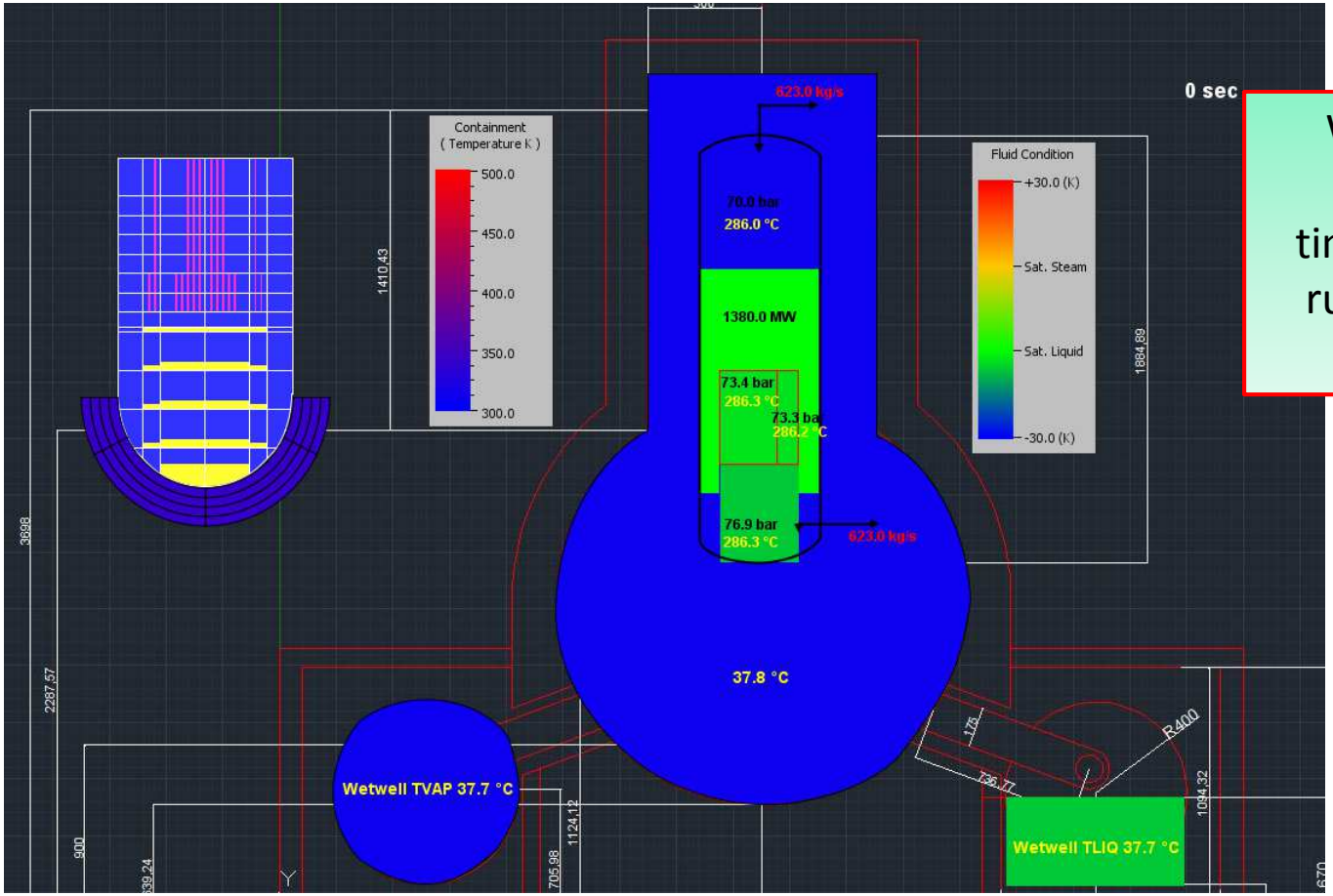
Start with all operating steady conditions and smaller time step



STEADY STATE

Attempt #4

Start with all operating steady conditions and smaller time step



With a smaller (0.01) **maximum** allowed timestep the calculation runs fine from the very beginning!!

CONCLUSIONS

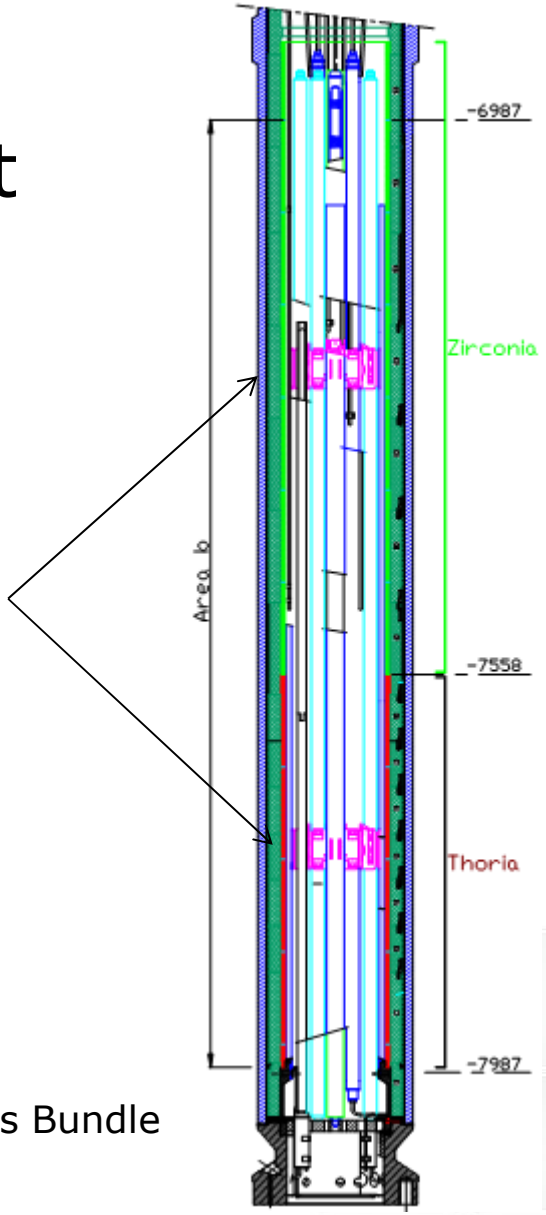
- Time step has crucial importance
- Some code behaviours are unexplainable (ex. Valve closing)
- Interactive variables are very useful
- Join our folder-in-the-cloud and share information

Grazie

Some bugs??

Supporting structures can't be just made of Zircaloy

Spacer grids



Phebus Bundle