Integrity Analysis of Turbine Building for the MSLB Using GOTHIC code for Wolsong NPP Unit 2

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1. Introduction

A break in the piping between the steam generators and the turbine can lead to rapid loss of secondary circuit inventory. A break inside the turbine building leads to pressure differentials between different areas of the turbine building. In order to improve the environmental protection of various components within the turbine building, a wall has been erected which effectively separates the area in which these components are housed from the rest of the turbine building. Relief panels installed in the turbine building ensure that the pressure differential across the wall would be less than that required to jeopardize the wall integrity [1].

The turbine building service wing is excluded from the scope of this analysis. It is further assumed that any doors in the heavy wall are as strong as the wall itself, with no gaps or leakage around the doors.

For the full scope safety analysis of turbine building for Wolsong NPP unit 2, input decks for the various objectives, which can be read by GOTHIC 7.2a, are developed and tested for the steady state simulation [2].

The input data files provide simplified representations of the geometric layout of the turbine building (volumes, dimensions, flow paths, doors, panels, etc.) and the performance characteristics of the various turbine building subsystems. The parameter values are based on best estimate or design values for that parameter. The analysis values are determined by conservatism depending on the analysis objective and may be different for various analysis objectives.

2. Turbine Building Modeling

The turbine building can be subdivided into four principal sections:

a. the turbine building service wing, which houses the diesel generators, etc.,
b. the turbine building wing, housing the large open space of the turbine building,
c. the turbine building wing with several closed rooms: cable tray room, battery and inverter room, etc., and
d. the turbine building wing, housing the feedwater system equipment, etc.

The turbine building service wing is excluded from the scope of this analysis. Further, there is a heavy wall running east-west along the grid line N, dividing the turbine building wing into two distinct parts and thus separating the above mentioned closed rooms and the feedwater system equipment from the rest of the turbine building wing. It is further assumed that any doors in the heavy wall are as strong as the wall itself, with no gaps or leakage around the doors. The scope of this analysis is thus limited only to that portion of the turbine building wing which is south of the heavy wall, along grid line N.

2.1 Turbine Building Model

The turbine building wing under consideration in this analysis is divided into three distinct areas, the basement area between elevation 85.57 m and 88.92 m, an area between elevation 88.92 m and 104.16 m and a large area above the operating floor at elevation 104.16 m. Figure 1 shows the Nodes for these portions of the turbine building wing.

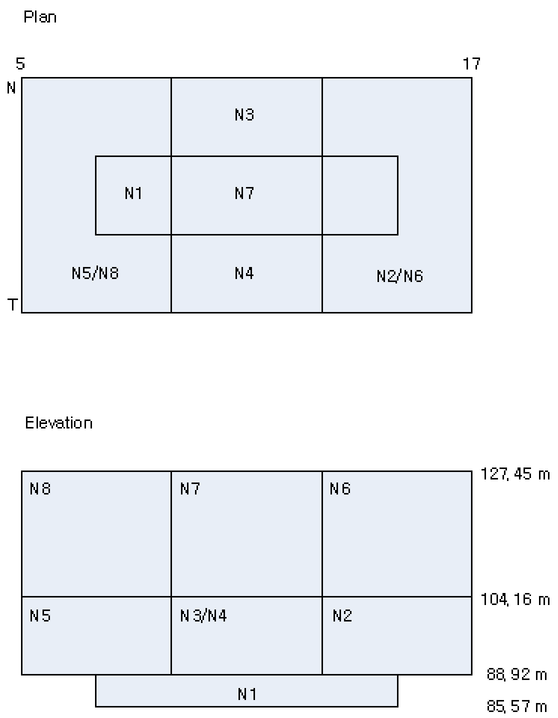

Fig. 1. Schematic Nodlization of the Turbine Building

2.2 GOTHIC Code

The GOTHIC computer code is used to analyze the turbine building pressure response following large steam pipe breaks. GOTHIC input requires the node information, including elevation, height, and hydraulic diameter. Node elevation and height are used to calculate the node gravitational head, and the cross-sectional area of the node is used to be calculated by node height.

2.3 Node Modeling Details

In order to perform the pressure transient calculations in the turbine building, it is necessary to estimate the volume of the building. The volumes calculated are derived from the drawings. 10% of this volume is removed, somewhat arbitrarily, to account for miscellaneous piping and equipment. This volume is further decreased by the approximate volume of the turbine slab and turbine-generator. The volumes, tabulated in Table 1, are assigned to the turbine building Nodes, based on their location in the turbine building.

Nodes 1 to 5 represent the turbine building volume below the operating floor upon which the turbine is supported (elevation 104.16 m). Nodes 6 to 8 represent the turbine building volume above the operating floor. Node 9, the atmospheric node, is modelled as a large node, connecting a pressure boundary at 1 atm.

Table I: Hydraulic Parameters of Turbine Hall Nodes

Node	**Volume (m^3)**	**Node El. (m)**	**Node Height (m)**
N01	5917.92	85.57	3.35
N02	22520.77	88.92	15.06
N03	5577.47	88.92	15.06
N04	8160.96	88.92	15.06
N05	13858.77	88.92	15.06
N06	38036.47	100.00	23.29
N07	29929.71	104.16	23.29
N08	22046.06	104.16	23.29
Total	146048.12		

2.4 Flow Path

The flow path end elevation is the lowest point of the flow path end in the node. Flow path end heights define the vertical distance occupied by the connection of a flow path to a node. Flow path end elevations are used to calculate the gravitational head across the flow path, the gravitational head within the volumes, and to determine whether the flow path end is above or below the liquid pool in the volume. The elevation and height of each flow path are modeled considering actual position and geometry.

The flow path area is the cross-sectional area in the direction of the flow path which joins two nodes. Flow path areas are calculated by evaluating the minimum area of flow, in the flow path, connecting the two nodes. Flow path areas could also be blow-out panels or louvres. In turbine building for the Wolsong NPP Unit 2, panels and louvers are provided between the turbine building and the outside atmosphere. Panels and louvers are located on grid line T and grid line 17, above and below elevation 104.16 m [3-9].

The blow-out panels, which separate the turbine building and the outside atmosphere, have a rupture pressure of 1 kPa ± 0.1 kPa. Tests (on similar panels) have shown that full opening may be achieved under 250 milliseconds.

The louvers (with dampers) are considered as permanent openings between the turbine building and the outside atmosphere, and have a free area of 42%.

The hydraulic diameter of each flow path is used to calculate the wall friction head in GOTHIC. It is calculated using following equation.

$$D_h = \frac{4A}{P_w}$$

where, D_h = hydraulic diameter of flow path
A = flow area
P_w = wetted perimeter

The hydraulic diameter of each flow path is used in the calculation of inertia length and flow resistance coefficient.

The friction length is taken as the actual distance of the flow path (i.e. the door thickness, the thickness of the orifice or thickness of concrete walls between two areas) and the inertia length is calculated using approximated formula.

The flow resistance coefficient (k value) is estimated based on the geometry of the flow path.

2.5 Initial Condition

In this model, the outside atmosphere is assumed to be at 101.325 kPa(a), 37℃ and 0% relative humidity. The turbine hall is assumed to be at a pressure of 101.325 kPa(a), 40℃ and 0% relative humidity.

3. Analysis Method

3.1 Turbine Building Analysis Methodology

All louvers are assumed to be fully open throughout the transient. If a set of blow-out panels in a particular node breaks, they are all assumed to break simultaneously.

3.2 Analysis Scope

A 100% steam balance header break, with break area equal to twice the cross-sectional area of the balance header, is simulated. This break is symmetric with respect to its effect on the primary circuit, that is, all steam generators and both primary circuit loops are affected similarly. The balance header is the largest steam pipe outside containment and thus causes the fastest loss of inventory.

In addition, a break on a main steam line between the steam balance header and the turbine, with break size equivalent to twice the area of the steam line is simulated. The break is inside the turbine building, near the turbine building safety wall. The location is chosen to examine the pressure impact on this wall, since a break near the wall may affect it more significantly than a steam balance header break farther from the wall.

The steam main failures are postulated to occur either in Node 3 or 4. The steam balance header failure is postulated to occur in Node 2.

4. Analysis Results

The results for the turbine building analysis cases are qualitatively analyzed. All of the differential pressures are less than the design values. Thus, the integrity of the turbine building wall is assured.

4.1 100% Steam Balance Header Break

Table II shows the differential pressure inside the turbine building during the transient. The maximum differential pressure is 2.293 kPa(d) across the between Node 2 and Node 6. This peak differential pressure occurs very quickly, and then decreases to almost zero by 2 to 3 seconds. Thus, the structural integrity of the turbine building is not affected. In all locations, the pressures are well below the analysis acceptance limits.

Table II: Differential Pressure of Turbine Hall Nodes

Node A	Node B	Differential Pressure (kPa(d))
1	2	1.046
1	3	0.613
1	4	1.139
1	5	0.738
2	3	0.988
2	4	1.608
2	6	2.293
3	4	1.112
3	5	0.685
3	7	1.193
4	7	1.135
5	8	1.095
6	7	1.323
7	8	1.300

4.2 100% Steam Break in Node 3

Table III shows the differential pressure inside the turbine building during the transient. The maximum differential pressure is 1.421 kPa(d) across the between Node 2 and Node 6. This peak differential pressure occurs very quickly, and then decreases to almost zero by 1 second. Thus, the structural integrity of the turbine building is not affected. In all locations, the pressures are well below the analysis acceptance limits.

Table III: Differential Pressure of Turbine Hall Nodes

Node A	Node B	Differential Pressure (kPa(d))
1	2	0.660
1	3	0.381
1	4	0.679
1	5	0.474
2	3	0.420
2	4	0.483
2	6	1.421
3	4	0.645
3	5	0.425
3	7	0.841
4	7	0.812
5	8	0.698
6	7	0.792
7	8	0.974

4.3 100% Steam Break in Node 4

Table VI shows the differential pressure inside the turbine building during the transient. The maximum differential pressure is 1.298 kPa(d) across the between Node 2 and Node 6. This peak differential pressure occurs very quickly, and then decreases to almost zero by 1 second. Thus, the structural integrity of the turbine building is not affected. In all locations, the pressures are well below the analysis acceptance limits.

Table VI: Differential Pressure of Turbine Hall Nodes

Node A	Node B	Differential Pressure (kPa(d))
1	2	0.764
1	3	0.565
1	4	0.682
1	5	0.489
2	3	0.625
2	4	0.620
2	6	1.298
3	4	0.710
3	5	0.474
3	7	0.727
4	7	1.067
5	8	0.757
6	7	0.728
7	8	1.008

5. Conclusions

For pipe breaks in the turbine building, the maximum differential pressure is 1.421 kPa(g), which is well below the acceptance criteria. And the maximum pressure both above and below the turbine floor is 3.62

kPa(g), which is well below the acceptance criteria of 8 kPa(g) and 13 kPa(g) for the upper and lower level respectively.

REFERENCES

[1] D. S. Jin, Main Steam Line Breaks, 86M-03500-AR-028, Rev.0, 2014.

[2] Frank Rahn, “GOTHIC Containment Analysis Package, User Manual, Version7.2a(QA)”, NAI 8907-02 Rev. 17, January 2006.

[3] Turbine Building Equipment Arrangement Drawing 8602-40000-7702-01-GA-E and 8602-40000-7703-01-GA-E.

[4] Turbine Building Equipment Arrangement Drawing 8624-40000-7705-01-GA-E.

[5] Turbine Building Equipment Arrangement Drawing 8602-40000-7710-01-GA-E to 8602-40000-7711-GA-E .

[6] Turbine Building Cross Section ‘A’ Equipment Arrangement Drawing 8602-40000-7713-01-GA-E.

[7] Turbine Building Equipment Arrangement Drawing 8602-40000-7706-01-GA-E to 8602-40000-7709-01-GA-E.

[8] Service Area S-4 Section Turbine Building Area 13 Section piping Main Steam Turbine Building Plan (Structural Steel) Drawing 8602-22500-7707-01-GA-E to 8602-22500-7716-01-GA-E.

[9] Turbine Building Wall Elevations Drawing 8602-22700-7701-01-GA-E to 8602-22700-7702-01 -GA-E.