

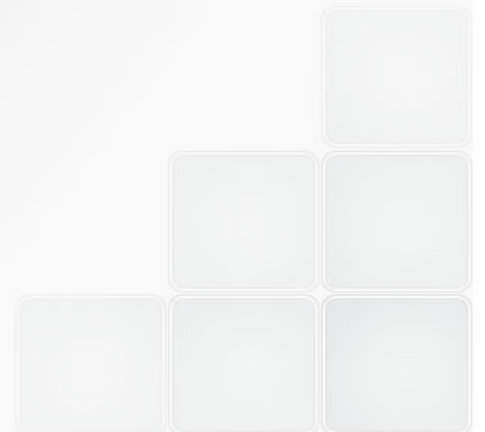


Development of an input deck for Fukushima accident

Tools and lessons learned

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

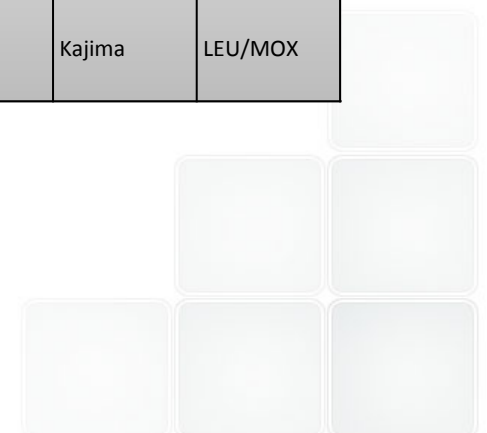


FUKUSHIMA PLANT DATA



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

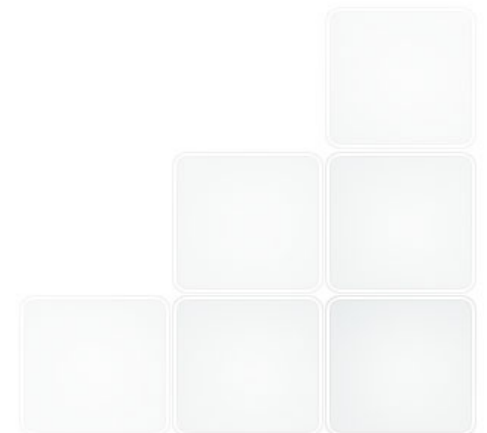
Unit	Type	Containment	Start construction	First criticality	Commercial operation	Electric power	Reactor supplier	Architecture	Construction	Fuel
Fukushima I – 1	BWR-3	Mark I	July 25, 1967	October 10, 1970	March 26, 1971	460 MW	General Electric	Ebasco	Kajima	LEU
Fukushima I – 2	BWR-4	Mark I	June 9, 1969	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



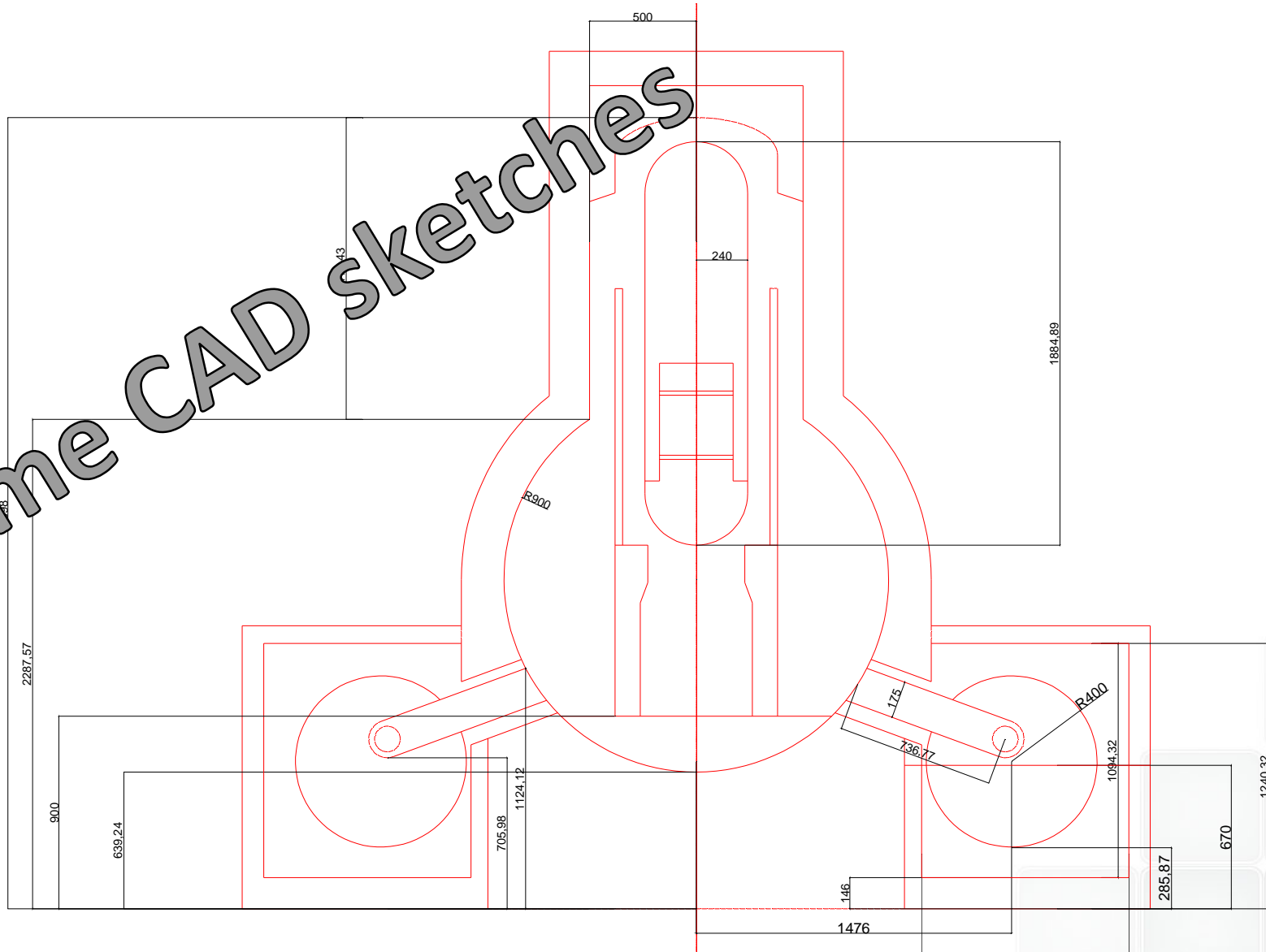
- Started collecting free data on the web, open literature, similar plants...
- Created a folder with useful data for creating a MELCOR input deck
- Draw some sketch in CAD
- Created a Dropbox folder that can be shared on request



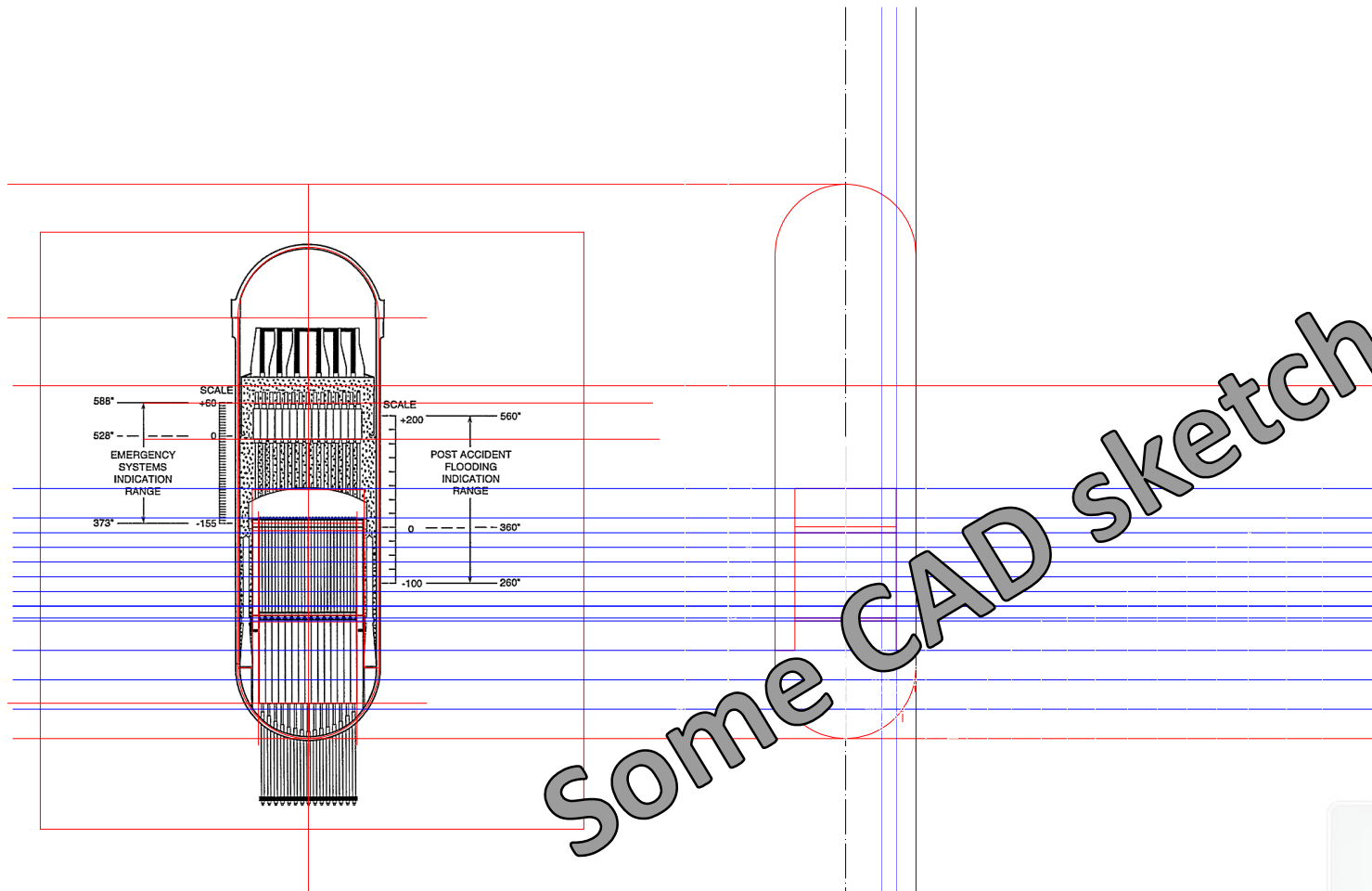
FUKUSHIMA PLANT DATA



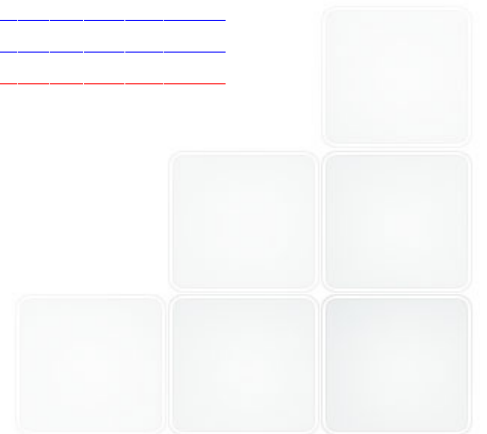
Some CAD sketches



FUKUSHIMA PLANT DATA



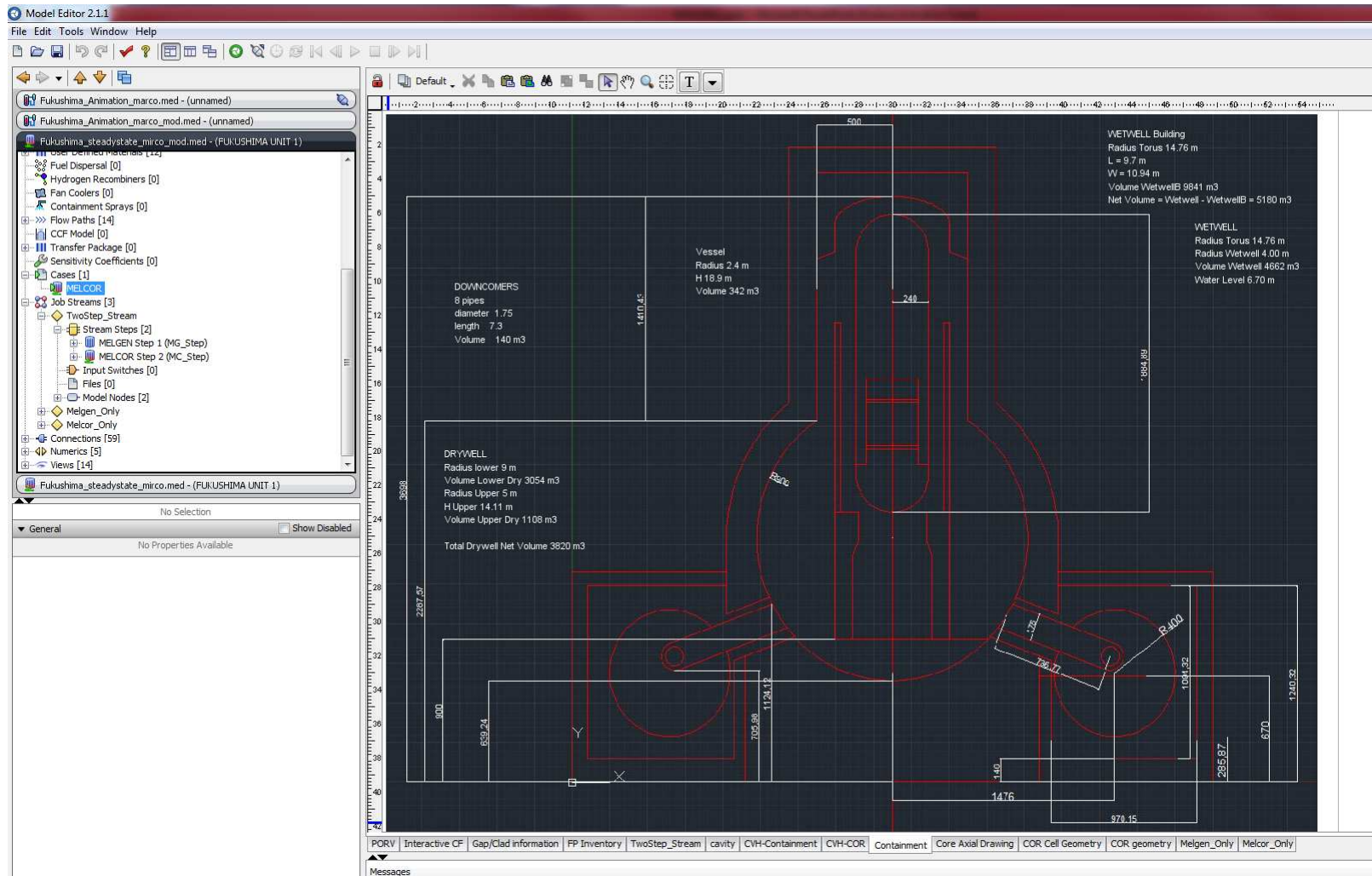
Some CAD sketches



FUKUSHIMA PLANT DATA



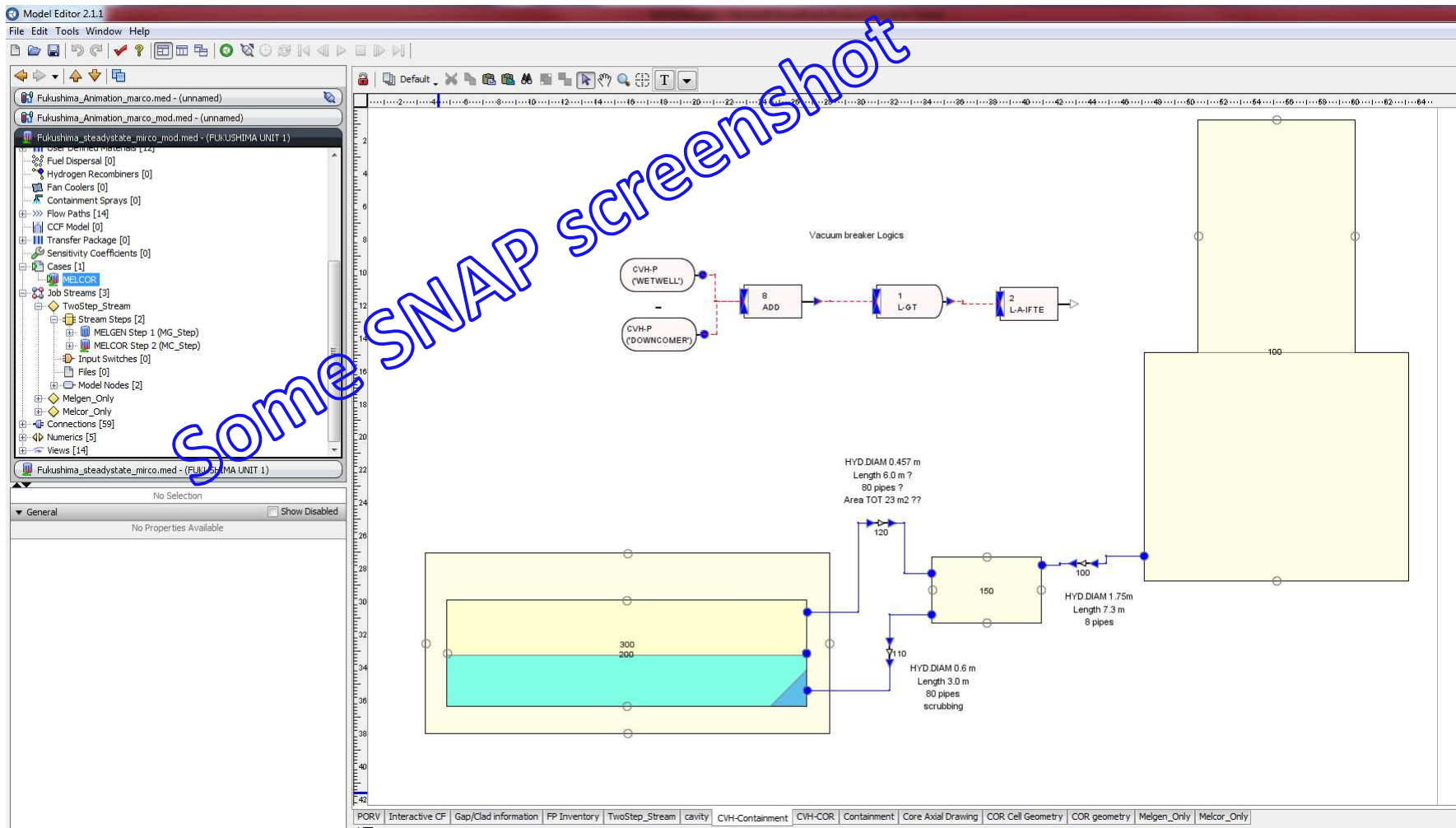
Decided to use SNAP to create the input deck in order to better explain the nodalization



FUKUSHIMA PLANT DATA



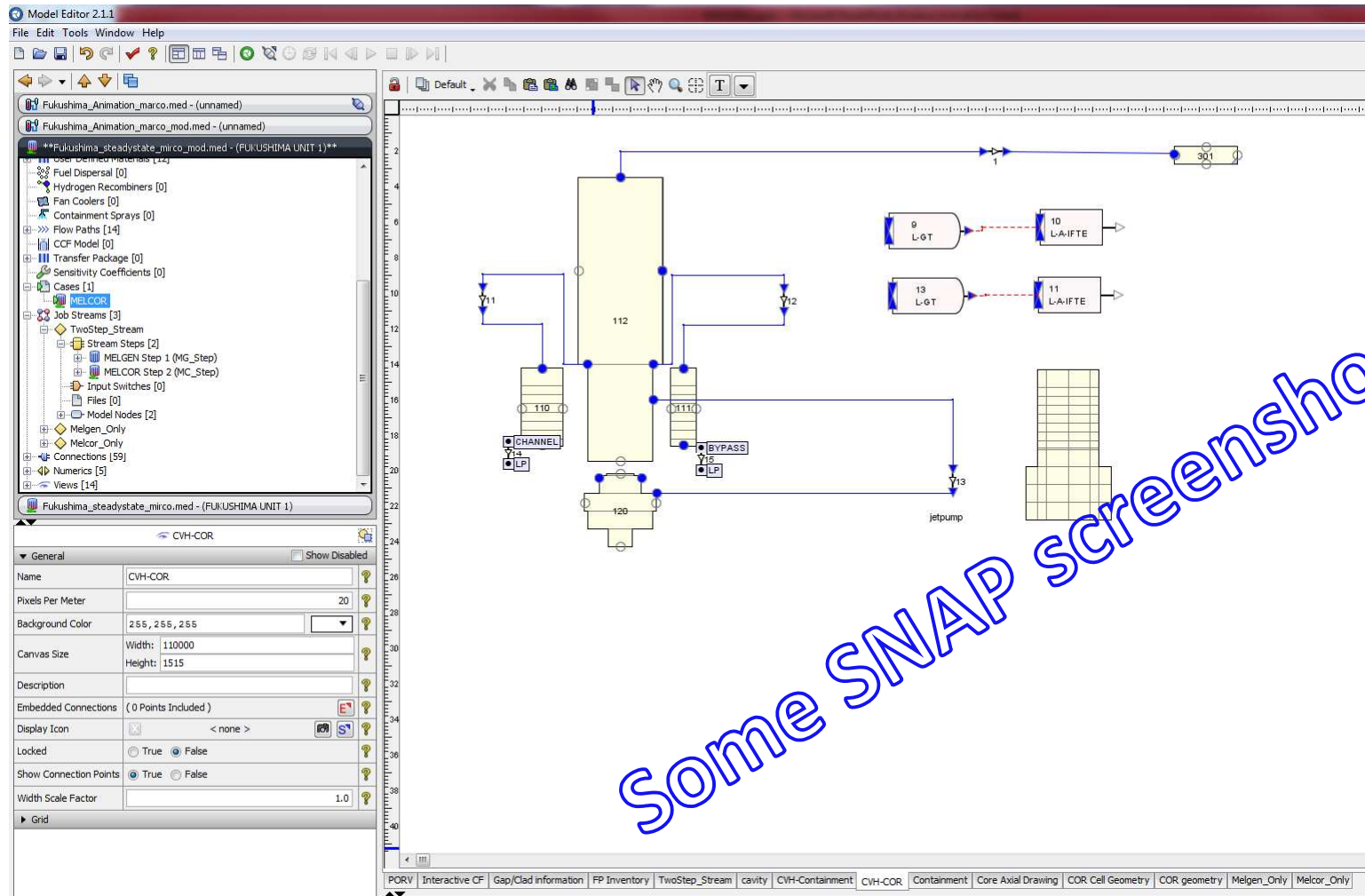
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FUKUSHIMA PLANT DATA



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FUKUSHIMA PLANT DATA



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

Model Editor 2.1.1

File Edit Tools Window Help

Fukushima_Animation_marco.med - (unnamed)

Fukushima_Animation_marco_mod.med - (unnamed)

Fukushima_steadystate_mircos.med - (FUKUSHIMA UNIT 1)

Fuel Dispersal [0]
 Hydrogen Recombiners [0]
 Fan Coolers [0]
 Containment Sprays [0]
 Flow Paths [14]
 CCF Model [0]
 Transfer Package [0]
 Sensitivity Coefficients [0]
 Cases [1]
 MELCOR
 Job Streams [3]
 TwoStep_Stream
 Stream Steps [2]
 MELGEN Step 1 (MG_Step)
 MELCOR Step 2 (MC_Step)
 Input Switches [0]
 Files [0]
 Model Nodes [2]
 Melgen_Only
 Melcor_Only
 Connections [99]
 Numerics [5]
 Views [14]

No Selection

General Show Disabled

No Properties Available

				FUEL	CLAD	CANISTER
Cladding Dext=12.30 mm	DHYCL 0.0123	[mm]				
Dint=10.58 mm	DHYPD 2.5E-02		15	1000.0	660.0	700.0
Cross Area=1.1882E-4 m2	DHYCNC 0.0134		2	500.0	500.0	500.0
	DHYCNCB 0.0134		11	500.0	500.0	500.0
Fuel Pin Dext=10.40 mm	DHYSP 6.0E-03		10	500.0	500.0	500.0
Cross Area=8.495E-5 m2	COR		9	500.0	500.0	500.0
	COR		8	500.0	500.0	500.0
CR Guide Tube	COR		7	500.0	500.0	500.0
Dext=250 mm	COR		6	400.0	0.0	200.0
Dint=230 mm	LP-plate		5	100.0		
Cross Area=0.0019 m2	LP		4	1000.0		
	LP		3	1000.0		
	LP		2	1000.0		
	LP		1	1000.0		

Control Rod
 Dext=15 mm
 Dint=12 mm
 Cross Area=5.88E-4

Support Columns
 ?????

SUPPORT STRUCTURES
 Control rod guide tubes are
 the support str. in the Lower Plenum

NON SUPPORT STUCT.
 Control Blades Level 6-13

Diagram showing packages: COR Package, TP Package, FDI Package, CAV Package. Arrows indicate flow paths between these packages.

Control poison is B4C
 The COR package ejects B4C and the CAV package does not recognize that material.
 It must be retained by the TP package by using the translation matrix to eliminate the B4C from the output masses.

Technical drawings on the right show details of the control rod assembly and fuel bundle assembly.

Technical drawing 1: UPPER GUIDE ROLLER TYPICAL # PLUGS 2, HANDLE, 275 mm, WELDED END FLUO, HELIUM ABSORBER RODS, SHEATH, 100 mm, BLADE, COUPLING RELEASE PINWOLE, 100 control rods 250 mm width 12 mm thick.

Technical drawing 2: BAIL HANDLE, UPPER TIE PLATE, FUEL BUNDLE, 50 Fuel rods 134 mm width 2 mm thick, 400 assemblies.

PORV | Interactive CF | Gap/Clad information | FP Inventory | TwoStep_Stream | cavity | CVH-Containment | CVH-COR | Containment | Core Axial Drawing | COR Cell Geometry | COR geometry | Melgen_Only | Melcor_Only

FUKUSHIMA PLANT DATA



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

The screenshot displays the Model Editor 2.1.1 interface. The left sidebar shows a project tree with folders for 'Fukushima_Animation_marco.med', 'Fukushima_Animation_marco_mod.med', and 'Fukushima_steadystate_mirc.med'. The main window is titled 'Core Geometry' and contains a list of model parameters and a diagram of the core geometry. A large blue watermark 'Some SNAP screenshot' is overlaid on the image.

Core Geometry

- Three rings modeled
- 13 axial levels (5 LP including sup. plate)
- Bottom of lower plenum at 17.0 m
- Bottom of core support plate at level 5 at 21.1 m
- Elevation of baffle plate, HLST=20.0 m

Lower Head

- Spherispherical cap
- Vessel radius of curvature = 2.4 m
- 6 Sections in the Lower Head
- Outer surface boundary at each ring boundary
- Section boundary at each axial boundary
- Outer surface interfaces with 'Wetwell'
- Four node layers through vessel wall, 0.165 m thick
- Accept defaults for layers
 - Equal layer thicknesses
 - carbon steel
 - No insulation layers

Core Support plate at level 5

- Three rings modeled
- Two inner rings of equal cross-sectional area, each 4.65 m^2 cross-sectional area
- Outer ring simulates peripheral part of lower plenum
 - Radius RCOR 1.72 m
 - Radius RVES 2.40 m

Radial boundary areas based on ring circumference and cell height

- Ring1: $R = \sim 1.216 \text{ m}$; $2 \pi R \sim 7.64 \text{ m}$
 - Levels 1-4, area $\sim 7.64 \text{ m} \times 1.0 \text{ m} \sim 7.64 \text{ m}^2$ ASCELR
 - Levels 5, area $\sim 7.64 \text{ m} \times 0.1 \text{ m} \sim 0.764 \text{ m}^2$
 - Levels 6, area $\sim 7.64 \text{ m} \times 0.4 \text{ m} \sim 3 \text{ m}^2$
 - Level 7-12, area $\sim 7.64 \text{ m} \times 0.5 \text{ m} \sim 3.82 \text{ m}^2$
 - Levels 13, area $\sim 7.64 \text{ m} \times 1 \text{ m} \sim 7.64 \text{ m}^2$
- Ring2: $R = \sqrt{(18 \text{ m}^2 / \pi) + 2.4 \text{ m}}$; $2 \pi R \sim 15 \text{ m}$
 - Levels 1, area $\sim 15 \text{ m} \times 2.95 \text{ m} \sim 45 \text{ m}^2$
 - Levels 2, area $\sim 15 \text{ m} \times 2.05 \text{ m} \sim 31 \text{ m}^2$
 - Levels 3, area $\sim 15 \text{ m} \times 0.95 \text{ m} \sim 14 \text{ m}^2$
 - Level 4, area $\sim 15 \text{ m} \times 0.1 \text{ m} \sim 1.5 \text{ m}^2$
 - Levels 5-8, area $\sim 15 \text{ m} \times 1 \text{ m} \sim 15 \text{ m}^2$
- Ring3: $R = \sqrt{(50 \text{ m}^2 / \pi) + 4 \text{ m}}$; $2 \pi R \sim 25 \text{ m}$
 - Levels 1, area $\sim 25 \text{ m} \times 2.95 \text{ m} \sim 74 \text{ m}^2$
 - Level 2, area $\sim 25 \text{ m} \times 2.05 \text{ m} \sim 51 \text{ m}^2$

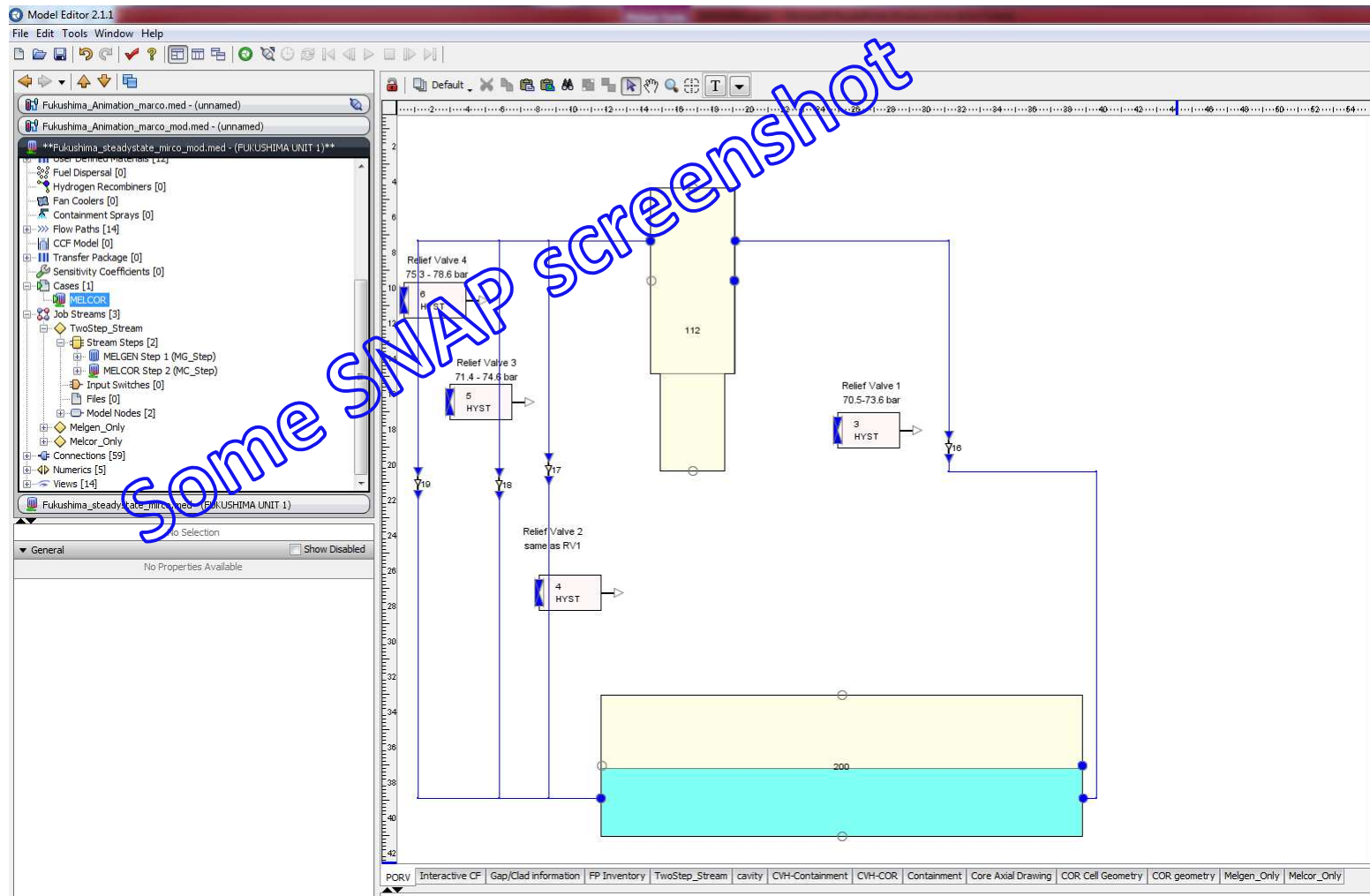
The diagram shows a cross-section of the core with three rings and 13 axial levels. The vertical axis is labeled from 0 to 42. Key dimensions are indicated: 240, 236.65, 172, 194.94, 121.6, and 850. A note indicates 'Rsegment=3.86'.

Bottom status bar: PORV | Interactive CF | Gap/Clad information | FP Inventory | TwoStep_Stream | cavity | CWH-Containment | CWH-COR | Containment | Core Axial Drawing | COR Cell Geometry | COR geometry | Melgen_Only | Melcor_Only

FUKUSHIMA PLANT DATA



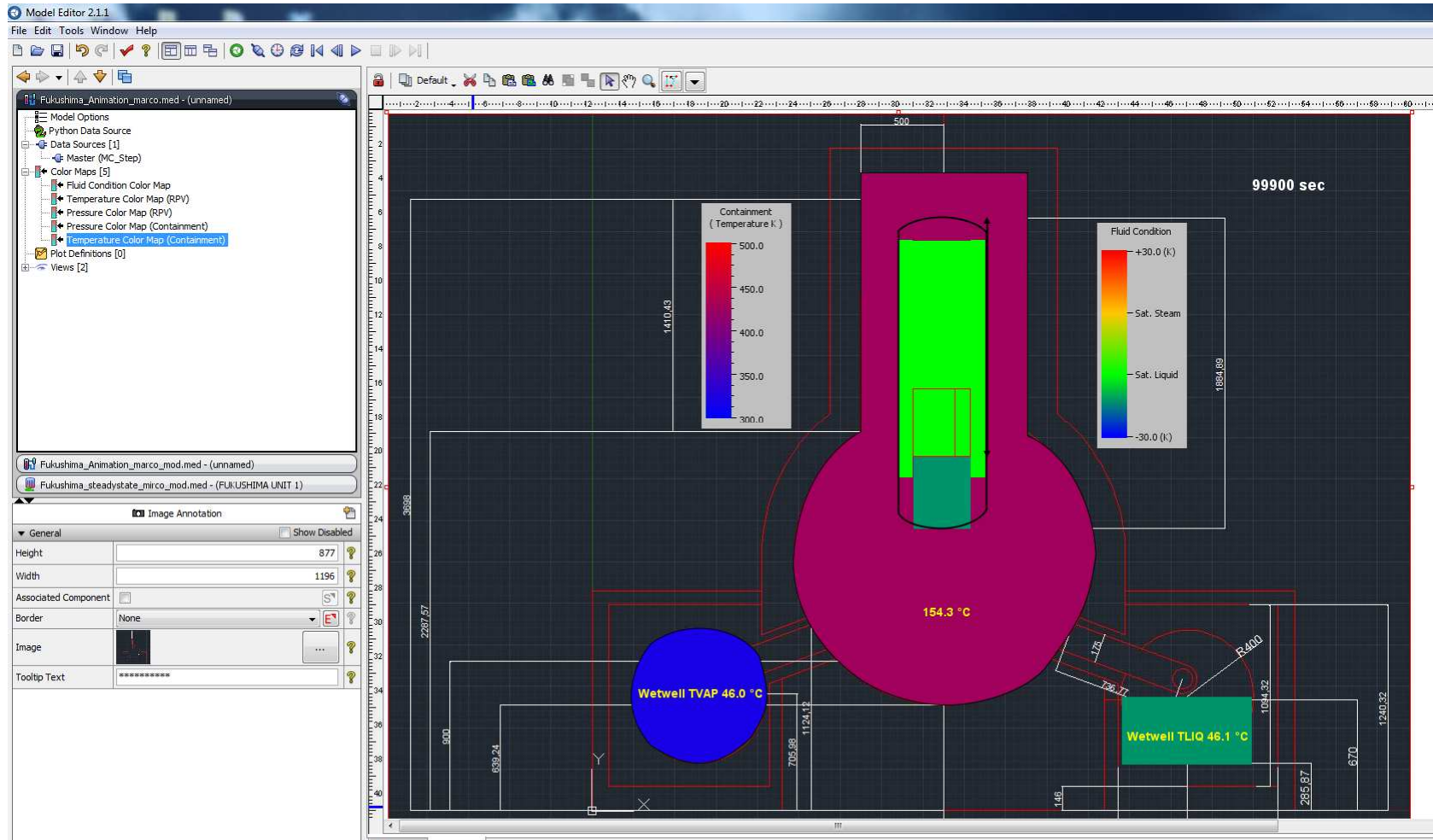
Decided to use SNAP to create the input deck in order to better explain the nodalization



FUKUSHIMA PLANT DATA



Simple animation to visualize the results

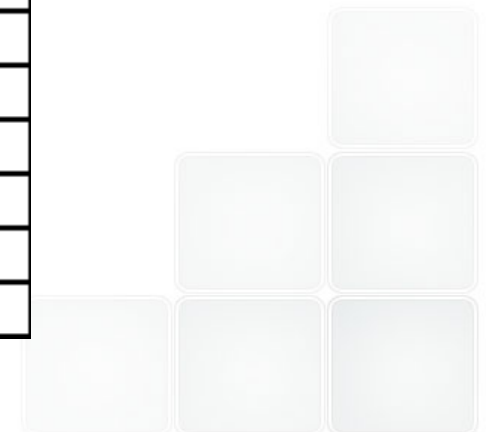


STEADY STATE



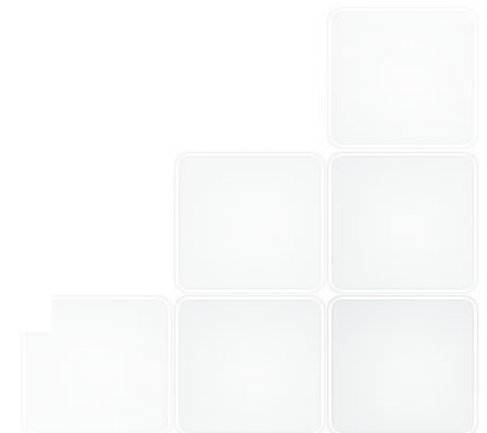
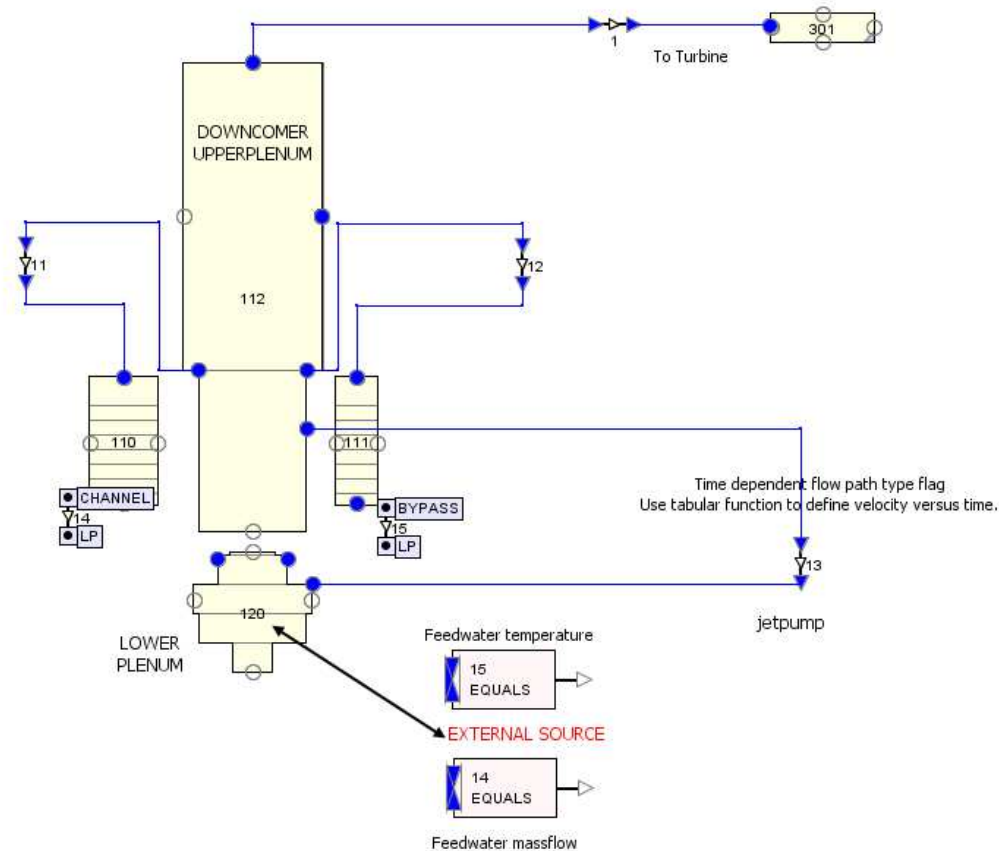
- ❑ No operating parameters available for Fukushima Daiichi Unit 1
- ❑ Model Validation performed using public data from Santa Maria de Garoña NPP (Spain)
 - Similar unit: BWR-3, Mark I, 1380 MWth

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?

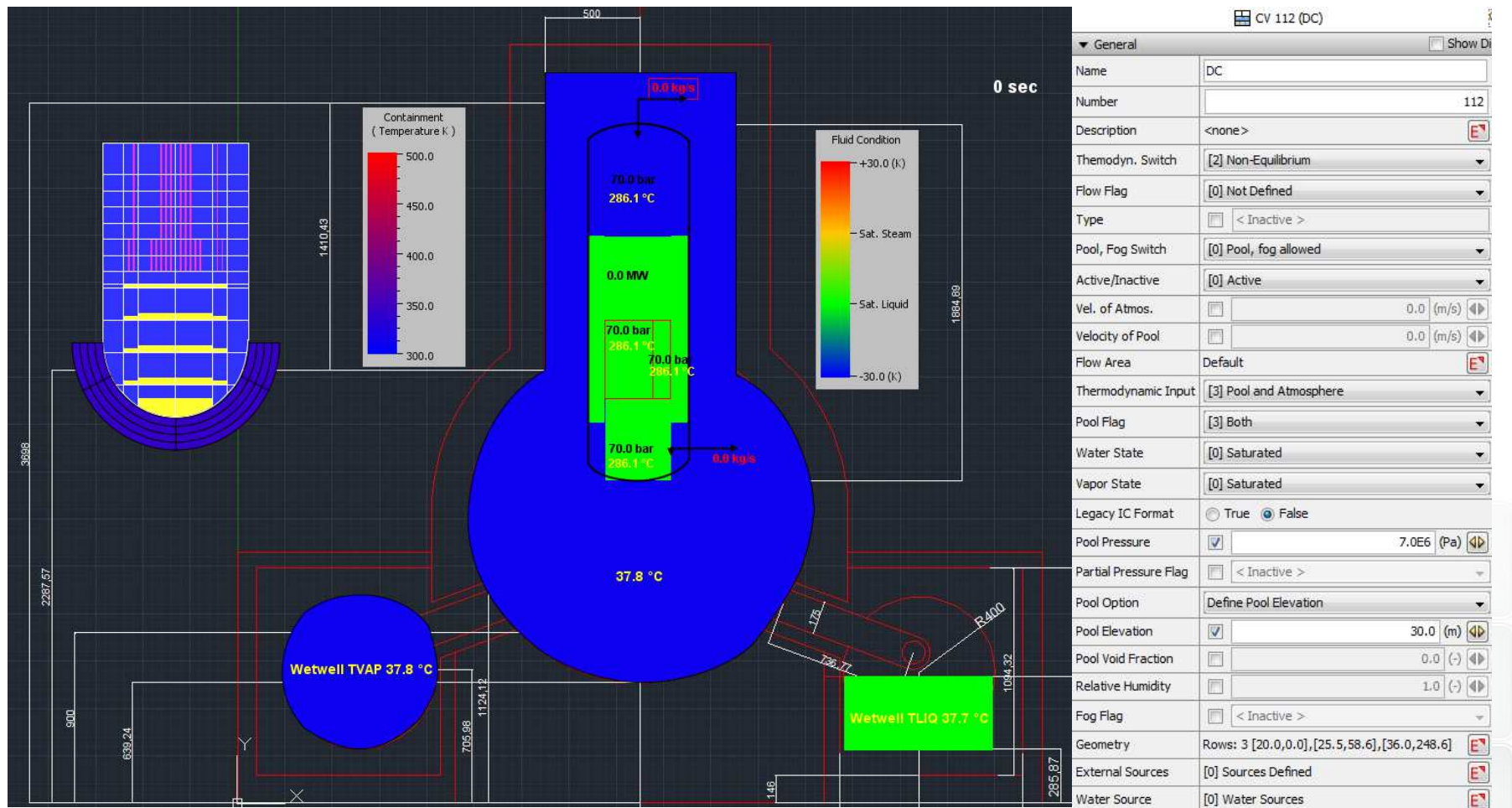


STEADY STATE



Attempt #1

Start with all operating steady conditions

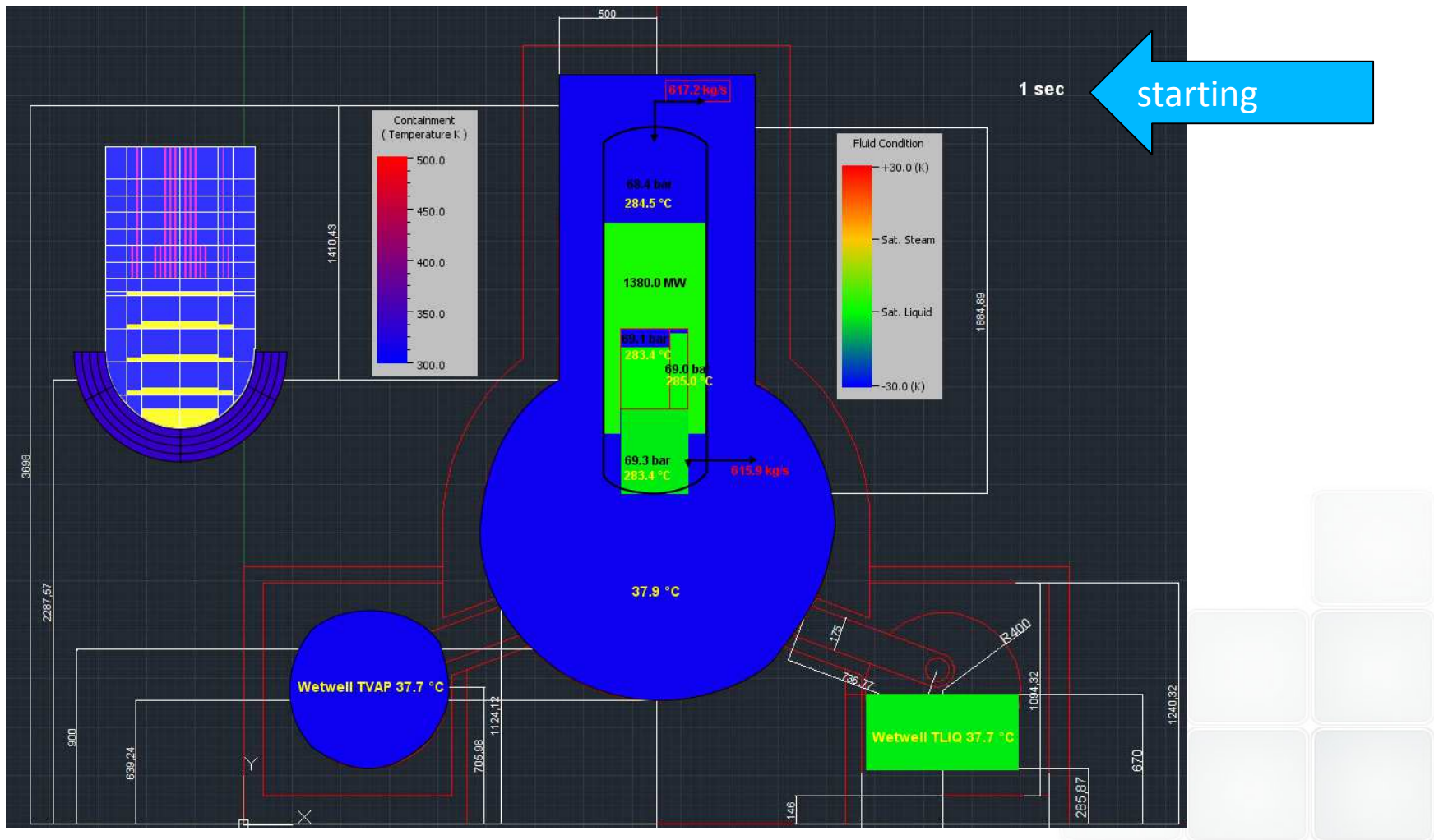


STEADY STATE



Attempt #1

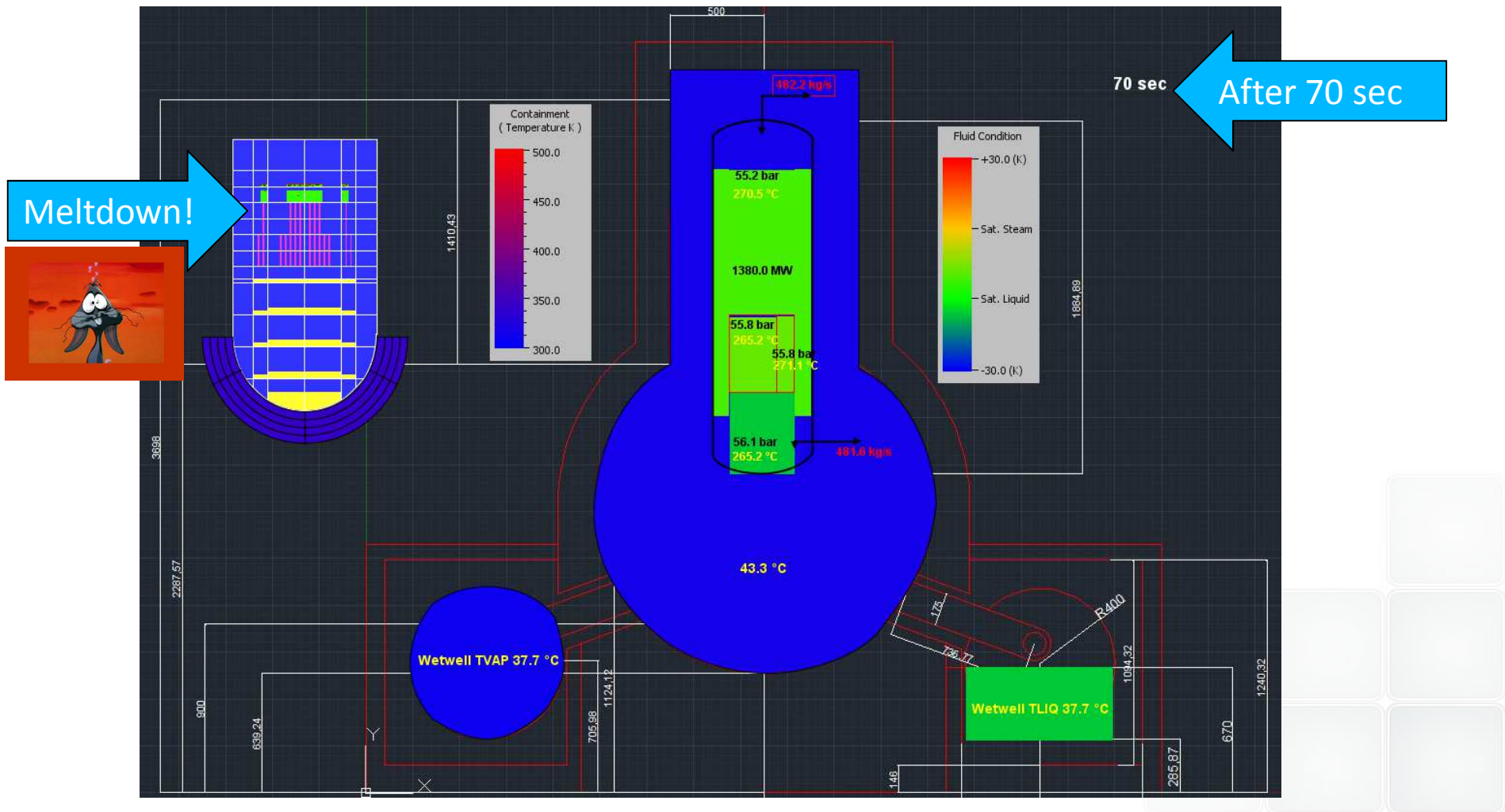
Start with all operating steady conditions



STEADY STATE

Attempt #1

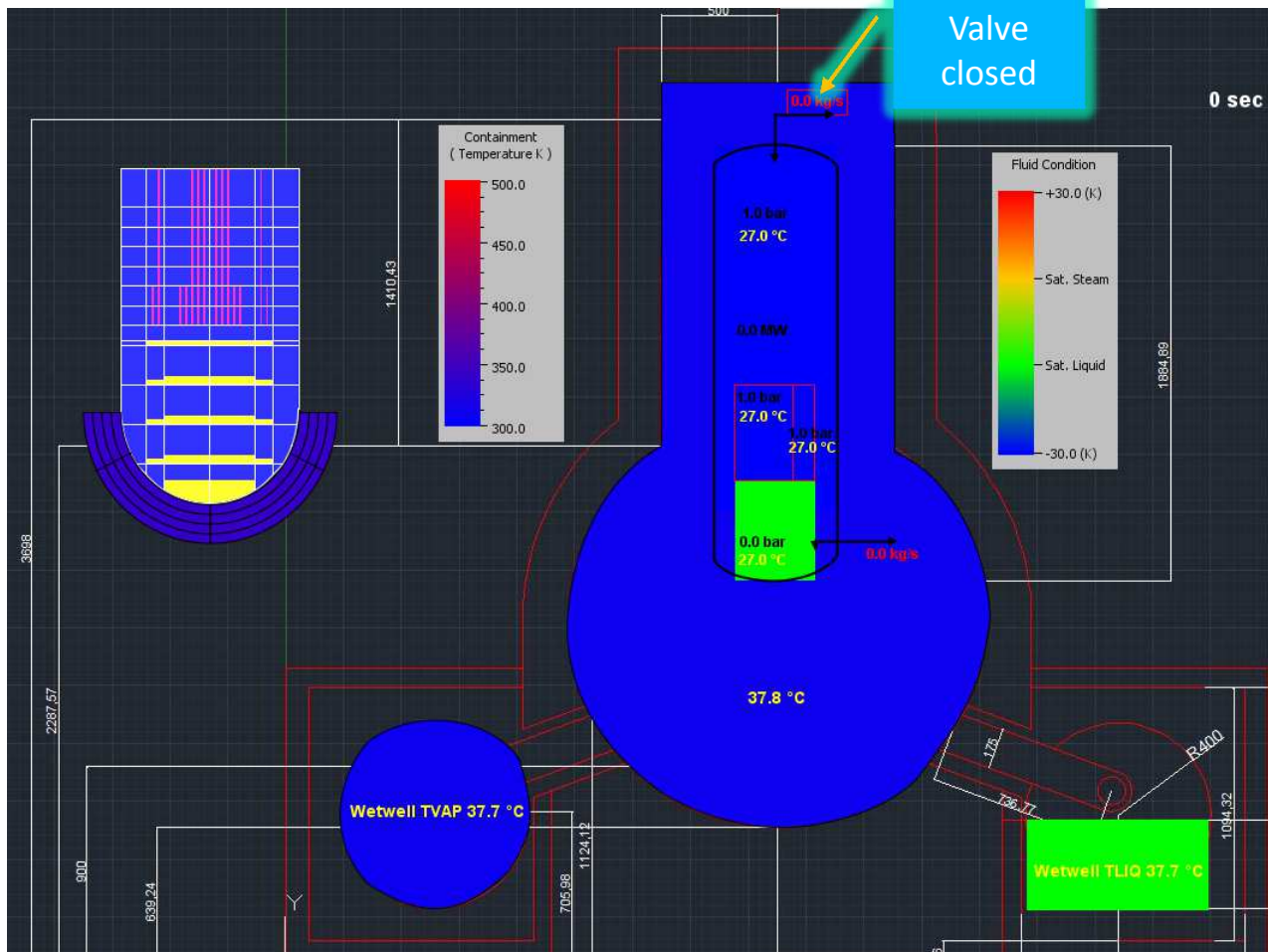
Start with all operating steady conditions



STEADY STATE



Attempt #2 Start with no power, vessel full

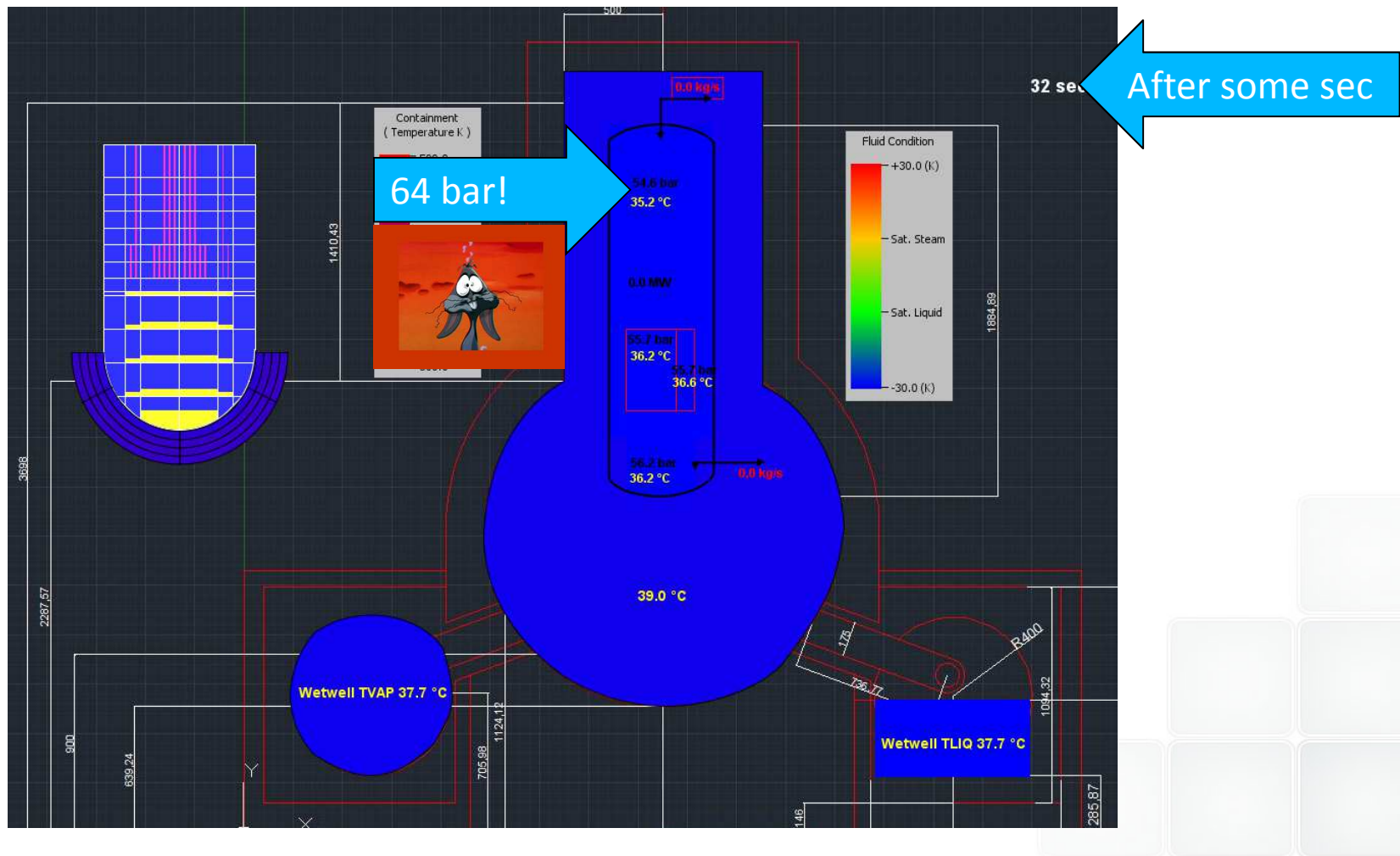


CV 112 (DC)	
General	
Name	DC
Number	112
Description	<none>
Thermodyn. Switch	[1] Equilibrium
Flow Flag	[0] Not Defined
Type	< Inactive >
Pool, Fog Switch	[0] Pool, fog allowed
Active/Inactive	[0] Active
Vel. of Atmos.	0.0 (m/s)
Velocity of Pool	0.0 (m/s)
Flow Area	Default
Thermodynamic Input	[3] Pool and Atmosphere
Pool Flag	[1] Only Pool
Water State	[1] Subcooled
Legacy IC Format	<input type="radio"/> True <input checked="" type="radio"/> False
Pool Pressure	<input checked="" type="checkbox"/> 1.0E5 (Pa)
Pool Temperature	<input checked="" type="checkbox"/> 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



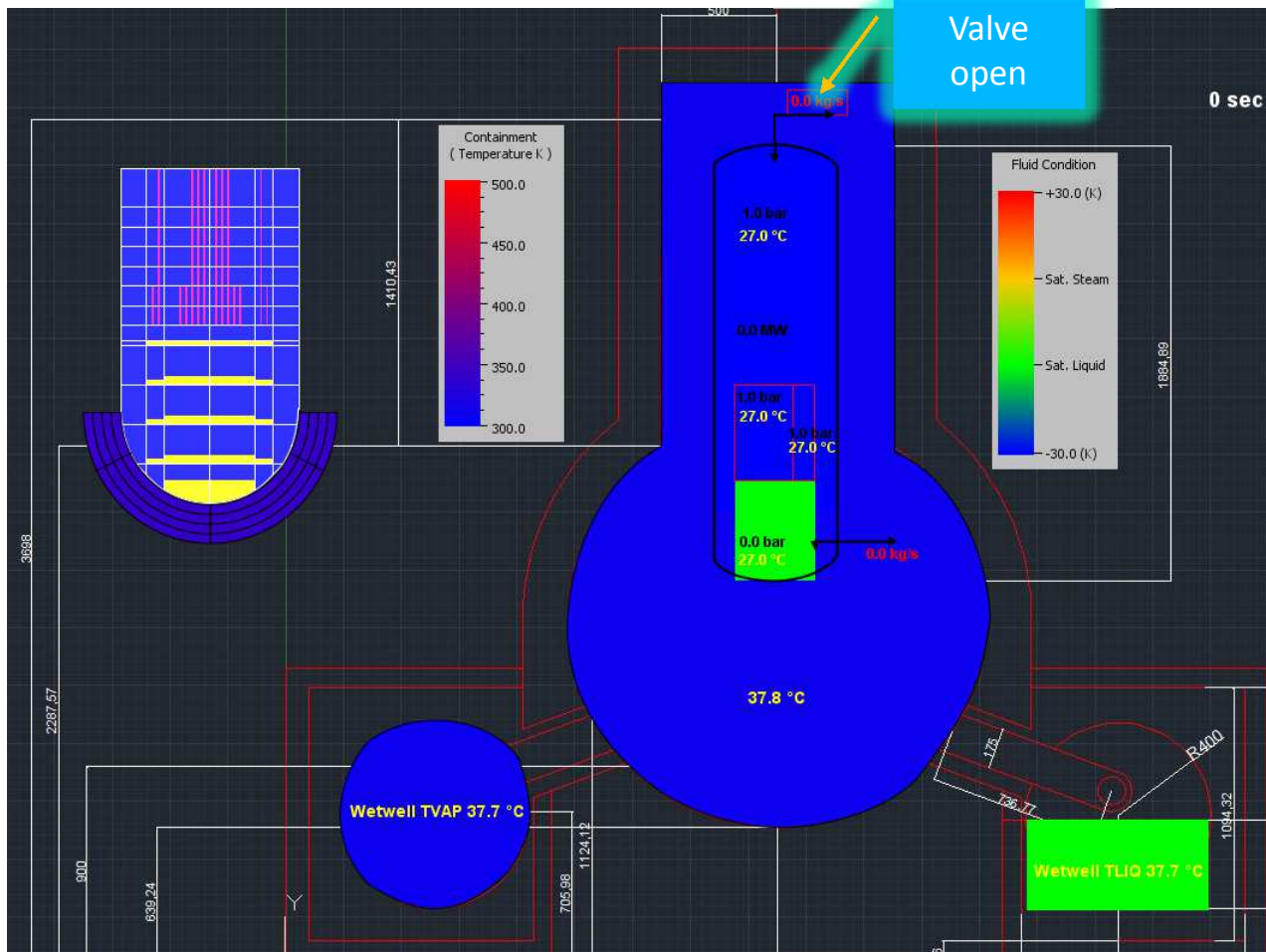
Attempt #2
Start with no power, vessel full



STEADY STATE



Attempt #2 bis
Start with no power, vessel full

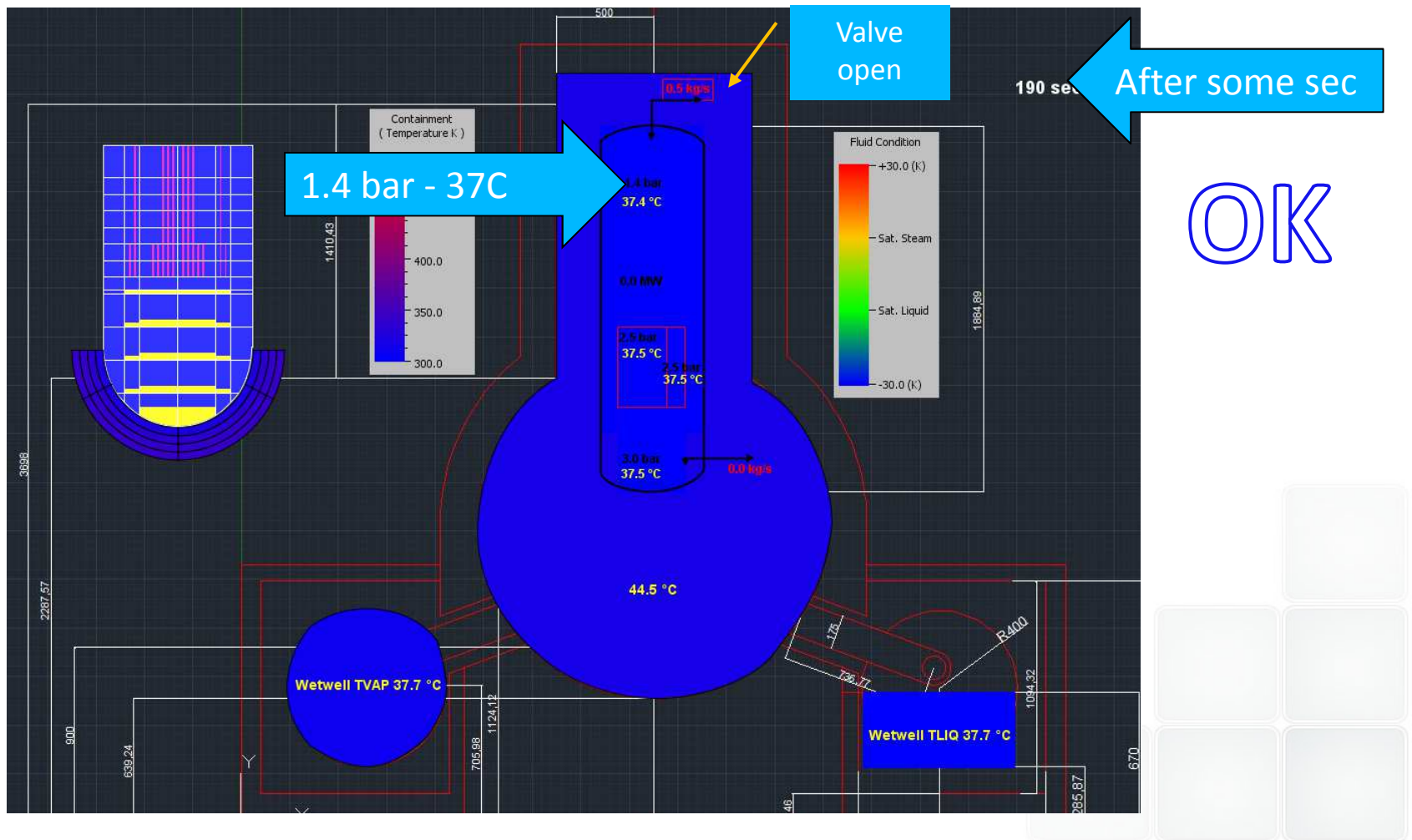


CV 112 (DC)	
General	
Name	DC
Number	112
Description	<none>
Thermodyn. Switch	[1] Equilibrium
Flow Flag	[0] Not Defined
Type	< Inactive >
Pool, Fog Switch	[0] Pool, fog allowed
Active/Inactive	[0] Active
Vel. of Atmos.	0.0 (m/s)
Velocity of Pool	0.0 (m/s)
Flow Area	Default
Thermodynamic Input	[3] Pool and Atmosphere
Pool Flag	[1] Only Pool
Water State	[1] Subcooled
Legacy IC Format	<input type="radio"/> True <input checked="" type="radio"/> False
Pool Pressure	<input checked="" type="checkbox"/> 1.0E5 (Pa)
Pool Temperature	<input checked="" type="checkbox"/> 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



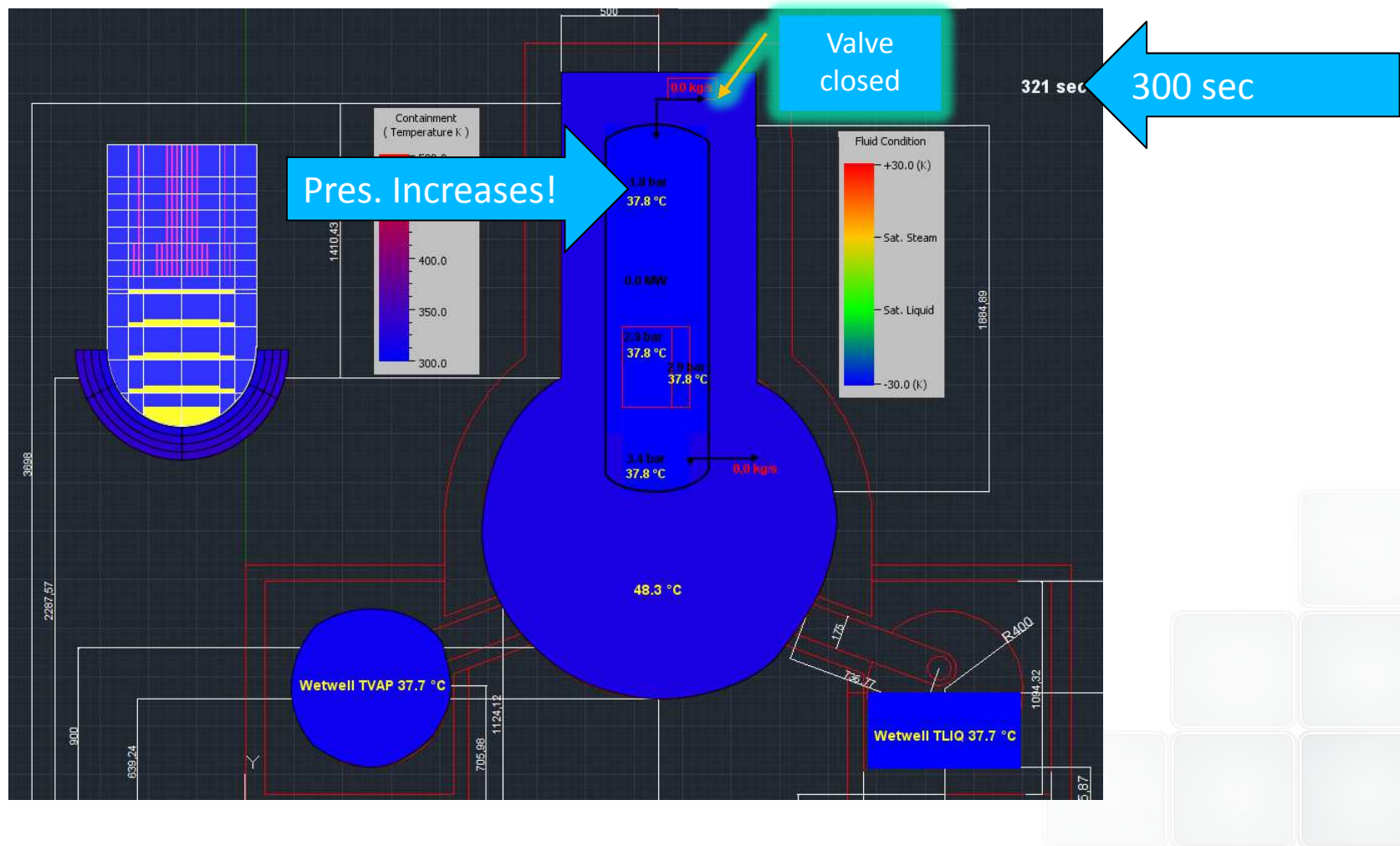
Attempt #2 bis
Start with no power, vessel full



STEADY STATE



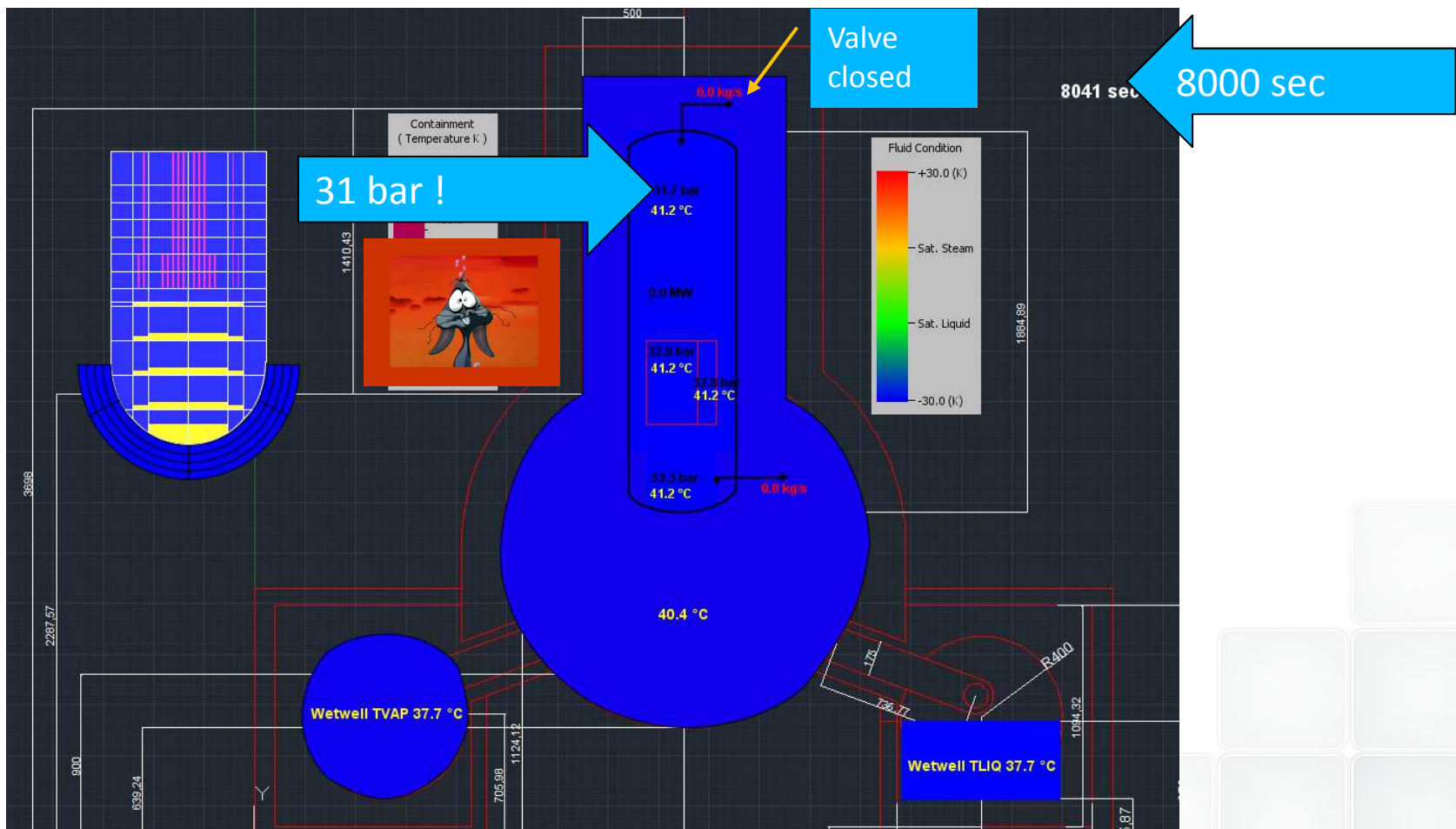
Attempt #2 bis
Start with no power, vessel full



STEADY STATE



Attempt #2 bis
Start with no power, vessel full

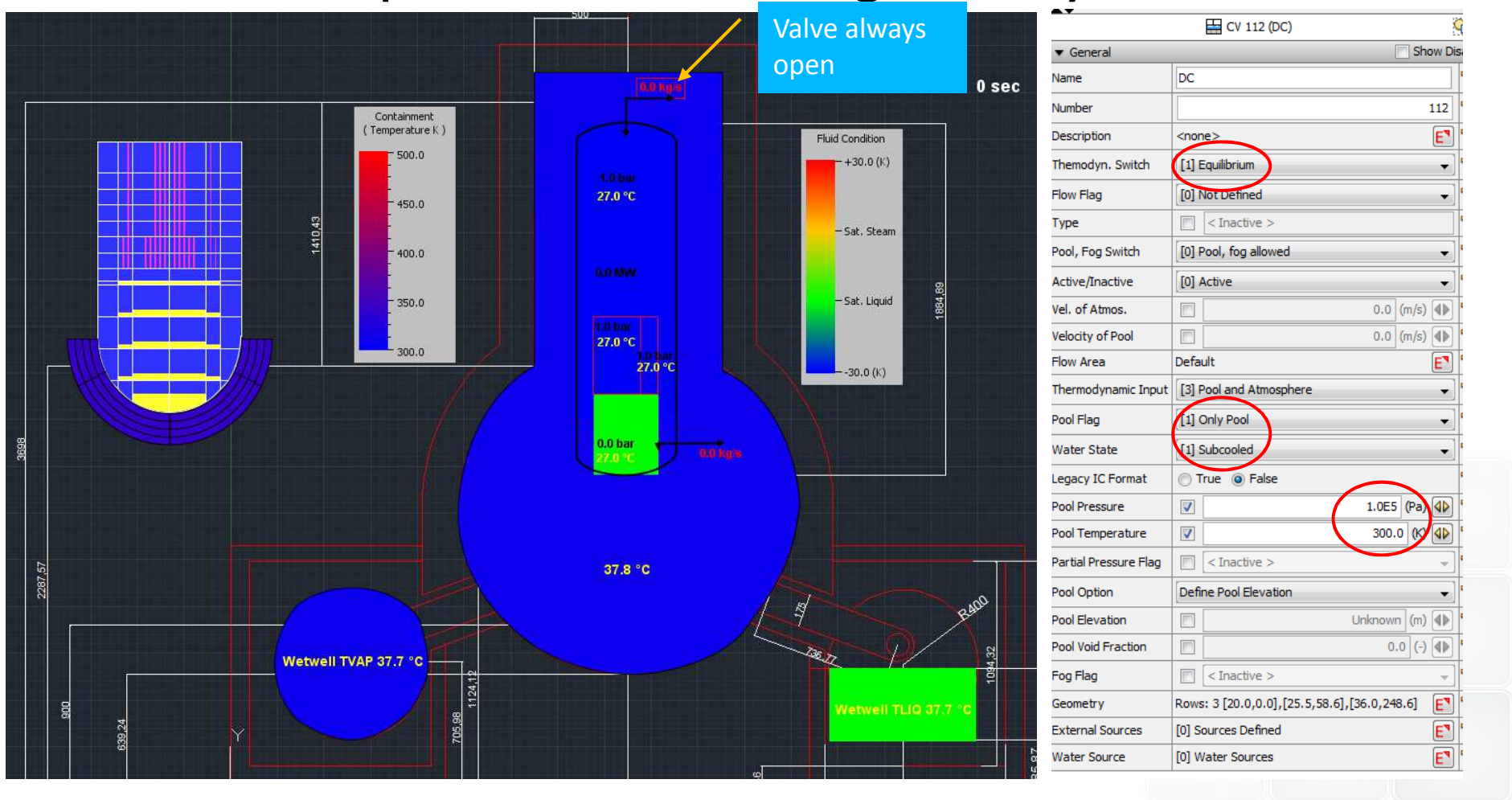


STEADY STATE



Attempt #3

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

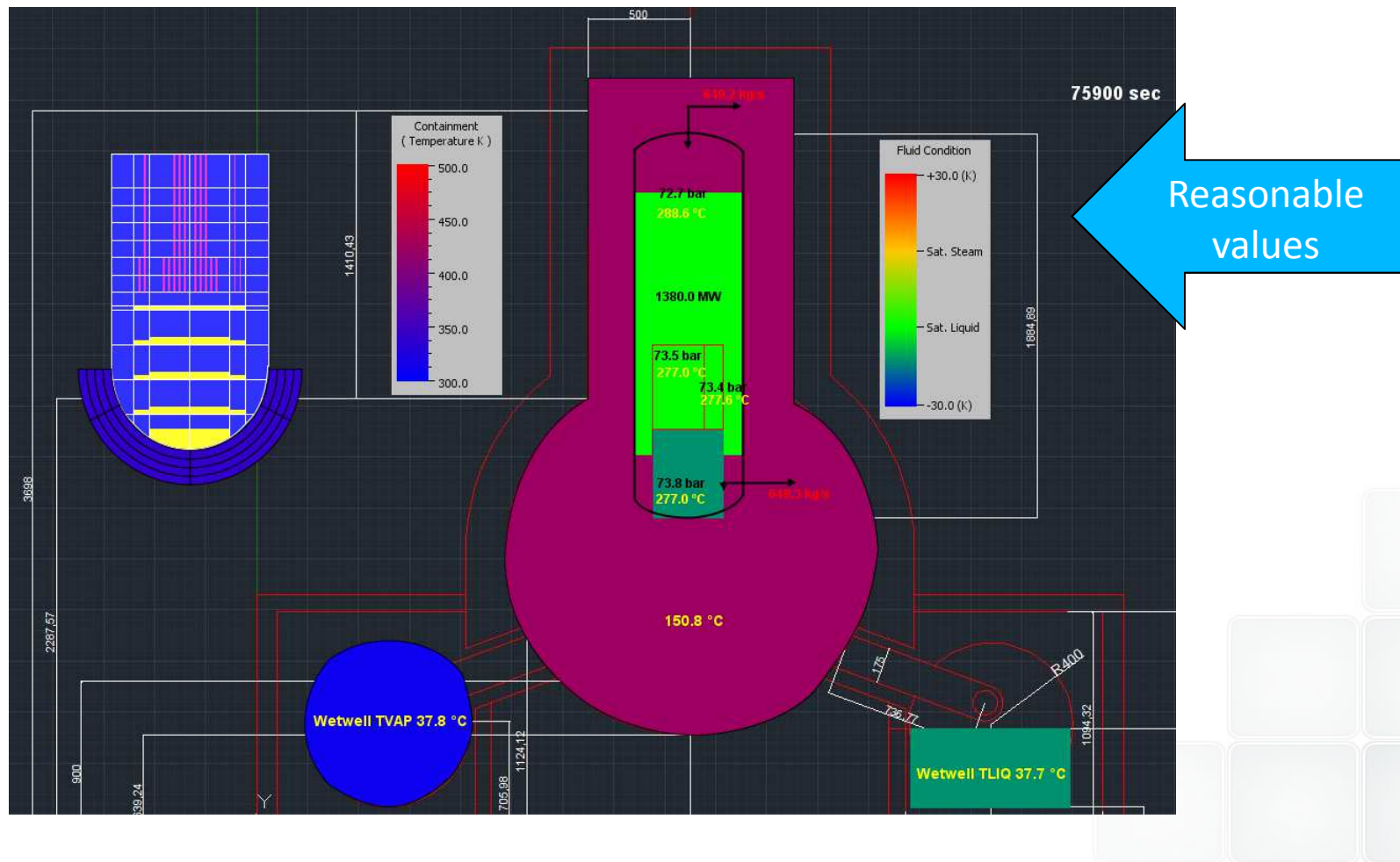


STEADY STATE



Attempt #3

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

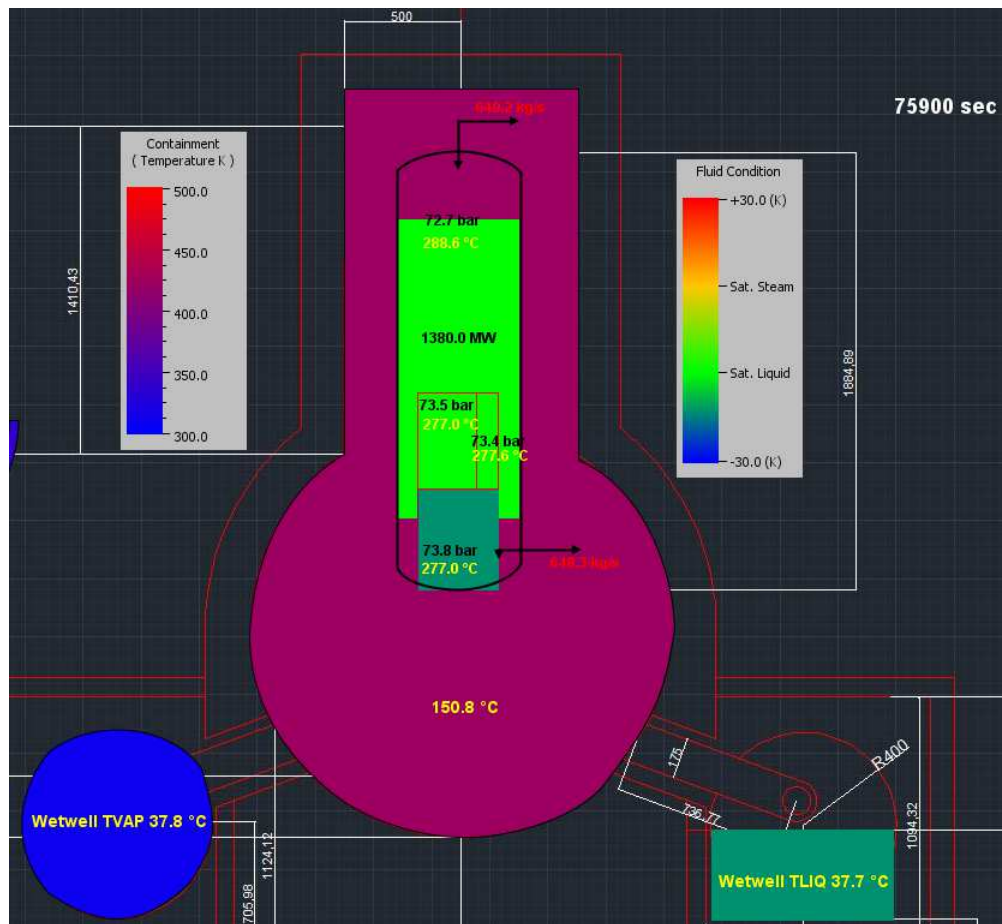


STEADY STATE



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

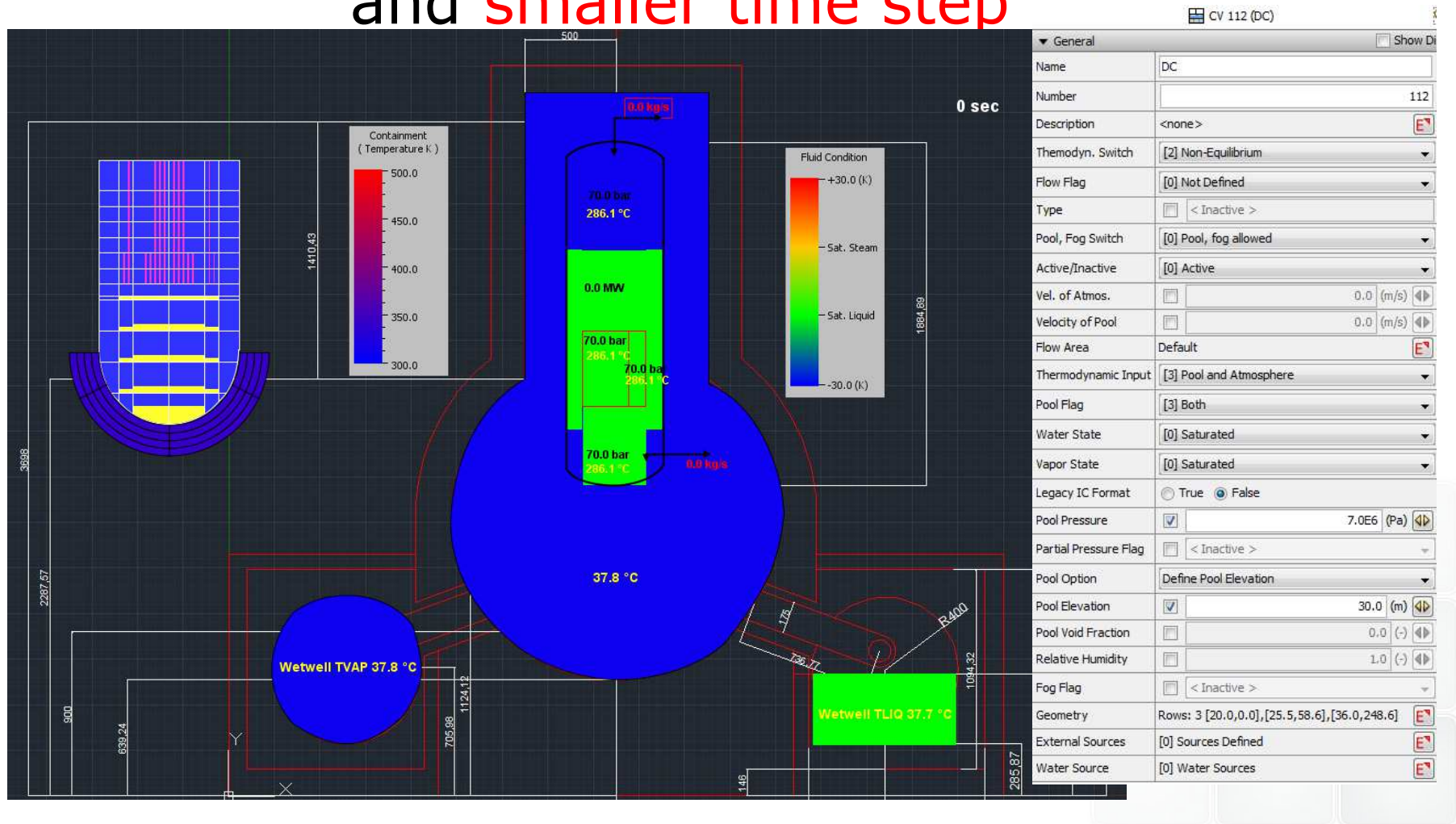
Interactive Variable:
 Channel set to CFVALU_17
 Variable set to "feedwtcntrl"
 1.0
 H2O MFLOW FP2 = 649
 Result: CF16 = 648

STEADY STATE



Attempt #4

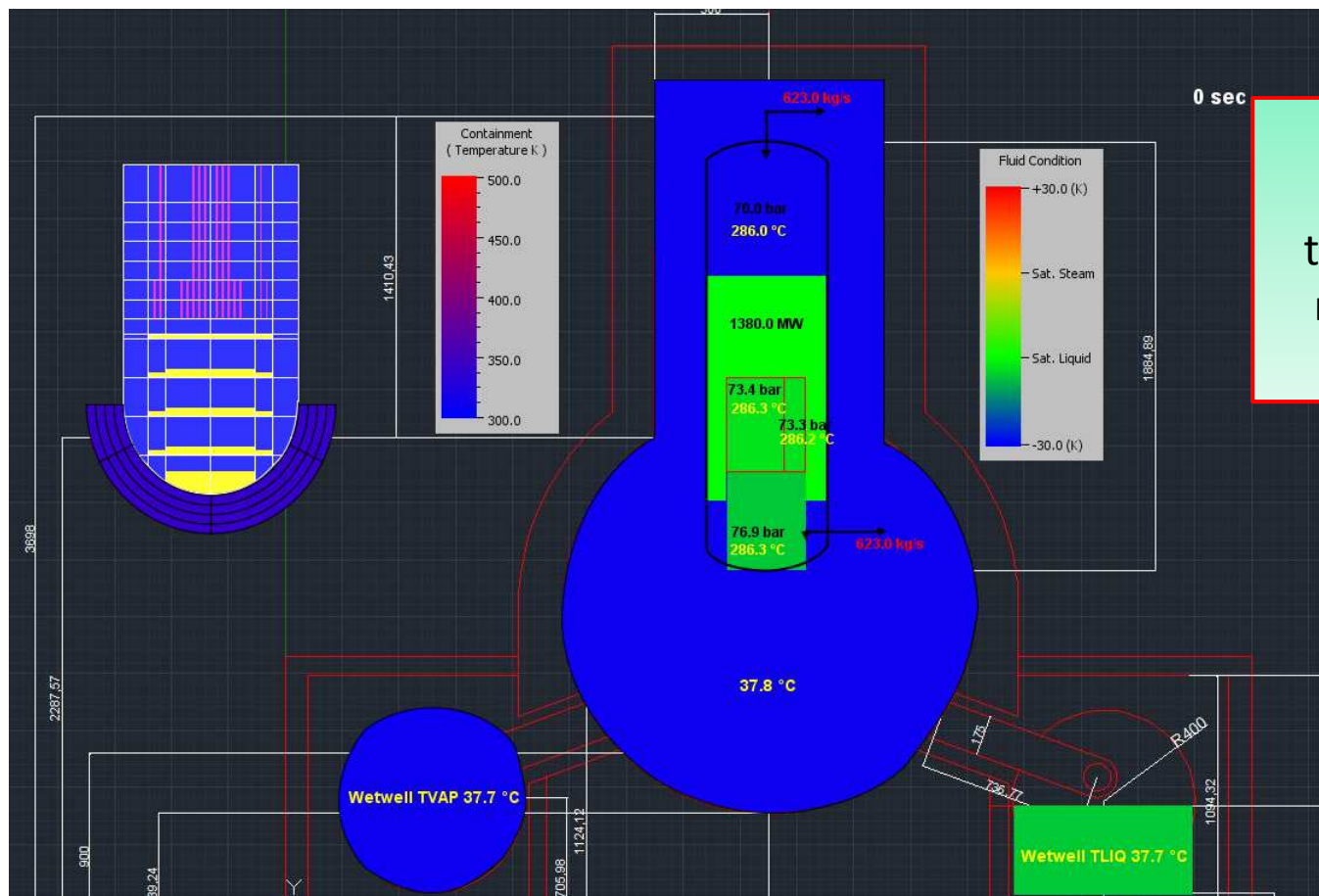
Start with all operating steady conditions and **smaller time step**



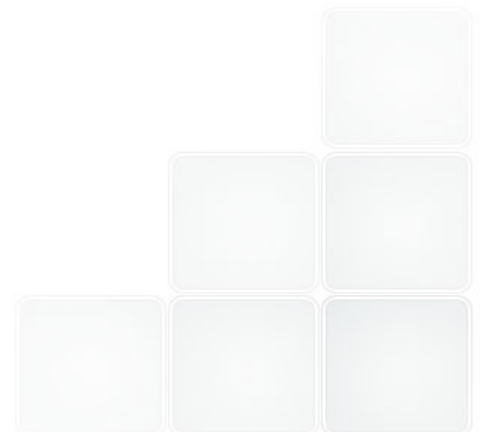
STEADY STATE

Attempt #4

Start with all operating steady conditions
and **smaller time step**



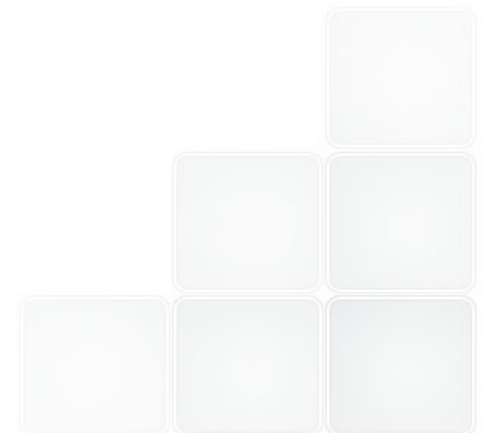
With a smaller (0.01)
maximum allowed
timestep the calculation
runs fine from the very
beginning!!



CONCLUSIONS

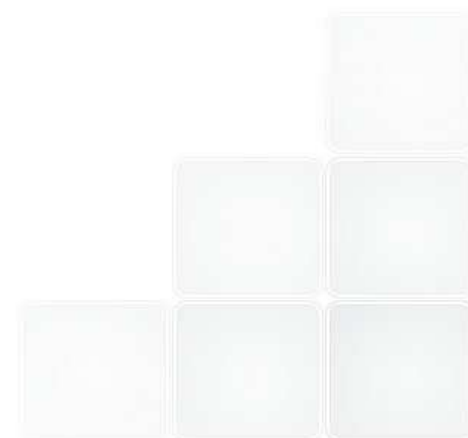


- Time step has crucial importance
- Some code behaviours are unexplainable (ex. Valve closing)
- Interactive variables are very useful
- Join our folder-in-the-cloud and share information





Gratie



Some bugs??

Supporting structures can't be just made of Zircaloy

Spacer grids

Phebus Bundle

