GOTHIC Reactor Building Mixing Analysis

Performed by
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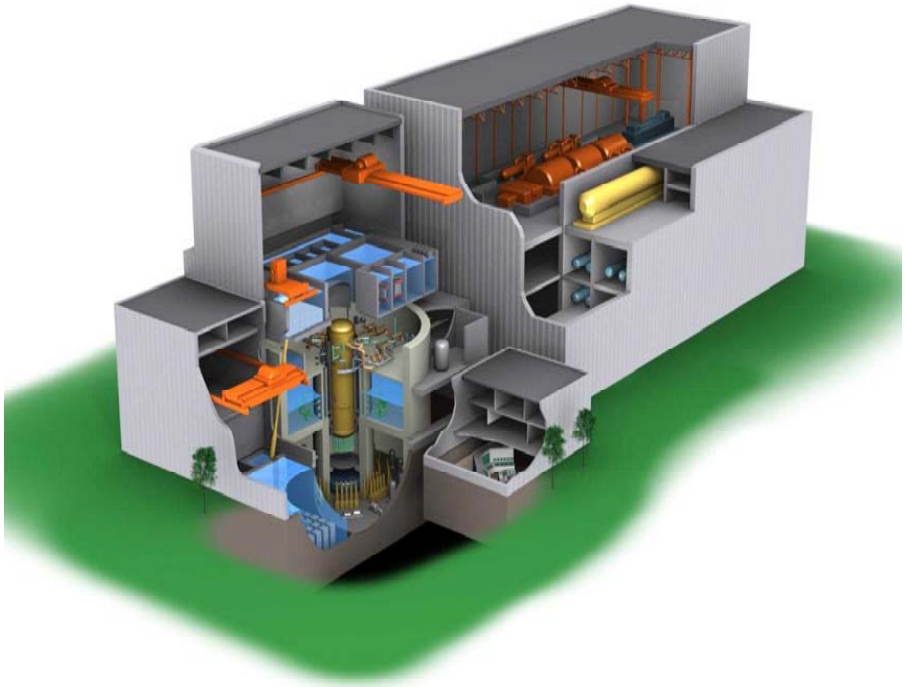

Presented by
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GE Hitachi Nuclear Energy

Computer Code

- Calculation performed with GOTHIC 7.2a
- GOTHIC (Generation of Thermal Hydraulic Information for Containment)
- GOTHIC is developed and maintained under the Numerical Application Inc. QA program in compliance with 10CFR50 Appendix B

ESBWR Application

Evaluation of Reactor Building response to design basis accidents with respect to

- Mixing of fission products released from containment
- Pressure and temperature determination

Application Validation by Empirical Testing From Qualification Report

Hanford Containment Mixing Test

- Experimental program to study mixing of hydrogen and helium in a nitrogen atmosphere by natural and forced convection
- Good test fidelity to ESBWR's nitrogen inerted containment considering hydrogen generation by radiolysis
  - Other applicable tests can be found in sections 14 through 22 of the GOTHIC qualification report

Mixing Model

Volumes

- The principal element of a model is a control volume, which is used to model the space within a building or subsystem that is occupied by fluid. The fluid may include noncondensing gases, steam, drops or liquid water. As a minimum, a GOTHIC model consists of at least one lumped parameter volume. Typically, a control volume represents a room or group of rooms within a building, or the fluid region of a subsystem.
- Nodalization of those compartments of the reactor building that participate in the process of dilution and mixing of fission products and gases released from the primary containment in case of LOCA and/or SBO is considered.

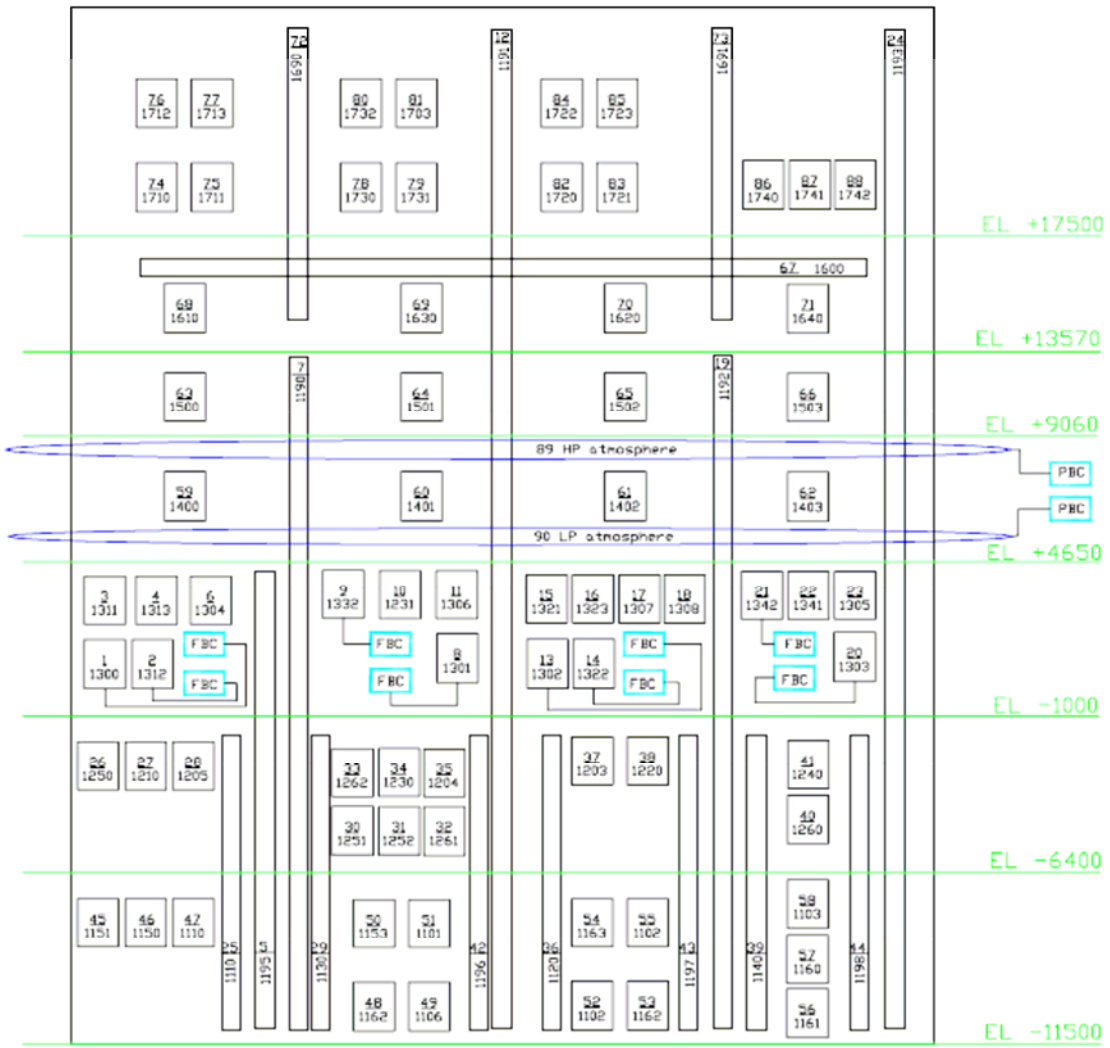
Input data

- ESBWR nuclear island general arrangement: 105E3908 issue 3
- RB rooms free volume = 90%

{{{Security-Related Information - Withhold Under 10 CFR 2.390.}}}

GOTHIC Nodalization

Reactor Building



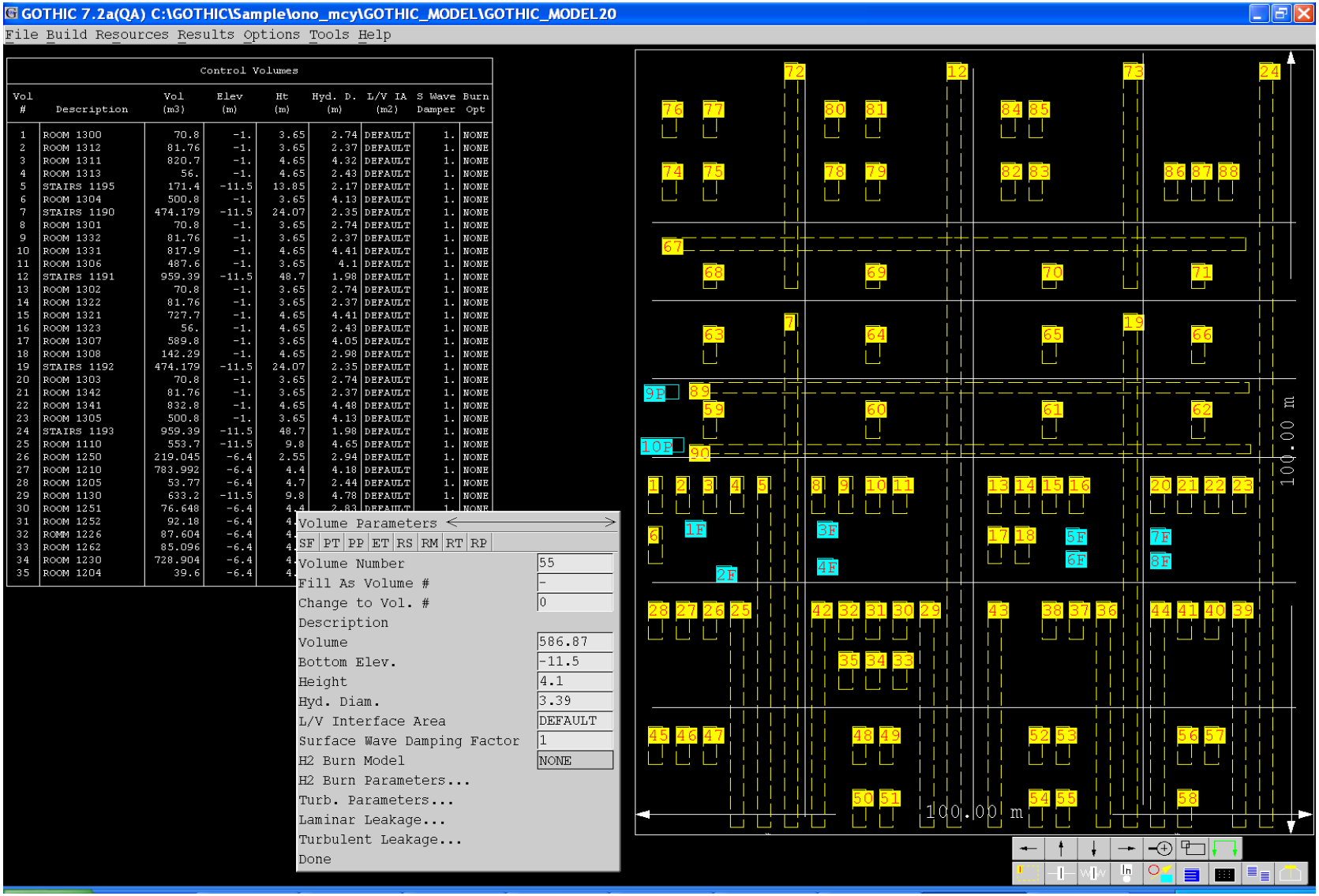
ROOM

GOTHIC NUMBER

ESBWR NUMBER

PBC: Pressure boundary condition
FBC: Flow boundary condition

GOTHIC Volume Nodalization



Flow Paths Considered

FLOW PATHS

Flow paths model hydraulic connections between any two computational cells, which includes lumped parameter volumes and cells in subdivided volumes. Flow paths are used to model flow through doorways, pipe penetrations, pipes, vents and so forth. A flow path can also model a hydraulic connection in which both connections are in the same volume or cell.

- Doorways. Door clearances
- HVAC ducts

GOTHIC Door Room to Room Flow Paths

Description	Door type	Vol A	Vol B	Elevation (m)
1110-1130	1f	25	29	-10.45
1110-1140	1f	25	39	-10.45
1120-1130	1f	36	29	-10.45
1120-1140	1f	36	39	-10.45
1130-1196	1f	29	42	-10.45
1120-1107	1	36	52	-10.45
1140-1198	1fw	39	44	-10.45
1151-1150	1r(esp)	45	46	-10.45
1150-1100	1r(esp),1r(esp)	46	47	-10.45
1100-1190	1fhem	47	7	-10.45
1196-1100	1fh	42	47	-10.45
1100-1101	1f	47	51	-10.45
1101-1191	1fh	51	12	-10.45
1101-1152	1r(esp)	51	48	-10.45
1101-1153	2r(esp)	51	50	-10.45
1101-1102	1fw	51	55	-10.45
1102-1197	1f	55	43	-10.45
1102-1163	2r(esp)	55	54	-10.45
1102-1162	1r(esp)	55	53	-10.45
1102-1198	1f	55	44	-10.45
1102-1103	1fw	55	58	-10.45
1103-1160	1r(esp)	58	57	-10.45
1160-1161	1r(esp)	57	56	-10.45
1103-1193	1f	58	24	-10.45
1103-1195	1f	58	5	-10.45
1103-1100	1fw	58	47	-10.45
1102-1192	1fem	55	19	-10.45
1106-1101	1r(esp)	49	51	-10.45
1110-1205	1fem	25	28	-6.4
1205-1140	1fem	28	39	-6.4
1205-1195	1f	28	5	-6.4
1203-1197	1f	37	43	-6.4
1203-1198	1f	37	44	-6.4
1210-1230	1f	27	34	-6.4
1210-1240	1f	27	41	-6.4
1240-1220	1f	41	38	-6.4
1204-1230	1f	35	34	-6.4
1210-1190	1f	27	7	-6.4
1230-1191	1fem	34	12	-6.4
1220-1192	1f	38	19	-6.4
1240-1193	1fem	41	24	-6.4
1300-1312	1f	1	2	-1

Description	Door type	Vol A	Vol B	Elevation (m)
1301-1332	1f	8	9	-1
1302-1322	1f	13	14	-1
1303-1342	1f	20	21	-1
1300-1303	1f	1	20	-1
1301-1302	1f	8	13	-1
1312-1304	1fr	2	6	-1
1332-1306	1fr	9	11	-1
1322-1307	1fr	14	17	-1
1342-1305	1fr	21	23	-1
1304-1306	1f,3f	6	11	-1
1306-1307	1f,3f	11	17	-1
1307-1305	1f,3f	17	23	-1
1305-1195	1f	23	5	-1
1304-1195	1f	6	5	-1
1307-1308	1(ab),3(ab)	17	18	-1
1308-1331	1fhem	18	10	-1
1331-1311	2f	10	3	-1
1311-1341	1f	3	22	-1
1341-1321	2f	22	15	-1
1321-1308	1fhem	15	18	-1
1321-1323	1	15	16	-1
1311-1313	1	3	4	-1
1311-1190	1f	3	7	-1
1331-1191	1f	10	12	-1
1321-1192	1f	15	19	-1
1341-1193	1f	22	24	-1
1300-rbc	no door	1	1F	-1
1312-rbc	no door	2	2F	-1
1301-rbc	no door	8	3F	-1
1332-rbc	no door	9	4F	-1
1302-rbc	no door	13	5F	-1
1322-rbc	no door	14	6F	-1
1303-rbc	no door	20	7F	-1
1342-rbc	no door	21	8F	-1
1400-1401	2f	59	60	4.65
1401-1402	1f	60	61	4.65
1402-1403	2f	61	62	4.65
1403-1400	1f	62	59	4.65
1400-1190	1f	59	7	4.65
1401-1191	1f	60	12	4.65
1402-1192	1f	61	19	4.65
1403-1193	1f	62	24	4.65

Description	Door type	Vol A	Vol B	Elevation (m)
1403-OUT	2fex	62	89	4.65
1400-OUT	2fex	59	89	4.65
1490-OUT	3fex,3fex	91	90	4.65
1192-OUT	1femex	19	90	4.65
1193-OUT	1femex	24	90	4.65
1191-OUT	1fex,estanca	12	90	4.65
1190-OUT	1femex	7	90	4.65
1500-1501	2f	63	64	9.06
1501-1502	1f	64	65	9.06
1502-1503	2f	65	66	9.06
1503-1500	1f	66	63	9.06
1500-1190	1f	63	7	9.06
1501-1191	1fem	64	12	9.06
1502-1192	1f	65	19	9.06
1503-1193	1fem	66	24	9.06
1610-1600	1f	68	67	13.57
1630-1600	1f	69	67	13.57
1620-1600	1f	70	67	13.57
1640-1600	1f	71	67	13.57
1600-1190	1f	67	72	13.57
1600-1191	1f	67	12	13.57
1600-1691	1f	67	73	13.57
1600-1193	1f	67	24	13.57
1600-1490	3fex	67	91	13.57
1710-1711	1r	74	75	17.5
1710-1712	1r	74	76	17.5
1710-1713	1r	74	77	17.5
1710-1730	1f	74	78	17.5
1730-1731	1r	78	79	17.5
1730-1732	1r	78	80	17.5
1730-1703	1r	78	81	17.5
1720-1721	1r	82	83	17.5
1720-1722	1r	82	84	17.5
1720-1723	1r	82	85	17.5
1720-1740	1f	82	86	17.5
1740-1741	1r	86	87	17.5
1740-1742	1r	86	88	17.5
1710-1690	1f	74	72	17.5
1730-1191	1f	78	12	17.5
1720-1691	1f	82	73	17.5
1740-1193	1f	86	24	17.5
1740-1490	3fex	86	91	17.5

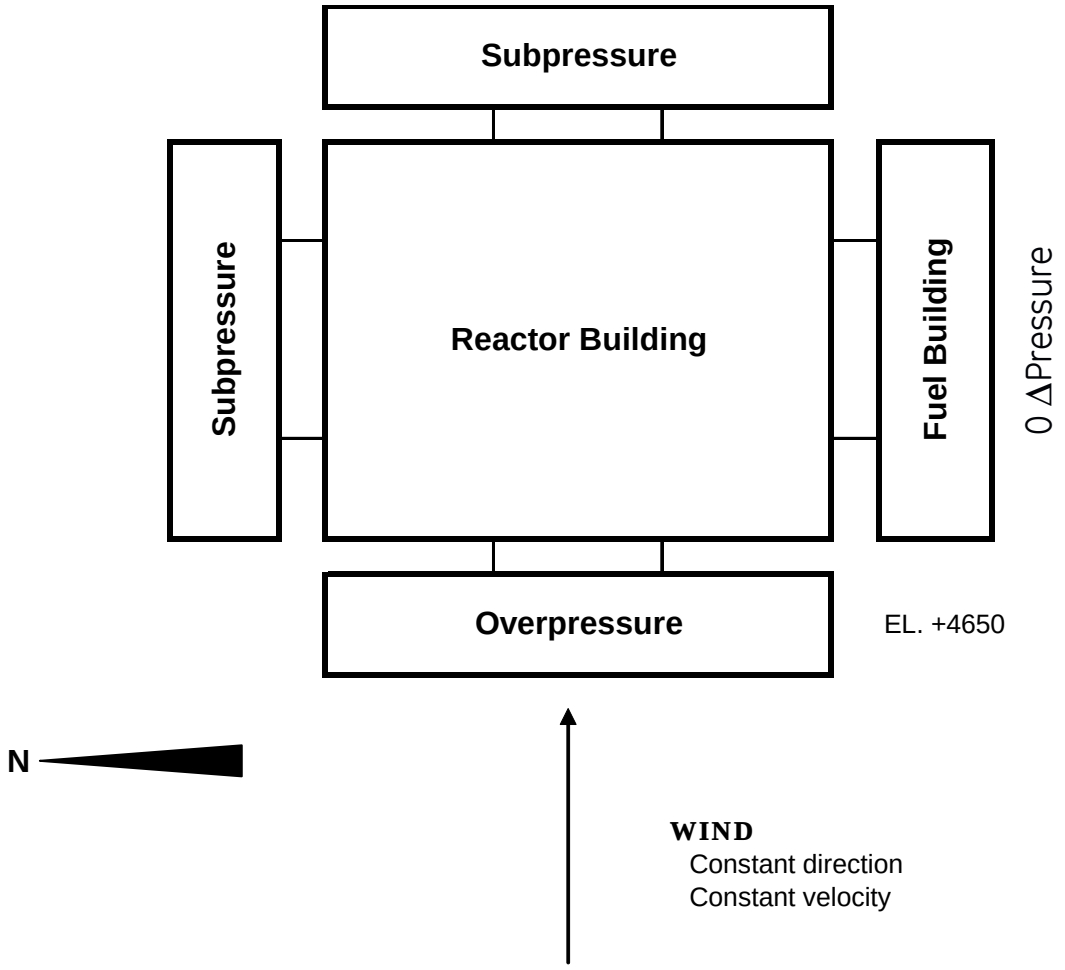
GOTHIC Flow Path Nodalization

Boundary Conditions

Fluid boundary conditions allow the user to specify mass sources and sinks and energy sources and sinks for control volumes

- Containment leakage
- Wind velocity and direction

BOUNDARY CONDITIONS
WIND PRESSURE IN REACTOR BUILDING



Tracer Gas

- A tracer gas is applied in GOTHIC for a comparison to the 40% mixing assumption in the ESBWR dose calculation
- The release simulated in GOTHC is compared to the release in the dose calculation
- The leakage from containment is mainly from steam and nitrogen
- Radioisotopes can move through the Reactor Building toward outdoors suspended on nitrogen and/or steam
- Taking into account that steam will condense across the Reactor Building, it is fully conservative to consider that all radioisotopes are suspended on nitrogen, so a maximum dose will be obtained outside the reactor building

NITROGEN is the tracer gas

Internal Room Temperatures

- The internal room temperatures in the Reactor Building can affect the mixing behavior
- The internal room temperatures are taken from the heat up calculation, normal operating temperatures are also considered

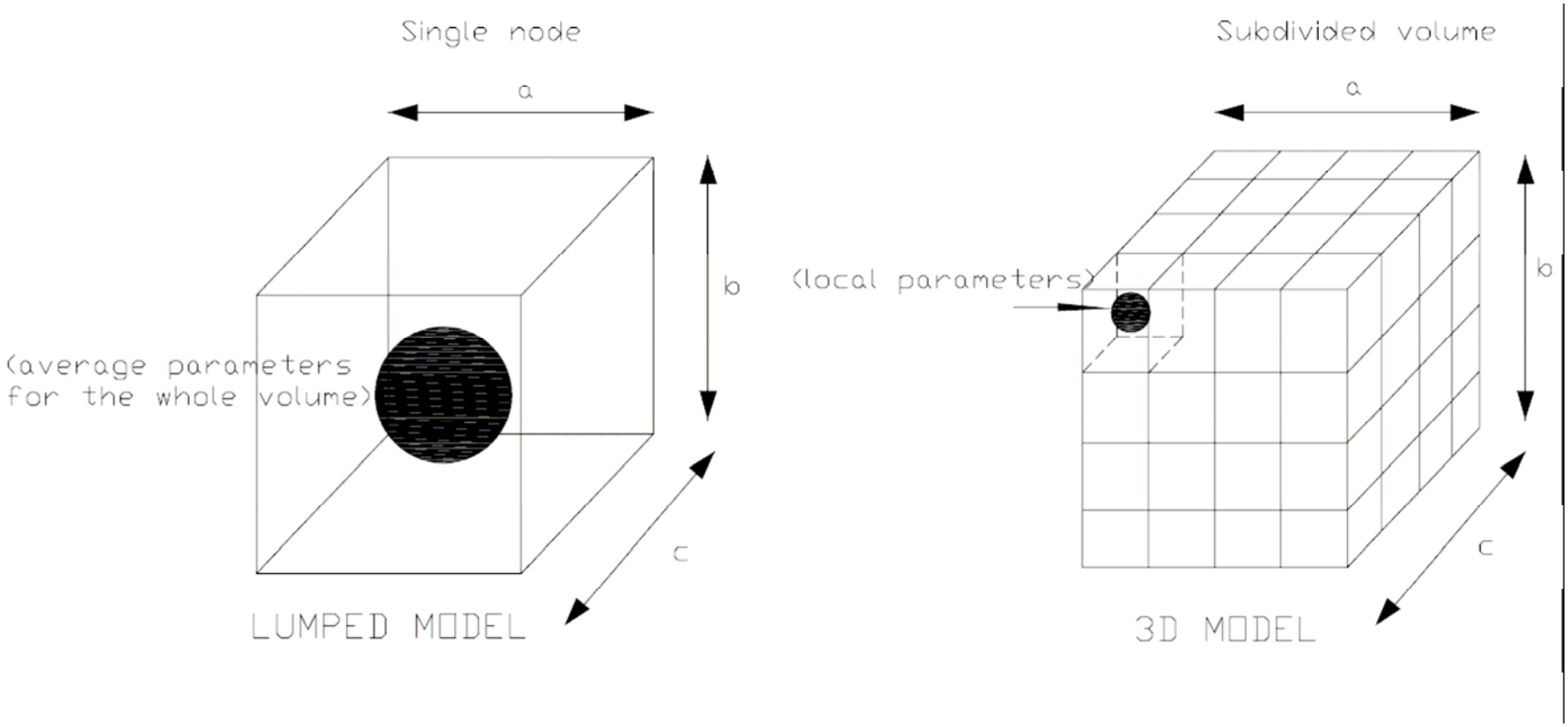
Multidimensional vs. lumped modeling

- A control volume represents a room within a building or a fluid region.

  GOTHIC allows computational volumes to be treated as:
  - Lumped parameter (single node)
  - Multidimensional nodalization

- Selection criteria for subdivided volumes
  - Volume size
  - Inlet and outlet location
  - Location of heat sources

Multidimensional vs. lumped nodalization



Penetrations and Leakage

- The total leakage is equal to 0.4 % wt of Containment volume at 310 kPa (g) (45 psig) and Standard Temperature 20°C (68°F)
- Total Leakage has been distributed proportional to the penetration areas
- Similar to methodology used to develop the volume credited for mixing in the dose analyses

Results

Results from this analysis are compared to the dose calculation assumptions to confirm that it uses a bounding value