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Your ref: Project Number 740
Our ref: DCP/NRC2036

November 5, 2007

Subject: AP1000 COL Standard Technical Report Submittal of APP-GW-GLN-143, Revision 0 (TR 143)

In support of Combined License application pre-application activities, Westinghouse is submitting AP1000 Standard Combined License Technical Report Number 143. The enclosed Technical Report, APP-GW-GLN-143 (TR-143), has been prepared to address a potential AP1000 Design Certification amendment acceptance review issue related to shield building changes identified in TR-127 (APP-GW-GLR-127, Revision 1). The issue was identified as Issue SPBA-1 in the attachment to Westinghouse Letter DCP/NRC2035, "NRC Acceptance Review of AP1000 Design Certification Amendment Application", dated November 2, 2007.

The issues considered are related to shield building changes that impact the airflow that contributes to the passive containment cooling. The changes to the shield building have been included in Technical Reports APP-GW-GLN-105 (TR-105) and APP-GW-GLR-127 (TR-127). These issues were discussed during a phone call between Westinghouse and the NRC staff on October 25, 2007. The NRC requested additional information on the details of the design changes, changes in modeling of airflow through the vents, the impact of the changes on the response to external airflow, the impact on results of test programs, the impact on containment pressure, and the potential for blocking of the vents. These items are discussed and additional information provided in the enclosed report.

This report is submitted as part of the NuStart Bellefonte COL Project (NRC Project Number 740). The information included in this report is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification.

The purpose for submittal of this report was explained in a March 8, 2006 letter from NuStart to the NRC.

Pursuant to 10 CFR 50.30(b), APP-GW-GLN-143, Revision 0, "Evaluation of the Effect of Shield Building Changes on Containment Response and Safety Analyses," Technical Report Number 143, is submitted as Enclosure 1 under the attached Oath of Affirmation.

It is expected that when the NRC review of Technical Report Number 143 is complete, the report will be considered approved for all COL applicants referencing the AP1000 Design Certification.

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Questions or requests for additional information related to content and preparation of this report should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Westinghouse requests the NRC to provide a schedule for review of the technical report within two weeks of its submittal.

Very truly yours,

Andrew J. Sterdis

A. Sterdis, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Attachment

1. "Oath of Affirmation," dated November 5, 2007

/Enclosure

1. APP-GW-GLN-143, Revision 0, "Evaluation of the Effect of Shield Building Changes on Containment Response and Safety Analyses," Technical Report Number 143

cc:	D. Jaffe	-	U.S. NRC	1E	1A
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	G. Curtis	-	TVA	1E	1A
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	C. Pierce	-	Southern Company	1E	1A
	E. Schmiech	-	Westinghouse	1E	1A
	G. Zinke	-	NuStart/Entergy	1E	1A
	R. Wright	-	Westinghouse	1E	1A

ATTACHMENT 1

"Oath of Affirmation"

ATTACHMENT 1

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of:	)
NuStart Bellefonte COL Project	)
NRC Project Number 740	)

APPLICATION FOR REVIEW OF
"AP1000 GENERAL COMBINED LICENSE INFORMATION"
FOR COL APPLICATION PRE-APPLICATION REVIEW

W. E. Cummins, being duly sworn, states that he is Vice President, Regulatory Affairs and Standardization, for Westinghouse Electric Company; that he is authorized on the part of said company to sign and file with the Nuclear Regulatory Commission this document; that all statements made and matters set forth therein are true and correct to the best of his knowledge, information and belief.

W. E. Cummins
Vice President
Regulatory Affairs and Standardization

Subscribed and sworn to
before me this day
of November 2007.

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Patricia S. Aston, Notary Public
Murrysville Boro, Westmoreland County
My Commission Expires July 11, 2011
Member, Pennsylvania Association of Notaries

Patricia S Aston
Notary

ENCLOSURE 1

APP-GW-GLN-143, Revision 0

"Evaluation of the Effect of Shield Building Changes on Containment Response and Safety Analyses"

Technical Report 143

AP1000 DOCUMENT COVER SHEET

TDC: ______ Permanent File: ______

AP1000 DOCUMENT NO.	REVISION	PAGE	ASSIGNED TO	OPEN ITEMS (Y/N)
APP-GW-GLN-143	0	1 of 59	W-Sterdis	

ALTERNATE DOCUMENT NUMBER: TR-143 WORK BREAKDOWN #:

ORIGINATING ORGANIZATION:

TITLE: Evaluation of the Effect of Shield Building Changes on Containment Response and Safety Analyses

ATTACHMENTS:	DCP #/REV. INCORPORATED IN THIS DOCUMENT REVISION:
CALCULATION/ANALYSIS REFERENCE:	

ELECTRONIC FILENAME	ELECTRONIC FILE FORMAT	ELECTRONIC FILE DESCRIPTION
APP-GW-GLN-143	MSWord	

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**Plant Applicability: ☒ All AP1000 plants except: NO EXCEPTIONS

☐ Only the following plants:

APPLICABILITY REVIEWER** for J. A. Speer	SIGNATURE / DATE 11/5/07
RESPONSIBLE MANAGER* C. A. McGINNIS	SIGNATURE / DATE 11-5-07

* Approval of the responsible manager signifies that the document and all required reviews are complete, the appropriate proprietary class has been assigned, electronic file has been provided to the EDMS, and the document is released for use.

APP-GW-GLN-143
Revision 0

November 2007

AP1000 Standard Combined License Technical Report

Title: Evaluation of the Effect of Shield Building Changes on Containment Response and Safety Analyses

Westinghouse Electric Company LLC
Nuclear Power Plants
Post Office Box 355
Pittsburgh, PA 15230-0355

Document Number: APP-GW-GLN-143 **Revision Number:** 0

Title: Evaluation of the Effect of Shield Building Changes on Containment Response and Safety Analyses

Brief Description of the change (what is being changed and why):

Changes to the shield building that can affect the Passive Containment Cooling System (PCS) airflow through the shield building are described in APP-GW-GLN-105. The PCS air flow, along with the water film applied to the containment shell outer steel surface, promotes cooling and depressurization of the containment in postulated accident conditions. The evaluation below summarizes the effect of these shield building design changes on the PCS operation and the pressure response of the containment as analyzed in the AP1000 safety analyses.

I. APPLICABILITY DETERMINATION

This evaluation is prepared to document that the shield building design changes described in APP-GW-GLN-105 is a departure from Tier 2 information of the AP1000 Design Control Document (DCD) that may be included in plant specific FSARs without prior NRC approval.

The changes evaluated in this report were identified in Technical Report APP-GW-GLN-105 and are included in Design Control Document Revision 16. The applicability determination for the changes is addressed in APP-GW-GLN-105. The following applicability determination is for the results of the evaluation summarized in this report.

A.	Does the proposed change include a change to:		
	1. Tier 1 of the AP1000 Design Control Document APP-GW-GL-700	☒ NO ☐ YES	(If YES prepare a report for NRC review of the changes)
	2. Tier 2* of the AP1000 Design Control Document, APP-GW-GL-700	☒ NO ☐ YES	(If YES prepare a report for NRC review of the changes)
	3. Technical Specification in Chapter 16 of the AP1000 Design Control Document, APP-GW-GL-700	☒ NO ☐ YES	(If YES prepare a report for NRC review of the changes)
B.	Does the proposed change involve:		
	1. Closure of a Combined License Information Item identified in the AP1000 Design Control Document, APP-GW-GL-700	☒ NO ☐ YES	(If YES prepare a COL item closure report for NRC review.)
	2. Completion of an ITAAC item identified in Tier 1 of the AP1000 Design Control Document, APP-GW-GL-700	☒ NO ☐ YES	(If YES prepare an ITAAC completion report for NRC review.)

☒ The questions above are answered no, therefore the departure from the DCD in a COL application does not require prior NRC review unless review is required by the criteria of 10 CFR Part 52 Appendix D Section VIII B.5.b. or B.5c

II. TECHNICAL DESCRIPTION AND JUSTIFICATION

The design changes to the shield building result in a more restrictive air flow path for the Passive Containment Cooling System (PCS). The purpose of this report is to describe the operation of the PCS and the modifications to the AP1000 WGOTHIC evaluation model resulting from this change. Also the applicability of the AP1000 containment test program is discussed in light of these design changes. Finally, the containment pressure response for design basis accidents (DBAs) and beyond design basis accidents (BDBAs) is presented to show the effect of these design changes on the AP1000 safety analysis. Finally, the applicability of the AP1000 containment test program is discussed in light of these design changes. The results of the evaluations reported below show that the AP1000 containment pressure response is virtually unchanged for DBAs, and the conclusions reached for BDBAs are still applicable.

This report is divided into six sections and an appendix:

1.0 Passive Containment Cooling System Design Description

2.0 Applicability of AP1000 Containment Tests and PIRT/Scaling Considerations

3.0 Changes to the AP1000 WGOTHIC Evaluation Model

4.0 Results of Limiting DBA and BDBA Events

5.0 Conclusions

6.0 References

Appendix A: Detailed Drawings of the Revised AP1000 Shield Building

1.0 Passive Containment Cooling System Design Description

The PCS is a safety-related system capable of transferring heat directly from the steel containment vessel to the environment. This transfer of heat maintains the containment below the design limit of 59.7 psig (74.4 psia) following a postulated design basis accident, and reduces the containment pressure and temperature in the longer term. The PCS makes use of the steel containment shell as a heat transfer surface where steam condenses on and heats the inside surface of the containment, and the heat is conducted through the steel shell. The heated outside surface of the steel shell is cooled by water and air making use of convection, radiation, and mass transfer (water evaporation) heat transfer mechanisms. The heat energy is carried as sensible heat and water vapor by naturally circulating air which is drawn from the environment via an "always open" air flow path, which flows upward along the containment vessel outer surface, and returns to the environment via an elevated discharge/exhaust. The containment shell is wetted by water which simply drains by gravity from a water storage tank incorporated into the shield building structure above the containment. The application of water to the containment external surface is automatically initiated in response to a Hi-2 containment pressure, and no operator action is required for at least 3 days to adjust the applied water flow rate or to replenish the passive containment cooling water supply. The PCS makes use of the steel containment vessel, the concrete shield building surrounding the containment which includes air inlets and an air exhaust, and an air baffle structure between the containment and shield building that defines the air flow path.

1.1 PCS Air Flow Path

The PCS air inlet structure is located around the top of the shield building cylindrical section and admit air into the shield building. The air enters a common plenum inside the shield building, then transitions to the annular space between the shield building inside wall surface and the air baffle where it flows downward. The air turns 180° at the bottom of this outer annulus and is admitted to the inner annulus between the containment shell and the air baffle, where it proceeds upward. The air exits the annulus at the top of the containment shell and enters the PCS exhaust structure which is large circular outlet at the top-center of the shield building, and is exhausted to the environment.

The PCS air flows continually during normal operation of the plant due to the heating of the air from the relatively warm containment shell or as induced by wind acting on the exterior of the shield building. Following a postulated event that results in the release of steam, heatup and pressurization of the containment, and heatup of the containment steel shell; the PCS air flow rate will increase as heat and water vapor is transferred from the containment shell to the air. The heated air/water vapor density is lower than the air outside the shield building causing a buoyancy-driven, natural circulation flow. The air flow rate is limited by the resistance of the PCS air flow path which consists of both form losses due to contractions, expansions and turns, as well as the friction losses along the flow path. The AP1000 PCS is shown in Figure 1-1.

The original design of the AP1000 shield building had 15 large openings through the shield building to admit air into the PCS. These openings were distributed uniformly around the top of the cylindrical portion of the shield building, and contained fixed, always open, louvers and screens to prevent weather and wildlife from entering the shield building. The inlets admitted air from outside into a common plenum inside the shield building that transitions to the outer flow annulus described above. This design was approved by the NRC as part of the AP1000 Design Certification. However, new regulations made it necessary to revise the shield building design, particularly the inlets and outlets to the PCS air flow path, to withstand additional threats such as aircraft crash.

In the revised design, the air inlets are still located at the top of the cylindrical portion of the shield building and are spaced uniformly around the circumference. A steel structure has been added around the top of the shield building cylindrical section. This steel structure contains 29 air inlets that are 9.5 ft high by 12 ft long. These openings are fitted with fixed louvers and screens to prevent the buildup of ice and to restrict birds and insects from entering the shield building. These inlets admit air into a common plenum that is formed by the steel outer structure and the outside of the concrete shield building. The air then enters the shield building . through 384 ducts, arranged in three rows, and uniformly distributed around the circumference of the shield building. These ducts are 16 inches by 16 inches and are angled upward at approximately 45° from the outside surface of the shield building to the inside of the shield building. As in the previous design, air entering through these ducts enters a common plenum inside the shield building that transitions to the outer flow annulus described above. The air flow resistance through the outer and inner annuli is not affected by this design change. The revised design also includes two heavy steel grates located in the PCS outlet which protect the containment shell from external hazards. Finally, the revised design has resulted in a five-foot reduction in the height of the shield build, which slightly decreases the buoyant driving head for the air/vapor mixture. It is recognized that the resistance to air flow is increased due to the local reductions in the flow area at the inlet ducts and in the vicinity of the grates in the air outlet.

The revised shield building design is described in more detail in Appendix A. The change in the air flow path resistance resulting from these changes is described in Section 3.0.

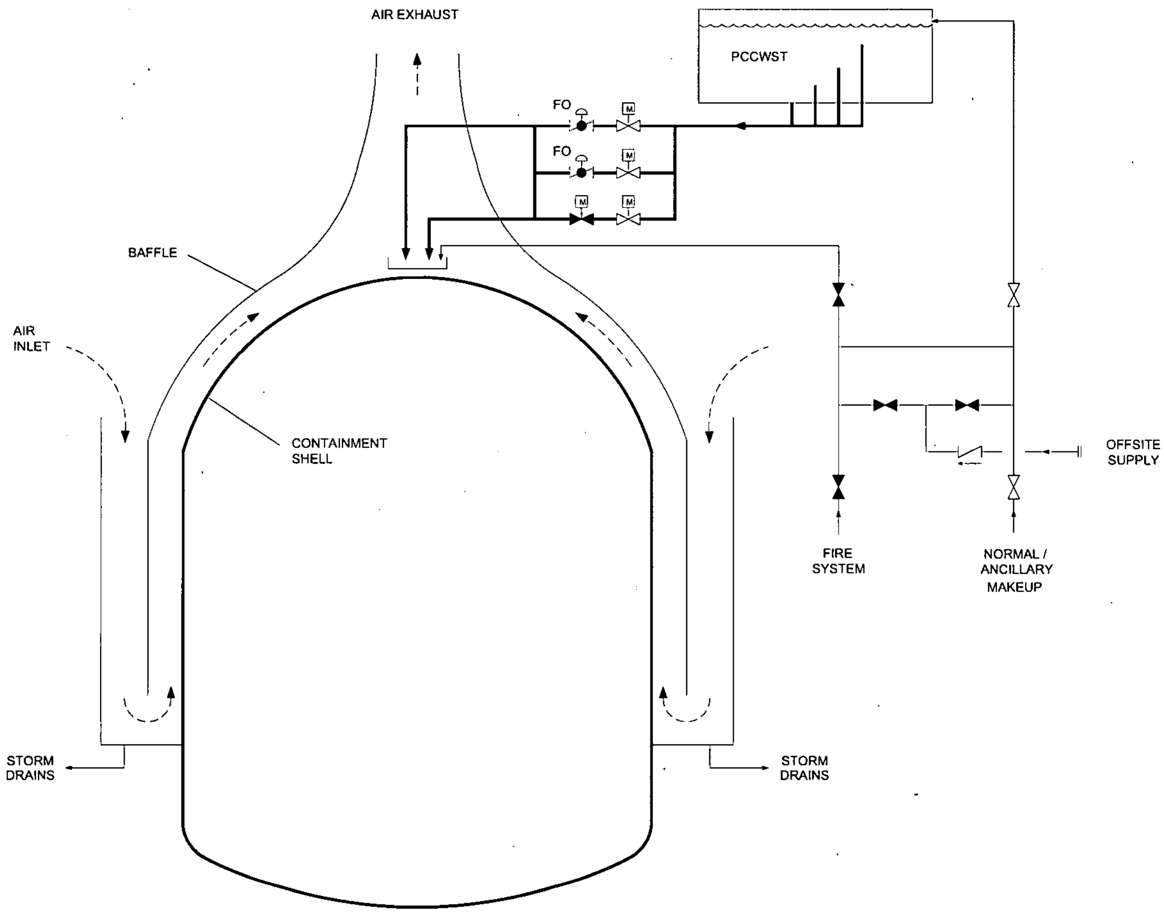

Figure 1-1: AP1000 Passive Containment Cooling System Schematic

2.0 Applicability of AP1000 Containment Tests and Phenomena Identification and Ranking Table (PIRT)/Scaling Considerations

2.1 Applicability of Tests

Several tests were performed to support the AP1000 Passive Containment Cooling System (PCS) design and to provide data for computer code validation. These include:

1. Simple tests to determine the wetability of the coating used on the containment vessel inside and outside steel surfaces
2. Condensation tests to determine steam condensation rates from air/steam mixtures on the inside surfaces of the containment vessel
3. Heat transfer tests to determine heat and mass transfer coefficients on the outside of the containment shell with both water evaporation and air-only cooling over a full range of expected conditions
4. Integral heat transfer tests (steam/air filled steel tanks with simulation of both inside and outside surface heat transfer) at two different scales to determine the heat removal characteristics of the PCS during simulated accident conditions
5. Air flow path characterization tests to determine the overall air flow path resistance and the pressure drop characteristics of the air flow path through the shield building
6. Wind tunnel tests to confirm that wind effects aid the PCS air flow rate, and thus, establish that simple natural circulation during calm conditions is the bounding minimum basis for PCS air flow through the shield building. These tests included establishing the location of the air inlets, determining the effect of wind speed and direction, verifying that the wind effects from surrounding buildings and structures do not impede air flow, and establishing bounding geographic limitations on plant siting.
7. Water distribution tests to demonstrate, at full scale, the effectiveness of the PCS water distribution devices in establishing the required water film coverage on the outer surface of the steel containment. This test included simulating the limiting surface shape and plate-to-plate alignments allowed by the ASME code.

The applicability of each of these tests will be discussed relative to the change in the shield building design.

1. Heat and Mass Transfer tests

These tests consisted of laboratory scale tests of steam condensation, evaporation, and free and forced convection on a heated steel plate. Heat and mass transfer correlations were developed from these tests that are incorporated into the WGOTHIC AP1000 evaluation model. These heat transfer mechanisms are not changed for the revised shield building design, and the test data developed are still applicable to the revised structure design.

2. Air Flow Path Characterization Tests

These tests consisted of a scale-model section of the PCS flow path from the inlets radially distributed around the top outside of the shield building cylindrical shell, through the shield building downcomer region between the air flow baffle and the shield building inside wall, the 180° turn at the operating deck elevation and entrance into and through the annulus between the air flow baffle and the steel containment shell, and out the air exhaust opening at the top-center of the shield building. The test apparatus is shown in Figure 2-1. Pressure difference measurements were taken and used to develop loss coefficients that were incorporated into the WGOTHIC AP1000 evaluation model. The changes to the revised shield building design resulted in incremental increases in the loss coefficients through the air inlets and through the air outlet region above the containment dome.

Since the Air Flow Path Characterization Tests were specific to the previous shield building design, they are not wholly applicable to the new design. However, these tests were used as a basis for calculating the losses for the new design. An analysis of the revised PCS air flow path was performed to determine the changes to the WGOTHIC AP1000 evaluation model. Details of this analysis are shown in section 3.0 and 4.0 of this report.

3. Wind Tunnel Tests

Background - The AP1000 Passive Containment Cooling System (PCS), as described in Section 2.0, utilizes the natural circulation of air upward along the outside surface of the steel containment vessel (SCV) to remove heat from inside the containment. Thus the SCV steel shell acts as the heat transfer surface and the air flow is employed either to assist in the evaporation of water from the SCV outer surface or to directly cool the SCV shell by convective heat removal.

A criterion in the design of the PCS was to have a shield building configuration and air flow path through the shield building, such that the wind would aid the natural circulation of PCS cooling air. This would result in being able to assume that no wind was present, and that only the buoyancy of the heated air or air/water vapor mixture need be considered in the analysis of the AP1000 containment pressure following postulated design basis or beyond design basis events. This goal was accomplished and documented in a series of wind tunnel tests performed at the University of Western Ontario's Boundary Layer Wind Tunnel Laboratory, as summarized below.

- Phase I Wind Tunnel Testing for the Westinghouse AP600 Reactor, April 1992 (Reference WCAP-13294) [Reference 1].
- Phase II Wind Tunnel Testing for the Westinghouse AP600 Reactor, August 1992 (Reference WCAP-13323) [Reference 2].
- Phase IVa Wind Tunnel Testing for the Westinghouse AP600 Reactor, May 1994 (Reference WCAP-14068) [Reference 3]
- Phase IVa Wind Tunnel Testing for the Westinghouse AP600 Reactor, Supplemental Report, September 1994 (Reference WCAP-14169) [Reference 4].
- Phase IVb Wind Tunnel Testing for the Westinghouse AP600 Reactor, July 1994 (Reference WCAP-14091) [Reference 5].

These tests and the test results, as related to the revised AP1000 shield building configuration, are discussed below.

University of Western Ontario Wind Tunnel Tests - A 1/96.67-scale model of the AP600 plant, including the adjacent buildings and cooling tower structure, was constructed and instrumented with pressure taps. The model was placed in the boundary layer wind tunnel which reproduces the wind gradient versus height and wind turbulences that occur in nature (See Figure 2-2). The tests were performed in phases to examine different aspects of the design and to enable modifications to the subsequent test conditions and test articles to suit the test objectives.

The Phase I testing [Reference 1] included test runs with changes to the plant model that are pertinent to the revised AP1000 shield building. These changes, listed below, were found not to violate the design criterion that the wind would always aid natural circulation induced PCS cooling air flow.

- The air exhaust/PCS water storage tank structure was raised and lowered 16 feet relative to the base case air inlet elevation. The tested air outlet elevations were 72'-10" ± 16' above outside edge of the shield building roof and showed no significant difference in the wind forces generated through the PCS air flow path.

  The revised AP1000 shield building to exhaust height is 59'-6" and is within the range tested.

- Two air exhaust/PCS water storage tank structure diameters were tested, 68 and 82 ft. The AP1000 air exhaust structure diameter is 89 ft, which closely corresponds to the larger tested diameter. Note that this larger diameter air exhaust structure was used for all subsequent test phases of the wind tunnel testing.

- The shield building was raised or lowered 16 feet relative to the turbine building roof elevation base case. The tested elevations had the shield building roof outside edge at 25'-2" and 9'-2" above the turbine building roof elevation, and at 6'-10" below the turbine roof elevation. (It is noted that the turbine building is the highest and largest building adjacent to the shield building.) These test runs again showed no significant difference in the resulting wind forces generated through the PCS air flow path.

  The revised AP1000 shield building roof outside edge is 23 ft. above the turbine building roof which is within the height difference tested.

- A shield building with a roof over-hang with air inlet openings 6'-5" below the top edge of the over-hang (10'-3" below top of cylindrical section of the shield building) was tested, and a shield building with a roof with no over-hang (inlets 3' below top edge of shield building) was tested. Note that, the test with the over-hang included the air inlets behind the over-hanging portion of the roof. Again, the test results with the shield building roof over-hang showed that the wind forces generated a positive effect on the air flow though the PCS air flow path. The revised AP1000 shield building roof line and air inlet location 8'- 7" below the top edge of the over-hang are very similar to the Phase I wind tunnel test article with the shield building roof over-hang.

- Test runs were made with the air exhaust/PCS water storage tank structure covered with an external missile shield. This design feature was not incorporated in the AP600 or AP1000 designs but it is noted only to illustrate that the effect of even this dramatic change in the air exhaust structure did not prevent the wind from aiding the PCS air flow.

Conclusion - It can be concluded that the wind tunnel tests included variations of the shield building design features that either encompass or very closely simulate, the revisions made to the AP1000 shield building. These tests confirmed that these shield building features; including a protruding roof over-hang, lowered air inlets, large variations in shield building and exhaust structure height, and increased exhaust structure diameter all met the criteria that wind would always aid the natural circulation of PCS cooling air. Therefore, it is concluded that the revised AP1000 shield building results in wind aiding the PCS air flow, and that safety analyses based on natural air circulation are valid.

4. Water Distribution Tests

The water distribution tests were conducted to determine, at full scale, the effectiveness of the PCS water distribution devices in establishing the required water film coverage on the outer surface of the steel containment. This test included simulating the limiting surface shape and plate-to-plate alignments allowed by the ASME code. Since there are no changes to this portion of the PCS, the testing that was done to support the WGOTHIC AP1000 evaluation model is still valid for the revised shield building design.

5. Integral Tests of the PCS

The integral tests were conducted determine the overall heat transfer characteristics and water film behavior using a simulated containment vessel over the full range of expected accident conditions. The tests were performed at two scales. The first, the Small Scale Test (SST) Facility was a 25 foot high, 3 food diameter pressure vessel into which steam was injected uniformly along the length. The cooling annulus around the vessel was formed by a Plexiglas cylinder with air inlets at the bottom and a fan at the top to achieve prototypic maximum air velocities. The facility is shown in Figure 2-3.

The second test facility, the Large Scale Test (LST) Facility, was a $1/8^{th}$ scale of the AP600 containment vessel and therefore had a more prototypic height-to-diameter ratio than the SST. This facility was used to study the distribution of steam and non-condensable gases inside the containment vessel, in addition to the overall heat transfer from inside the vessel to the outside environment. Steam was introduced into the interior of the vessel at several locations via simulated internal structural compartments. The LST also had air inlets at the bottom of an annulus formed by the containment vessel and a Plexiglas cylinder, and a fan at the top to enable the full range of air velocities that will occur in the much higher AP1000 plant to be achieved. The LST facility is shown in Figure 2-4. Both the SST and LST facilities had a water supply and water distribution devices at the top of the vessel to simulate the PCS water applied during accident scenarios.

These tests did not model the PCS air flow path explicitly, but the range of air velocities simulated in the tests envelope the air velocities that will occur in the revised shield building design for all accident conditions. Thus, these tests are applicable to the WGOTHIC AP1000 evaluation model for the revised shield building design.

2.2 PIRT Scaling Considerations

PIRT

The AP1000 containment PIRT (reference 6) was developed from the AP600 containment PIRT (reference 7) for limiting postulated design basis accidents (LOCA and Main Steam Line Break). The containment PIRT approach used is the same as described for the passive core cooling system in reference 9. The containment PIRT was reviewed by several Westinghouse internal experts and industry experts including:

- Dr. S. G. Bankoff, Dept. of Chemical Eng., Northwestern University
- Dr. L. E. Hochreiter, Dept. of Mech. and Nuclear Eng., Penn State University
- Dr. P. F. Peterson, Dept. of Nuclear Eng., University of California

The figure of merit for the PIRT is containment pressure. That is, all plausible phenomena are ranked (High, Medium, or Low) with respect to their relative influence on the figure of merit, in this case, containment pressure. Test and scaling analyses (reference 8) were subsequently performed to confirm the rankings of the phenomena.

The high-ranked PIRT phenomena are, of course, of most importance with respect to the containment test database and code validation. For purposes of model or code development, all high as well as medium ranked PIRT phenomena are included in AP1000 containment modeling.

The high-ranked (most important) PIRT phenomena for AP1000 LOCA or MSLB in containment are summarized as follows:

- Break-related phenomena (i.e. mass, energy, and momentum).
- Containment volume compliance, circulation, and stratification.
- Heat capacity of internal heat sinks and containment shell.
- Condensation inside containment on internal structures and containment shell.
- Conduction associated with internal heat sinks and through the containment shell.
- Evaporation from the containment shell liquid film to the passive containment cooling system (PCS) annulus riser.
- PCS cooling water flow rate and film stability/coverage.

The revised AP1000 shield building design changes that have potential impact on AP1000 containment pressure response include the following:

- Increased hydraulic resistance at the inlet and outlet of the PCS air flow path (hydraulic resistance increase of 33%).
- Decreased chimney height (height decrease of 5ft).

A re-examination of the containment phenomena in light of these PCS air flow path design changes indicates that while they may have some impact on the containment response, the nature of these PCS design changes does not introduce any new phenomena into the AP1000 containment PIRT. The PCS performance with respect to containment pressure response is still dominated by LOCA or MSLB energy transfer from the containment shell via condensation on the inside surface of the containment shell, conduction through the shell, and evaporation of the water film from the outer surface of the containment shell into the airflow circulating through the annulus and out the chimney. As there is not any new phenomena introduced to provide energy transport via the PCS, the next step is to assess whether or not the ranking of AP1000 containment PIRT phenomena warrant an upgrade to a high ranking.

The PCS air flow path design changes directly impact natural circulation (i.e. density or buoyancy-driven flow) through the PCS airflow path (i.e. annular down comer, annular riser, and chimney regions) due to the increased hydraulic resistance and buoyancy related change associated with the reduced chimney height. Changes in PCS natural circulation should primarily influence important phenomena such as evaporation from the PCS water film to the annular riser. PCS water flow and film stability/coverage, and condensation and conduction associated with the containment shell phenomena are also coupled to PCS performance and may be influenced, however, they are already high ranked phenomena and as such should remain high ranked in the AP1000 PIRT. The PCS design changes have little or no impact on other important containment phenomena such as break-related phenomena, containment volume compliance, circulation, and conduction or heat capacity associated with internal heat sinks. These high-ranked phenomena are not strongly coupled to the PCS natural circulation phenomena and hence their rankings should remain unchanged.

Scaling

To assess the potential impact on the rankings of PCS-related phenomena, key scaling groups related to heat transfer in the down comer, annulus, and chimney regions (shown in bold across from the heading **External Mixed Convection**) are reassessed relative to that in AP1000 PIRT and Scaling Assessment (reference 9). The relative or percent differences are calculated to determine if any ranking changes are warranted and to determine whether or not important phenomena represented by the test data base approved for AP1000 is still acceptable and continues to support code validation. The impact of the design changes on the operating range for the AP1000 heat and mass transfer correlations is shown in Table 2-1 below.

From the above table it can be seen that the percent differences of key scaling groups are small and therefore, the PIRT rankings of key phenomena are still valid and test data used for code validation is valid as well. The current AP1000 containment PIRT is confirmed for the PCS design changes and the scaling shows that the AP1000 test data base is acceptable to support code validation.

2.3 Summary

Extensive testing has been performed in support of the AP1000 passive containment cooling system. These tests range from separate effects tests to determine heat and mass transfer correlations and water distribution, to integral tests that simulate the containment response to a simulated accident. All of these tests, with the exception of the Air Flow Path Characterization Test are fully applicable to the revised shield building design. For this single test, additional analysis has been performed to conservatively determine the impact of the revised design on the air flow path resistance. This conservative resistance has been used in the WGOTHIC AP1000 evaluation model to assess its impact on the containment pressure response. Details of the change in the air flow path resistance are shown in Section 3.0, and the results of this sensitivity study are discussed in Section 4.0.

Table 2-1
Operating Range Comparison for AP600 and AP1000 Heat and Mass Transfer Parameters Including the Percent Difference for AP1000 with Design Changes

Heat Transfer Correlation	Parameter	Composite of Test Data	AP600 Range	AP1000 Range	**Percent Difference, Revised AP1000 Relative to AP1000**
Internal Free Convection: $h = 0.13\ k/(v^2/g)^{1/3}\ (\Delta\rho/\rho)^{1/3}\ Pr^{1/3}$	$\Delta\rho/\rho$	0.08 to 0.55	<0.40	<0.42	
	Pr	0.72 to 0.90	0.72 to 0.90	0.72 to 0.90	
	Sc	~0.52	~0.52	~0.52	
External Mixed Convection: $Nu_{force} = 0.023\ Re_d^{\ 0.8}\ Pr^{1/3}$ $Nu_{free} = 0.13\ (Gr_d\ Pr)^{1/3}$ For Opposed Mixed Convection: $Nu_{mix} = (Nu_{force}^{\ 3} + Nu_{free}^{\ 3})^{1/3}$ For Assisted Mixed Convection: $Nu_{mix} = Max\{(Nu_{free}^{\ 3} - Nu_{force}^{\ 3})^{1/3}, Nu_{free}, 0.75*Nu_{force}\}$	Re_d Annulus	<120000 evap. <500000 dry	<189000	<210000	**-14.0%**
	Re_d Downcomer		<151000	<190000	**-6.0%**
	Re_d Chimney		<1400000	<1800000	**-13.0%**
	Gr_d Annulus	$<7.0x10^{10}$evap. $<1.0x10^{11}$ dry	$<1.2 \times 10^9$	$<1.5 \times 10^9$	**-2.6%**
	Gr_d Downcomer		$<6.2 \times 10^9$	$<2.1 \times 10^{10}$	
	Gr_d Chimney		$<2.1 \times 10^{12}$	$<8.0 \times 10^{12}$	**2.9%**
	Pr	~0.72	~0.72	~0.72	
	Sc	~0.52	~0.52	~0.52	
Liquid Film Heat Transfer: $Nu_{turb} = 0.0038\ Re^{\ 0.4}\ Pr^{\ 0.65}$ $Nu_{wavy\ laminar} = 0.822\ Re^{\ -0.22}$	Re	20000	<3200	<3500	
	Pr	1.77 to 5.9	1.5 to 3.0	1.5 to 3.0	

Figure 2-1: PCS Air Flow Path Characterization Test

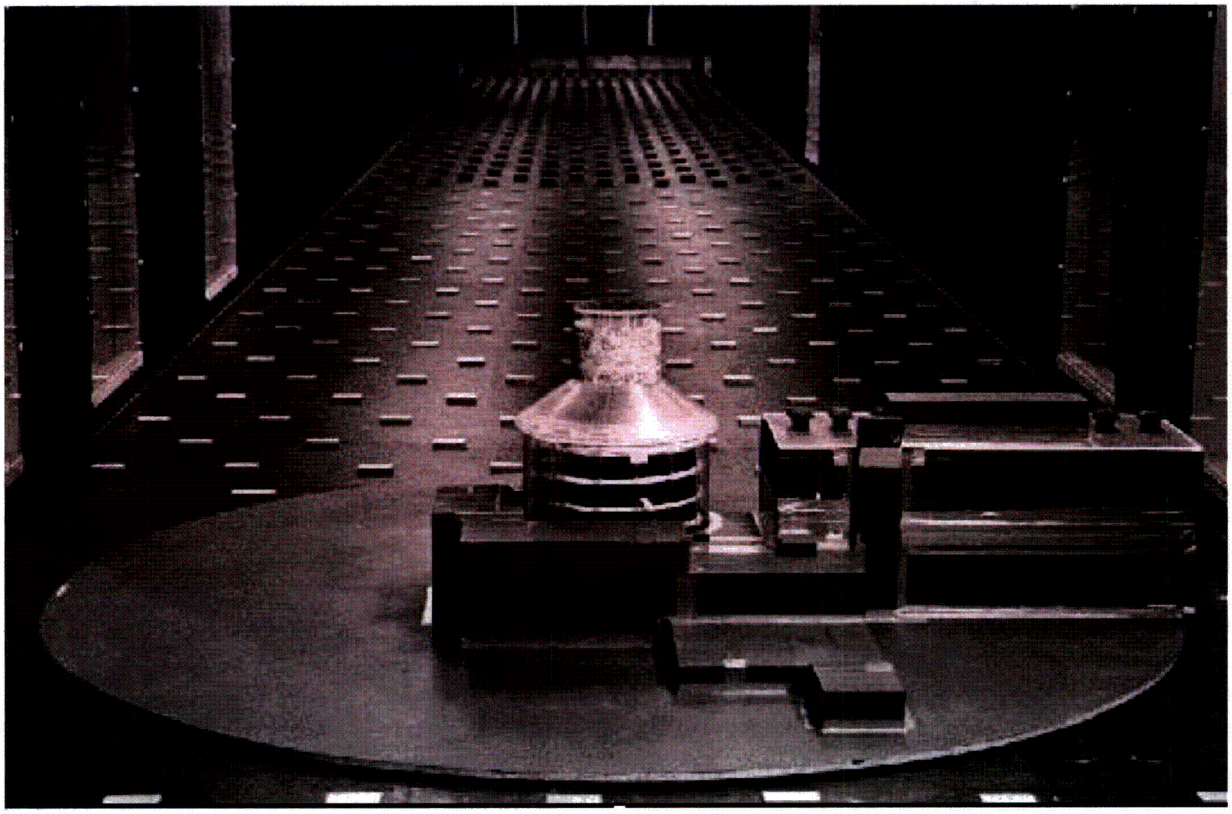

Figure 2-2: Illustration of the Plant Model in the University of Western Ontario Boundary Layer Wind Tunnel

Figure 2-3: AP1000 PCS Small Scale Test Facility

Figure 2-4: AP1000 PCS Large Scale Test Facility

3.0 AP1000 WGOTHIC Evaluation Model

The WGOTHIC computer code (References 10 and 11) was developed during the AP600 project to perform accident simulations for the containment. The code is based on the GOTHIC computer code (Ref. 12), and has been modified to include a model for the passive containment cooling system. The code has been extensively verified and validated using test data generated during the AP600 and AP1000 design certification effort. These tests are described in detail in Section 4.0.

The AP1000 WGOTHIC model consists of discrete control volumes that represent rooms inside the containment shell, and are connected to each other using flow paths. Inside the control volumes are passive heat sinks representing the equipment and structures inside the containment. Large pipe breaks are simulated by a release of mass and energy into a control volume using boundary conditions. These mass and energy releases are calculated using other codes and the data tables are imported into WGOTHIC in the form of mass flow and enthalpy as a function of time. The control volumes and heat sinks are initially assumed to be at the high operating range for the containment, and the containment is initially assumed to be filled with air at one atmosphere.

The PCS is also constructed of control volumes, flow paths and heat sinks. The air flow path consists of 18 control volumes and 19 flow paths ranging from the inlets to the air outlet. The heat sinks consist of the containment steel shell which is coupled to the control volumes inside the containment and to the PCS control volumes that make up the inner annulus between the baffle and the shell. Models were also developed to represent the radiative heat transfer from the shell to the baffle, from the baffle to the shield building, and radiative and convective heat transfer from the shield building to the environment. The inlets and outlet of the PCS air flow path are connected to boundary conditions that specify the air temperature, pressure and relative humidity. These values are conservatively biased to minimize the effectiveness of the heat removal process.

3.1 Changes to the WGOTHIC Model for the Revised Shield Building Design

As noted above, the revised shield building design results in changes to the PCS air flow path and resistances in the WGOTHIC evaluation model. The steel shell and the control volumes, flow paths and heat sinks inside containment are not changed. The initial conditions and boundary conditions are not changed. Only the control volumes and flow paths that make up the PCS are affected. The changes are summarized as follows:

Control Volumes

The top-most control volume top elevation is reduced by 5 feet. The volume is also reduced by 5 feet times the flow area.

Flow Paths

The flow path that represents the transition from the inner annulus to the outlet is shortened by 5 feet.

The flow area, and loss coefficients for the PCS inlets and outlet were modified to agree with the physical arrangement shown in Appendix A. Also changed was the inlet flow path hydraulic diameter which was changed to reflect the 16-in by 16-in ducts. A detailed analysis to determine the resistance of the PCS flow path is presented below.

3.1.1 PCS Air Resistance for the Inlets and Outlet

Inlet Structure

The air inlet structure for the AP1000 revised shield building design is shown in Figure 3-1. Air enters from the environment into a common plenum through 29 distinct openings, 9.5 ft high by 12 ft wide. Each opening has fixed louvers and screens to protect against weather and wildlife. The net flow area through the openings is 1253 ft^2. The common plenum is located behind these openings, but outside the shield building concrete wall. This plenum extends completely around the circumference and encloses a walkway for inspection of the louvers and screens. The walkway also provides access for inspection of the PCS air inlets; a series of 384 ducts that admit air from the plenum outside the shield building to a common plenum inside the shield building.

The air inlets through the shield building wall consist of 384 angled ducts with rounded entrances. The air enters through these ducts into a common plenum inside the shield building where it turns approximately 135° and enters the downcomer annulus through a restriction. Thus, the total resistance of the inlet assembly is made up of six parts, labeled 1-6 in Figure 3-1. These are:

1. Contraction and expansion loss from the environment through the louvers and screens
2. Contraction loss from outer plenum into the ducts
3. Friction loss through the ducts
4. Expansion loss from the ducts to the inner plenum
5. Turning loss in the inner plenum
6. Contraction and expansion loss from the inner plenum to the downcomer

Utilizing Reference 13, an estimate was made of each of these losses. The losses are associated with flow areas from Appendix A, and are summarized in Table 3-1.

Table 3-1: Components of Losses in the Revised Shield Building Inlets

Shield Building Inlet Structure Pressure Drop Component	Loss Coefficient	Reference Area (ft^2)
1. Louvers and screens	1.5	1253
2. Outer plenum into ducts	0.23	683
3. Friction in ducts	0.1375	683
4. Expansion from ducts into inner plenum	0.75	683
5. Turning loss in the plenum	3.1	850
6. Contraction/expansion loss from inner plenum to downcomer	0.2	1190

The total inlet loss is defined as

$$K_{inlet} = S\ k_i * (A_{ref} / A_i)^2$$

Where k_i is the individual losses
A_i is the flow area associated with the loss
and A_{ref} is the reference flow area (683 ft^2)

For the inlet, the total loss coefficient based on the flow area of the ducts is

$$K_{inlet} = 3.6$$

The hydraulic diameter of the inlet is equal to the duct characteristic dimension

$$Dh_{inlet} = 16 \text{ inches} = 1.3333 \text{ ft}$$

Outlet Structure

The outlet structure consists of a cylindrical opening in the center of the shield building roof. For the revised shield building design, two heavy grates have been added at the bottom and top of the opening.

The losses associated with the grates can be estimated by two contraction/expansion losses. From Reference 13, the total exit loss is

$$K_{grates} = K\text{-}1 + K\text{-}2 = 0.66$$

This loss coefficient is added to the existing loss for the outlet structure from the WGOTHIC evaluation model [Reference 12].

$$K_{outlet} = K_{tot} + K_{chimney} = 0.66 + 1.29 = 1.95$$

This loss is based on a reference flow area of

$$A_{outlet} = 804 \text{ ft}^2$$

from Appendix A

3.1.2 Changes to the WGOTHIC Evaluation Model for the Revised Shield Building Design

The WGOTHIC model was changed to reflect the changes in the PCS air flow path described in Appendix A. The inlet and outlet loss coefficients were changed as calculated above. The remaining loss coefficients were modified from the original WGOTHIC model to reflect changes in the flow area from Appendix A. The loss coefficients were adjusted in the following way:

$$K_{rev} = K_{org} * (A_{org} / A_{rev})^2$$

The resulting changes in the WGOTHIC evaluation model input for the PCS flow path is summarized in Table 3-2.

Table 3-2: Summary of Changes to WGOTHIC PCS Flow Path Input

Flow Path	Original Design Area (ft^2)	Loss Coef	Norm Loss	Hyd. Dia (ft)	Revised Design Area (ft^2)	Loss Coef	Norm Loss	Hyd. Dia (ft)
231	4360	35.02	0.307	21.67	683	3.6	1.317	1.3333
230	1431	0	0.000		1280	0.0	0.000	
229	1431	0.267	0.022		1280	0.334	0.035	
314	1431	0.5133	0.042		1280	0.642	0.067	
228	1431	0.52	0.042		1280	0.650	0.068	
227	1431	0.5133	0.042		1280	0.642	0.067	
226	1431	0.52	0.042		1280	0.650	0.068	
219	710	5.922	1.956		639	7.311	3.054	
220	408	0.2317	0.232		413	0.226	0.226	
221	408	0.2091	0.209		413	0.204	0.204	
222	408	0.2317	0.232		413	0.226	0.226	
223	408	0.2091	0.209		413	0.204	0.204	
313	408	0.2589	0.259		413	0.253	0.253	
224	408	1.457	1.457		413	1.422	1.422	
225	1918	6.677	0.302		4505	1.210	0.010	
232	804	2.046	0.527		804	2.046	0.540	
242	804	1.294	0.333		804	1.95	0.516	
Total			6.212				8.275	

The total resistance is normalized to the inner annulus flow area which is the smallest in the flow path. The net increase in the resistance for the revised design is 33% compared to the previous design.

These resistances are integrated into the AP1000 WGOTHIC evaluation model. In addition, the model is modified to reflect a 5-foot reduction in the overall height of the shield building.

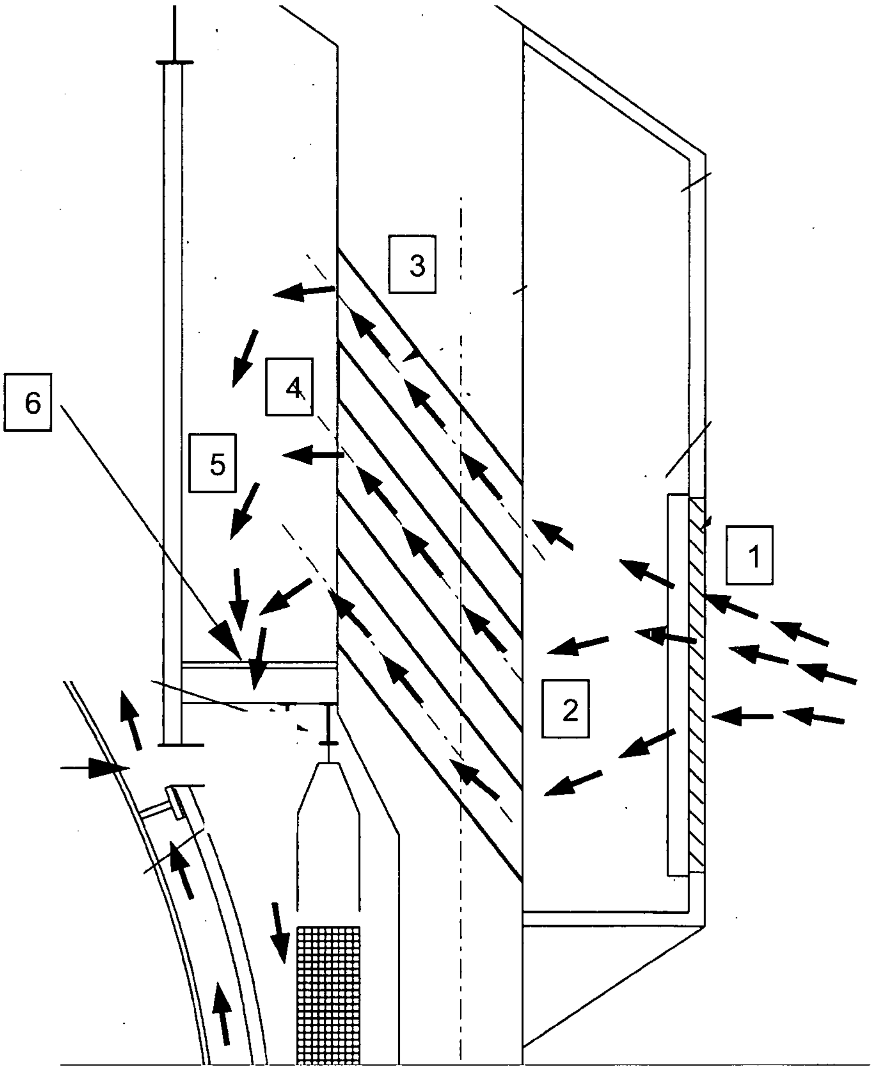

Figure 3-1: AP1000 PCS Air Flow Path Inlet Configuration – Revised Shield Building Design

4.0 Results for Limiting Design Basis and Beyond Design Basis Events

To determine the sensitivity of the containment pressure response to the shield building design changes, the AP1000 WGOTHIC evaluation model was used to analyze the limiting design basis and beyond design basis events.

4.1 Design Basis Events

For design basis events, the initiating event is assumed to be a large pipe break inside the containment. These include main steam line break (MSLB) and large loop piping LOCA events such as a double-ended cold leg break. The large release of mass and energy into the containment initially results in an almost adiabatic pressurization. After the initial blowdown event, the resulting pressure increase causes actuation of the PCS by opening the isolation valves at the bottom of the PCS water storage tank. There are three redundant and diverse valves that must fail to prevent water from being applied to the containment shell. Thus, for all DBAs, the PCS water cooling is assumed. The large thermal inertia of the steel shell causes a slow heatup due to steam condensation on the inside surface, and at first evaporation from the outside surface is limited. As the shell heats up, evaporation becomes more effective and slows the pressurization of the containment atmosphere. When the heat removal from the outside of the shell equals and exceeds the rate of energy released into containment, the peak pressure is reached for the event and begins to decrease.

For AP1000, the peak pressure DBA is the MSLB. A double-ended break of a main steam line results in high energy steam that initially pressurizes the containment. When the blowdown portion of the event is over, there is no additional energy released to containment. The pressure for this event is limited by the containment volume, and to a secondary degree, by energy absorption by the passive heat sink structures inside the containment including the steel shell. At the time that the blowdown is ended, the PCS water starts to become effective at removing heat from the outside of the shell and the pressure is decreased. For this reason, the MSLB is not a good choice for determining the effects of the PCS performance.

The LOCA event is characterized by two distinct phases; an initial blowdown period which continues until the reactor coolant system (RCS) pressure is nearly the same as the containment pressure, and a long term cooling period where the sensible heat of the RCS and the steam generators is released along with the reactor shutdown heat. This period can continue for several hours or days until the plant is recovered. During this time, it is assumed that only the passive safety-grade systems operate to mitigate the event.

Because of the longer time scale, the PCS is much more important for mitigating the effects of a LOCA. For this reason, the limiting DBA case is a cold leg break LOCA event. The WGOTHIC evaluation model that was used in previous DCD analyses was modified to reflect the revised shield building design as described in Section 3.0.

Limiting assumptions are made for the analysis of design basis events. Conservatively biased heat and mass transfer correlations are used to minimize the heat removal from containment. In addition, the initial RCS conditions reflect 102% operating power, and the containment initial conditions are biased to maximize pressurization. Finally, the decay heat released to containment has a 2-sigma uncertainty.

The DBA case used for the comparison of the original and revised shield building designs is the cold leg break LOCA.

DBA Results – Cold Leg LOCA

For this case, the pressure increases very rapidly due to the initial blowdown event. As the internal passive heat sinks (including the containment shell) begin to condense steam, the pressure levels off. As the RCS and steam generator sensible heat is released to containment, the pressure increases, eventually reaching a peak at about 1800 seconds after the event initiation. The PCS water evaporation effectively cools the containment shell and the pressure slowly decreases. The containment pressure response for both the previous design and the revised design are shown in Figure 4-1. The difference between the two cases cannot be differentiated on the plot.

These results show that there is a negligible impact on the peak pressure for DBA resulting from the revised shield building design. There is a small reduction in air flow through the PCS due to the more restrictive air flow path, but the evaporative heat transfer which makes up the majority of the heat removal from the containment shell is not affected by this reduction. Since the overall heat removal for both designs is essentially the same, the peak pressure is also the same. Thus, the revised shield building design has no adverse impact on the ability of the PCS to mitigate a design basis event.

4.2 Beyond Design Basis Events

For the purpose of this comparison, it is assumed that the limiting beyond design basis event is an initiating event coupled with a loss of the PCS water. This is a highly unlikely occurrence since it requires the failure of three redundant and diverse active vavles for the water to be lost. The probability of this occurring is calculated to be approximately 10^{-6}/yr. The pressure limit for beyond design basis events is assumed to be the maximum pressure capacity limit from Section 3.8.2 of the AP1000 DCD of 129 psig (143.7 psia) which is well below the expected failure limit of the containment. Containment pressurization occurs over a long period of time. For this reason, the initiating event is relatively unimportant for beyond design basis accidents, as the integrated energy associated with an event such as blowdown is very small compared to the integrated reactor decay heat. Analysis of beyond design basis events are generally performed using "best estimate" assumptions.

The initiating event for this study is a loss of offsite power. The reactor is shutdown and the passive core cooling system is actuated. For this non-LOCA event, the reactor decay heat is deposited into the in-containment refueling water storage tank (IRWST) by the passive residual heat removal heat exchanger (PRHR HX). In WGOTHIC, this is accomplished by placing a heater into the IRWST with a heat rate equal to the reactor decay heat. Within a few hours, the IRWST heats up and begins to boil. Steam is introduced to the containment and condenses on the passive heat sinks and the containment shell. Because of the long time period, the heat sinks become saturated, and the only heat removal mechanism is the heat transfer through the containment shell to the environment. The containment pressure remains flat after the initiation of the event, and begins to increase once steaming of the IRWST occurs. The pressure increases logarithmically until the heat removal matches the decay heat.

Due to the lack of water on the outside of the shell, the only mechanism for heat removal is natural convection from the outside surface of the shell. The heated air in the PCS is less dense than the air outside setting up a natural circulation flow. This flow is determined by a balance between the flow resistance of the PCS flow path and the thermal driving head generated by the density difference. As the flow path becomes more restrictive, the shell temperature must increase to remove the same amount of heat. This increase in shell temperature corresponds to an increase in the containment atmosphere pressure and temperature.

BDBE Results – Loss of Offsite Power

The results of the BDBE case are shown in Figures 4-2 and 4-3. For this case, the increase in pressure occurs very slowly and no significant difference between the original and revised shield building designs becomes apparent until a long time after the event initiation. Figure 4-2 shows that both cases reach the maximum containment capability limit of 143.7 psia at approximately 45 hours. This allows considerable time for operators to either repair the PCS water supply, or to provide alternative water sources. Figure 4-3 shows the difference between the containment responses for the two designs on an expanded scale. The increased flow resistance of the revised design eventually results in a containment pressure that is approximately 5 psi higher 83 hours after the initiating event.

4.3 Summary of Results

These calculations show that the change to the shield building design has a very limited impact on the containment safety analysis. This is true for both design basis and beyond design basis events. For the design basis events, the heat removal is dominated by evaporation from the outer surface of the shell. The small change in the PCS air flow path resistance resulting from the shield building design change does not affect the peak pressure for these events. For the beyond design basis events, the increased flow resistance results in slightly higher containment pressure, but do not change the results or conclusions in the AP1000 DCD and PRA.

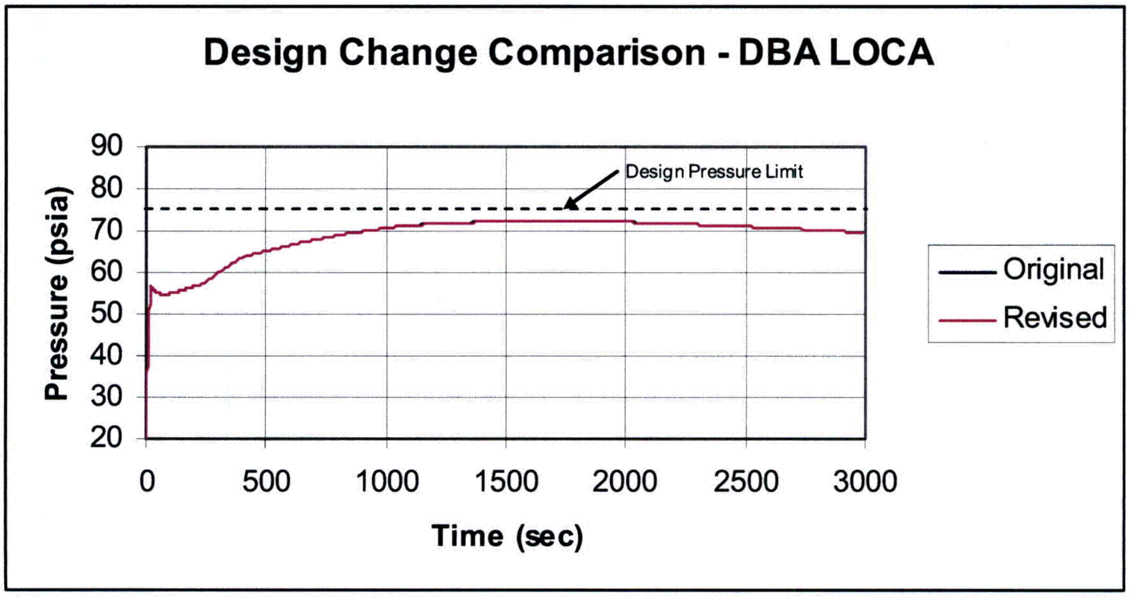

Figure 4-1: Comparison Pressure Plot for DBA Cold Leg LOCA

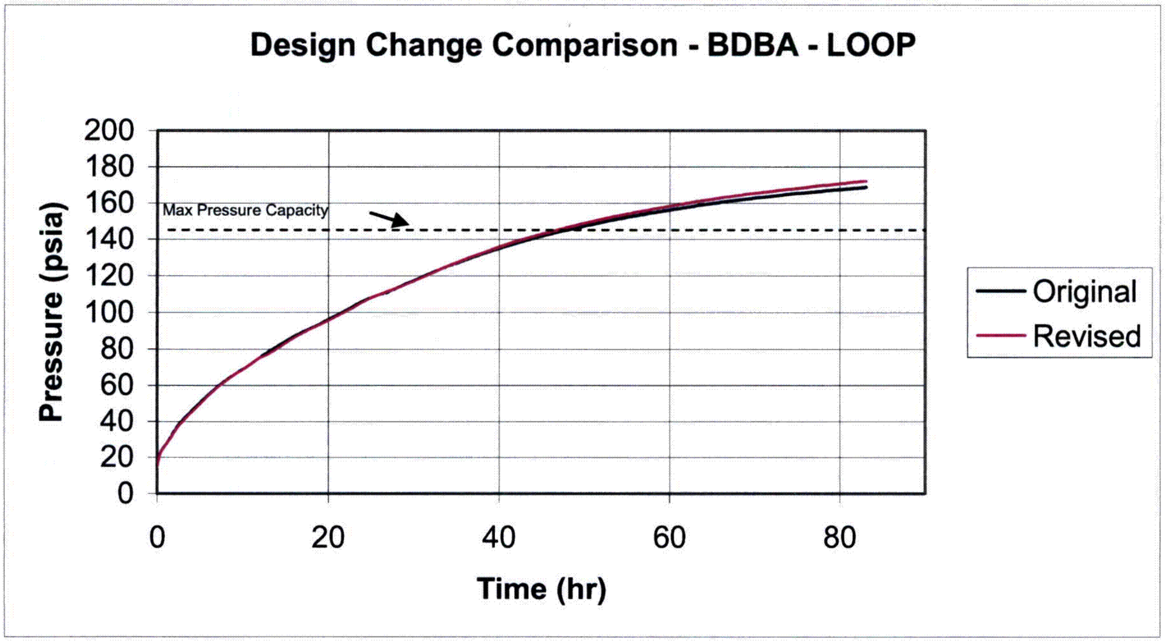

Figure 4-2: Comparison Plot for BDBA Loss of Offsite Power

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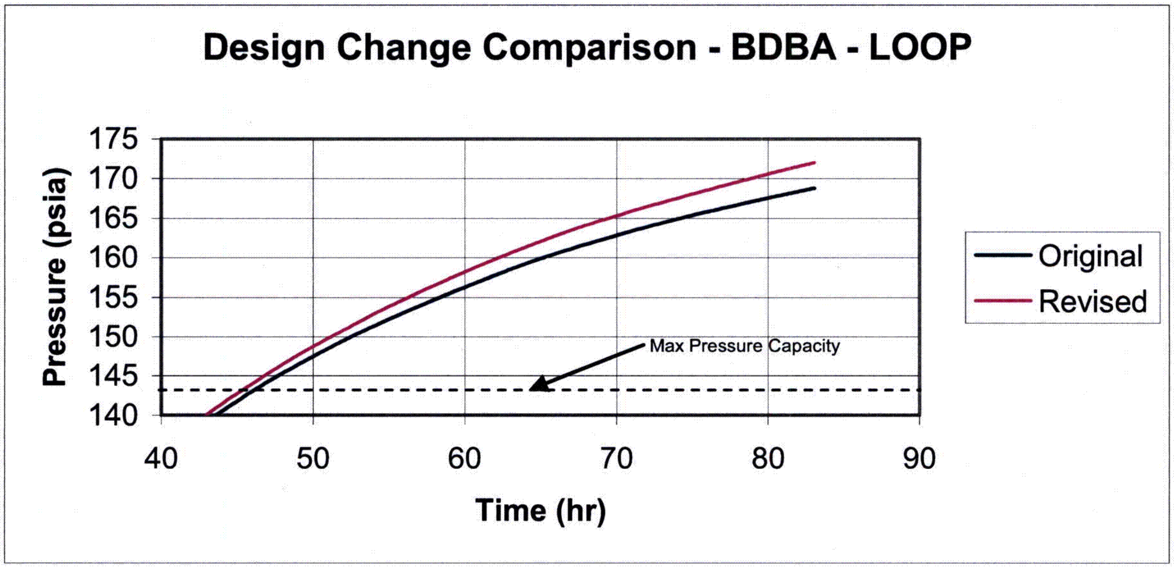

Figure 4-3: Comparison Plot for BDBA Loss of Offsite Power – expanded scale

5.0 Conclusions

The results of this evaluation show that the revised shield building design results in an increase in the resistance to air flow through the passive containment cooling system. A conservative assessment of the resistance was performed and was used to modify the AP1000 WGOTHIC evaluation model to determine the effect on the containment pressure response for design basis and beyond design basis events.

For the design basis events where the PCS water is assumed to be available, the evaporative heat transfer from the outside of the containment shell compensates for the small reduction in flow by slightly increasing the PCS outlet temperature and corresponding water vapor fraction. This results in essentially no change in the total heat removal from the shell and no discernable change in the peak containment pressure.

For the beyond design basis events where the PCS water is assumed not to be available, the higher air flow resistance results in lower air flow and higher exit air temperature. To achieve the higher air exit temperature, the containment shell temperature is higher for this case, and the corresponding containment atmosphere pressure and temperature are increased. This difference is cumulative and become more pronounced at a very long time after the event initiation. However, the time to reach the maximum pressure capacity of the containment is virtually the same for both designs.

These results show that the current containment pressure response curves in Chapter 6.2 of the AP1000 DCD are still applicable and do not need to be revised. Similarly, the results and conclusions in Chapter 19 are still applicable and do not need to be revised.

It is also concluded that the revised AP1000 shield building does not result in tests performed for the passive containment cooling

6.0 References

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7. M. Loftus, D. Spencer, J. Woodcock, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", WCAP-14812.
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12. NTD-NRC-95-4563, GOTHIC Version 4.0 Documentation, 1995.
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Appendix A: Detailed Sketches of the AP1000 Revised Shield Building Design

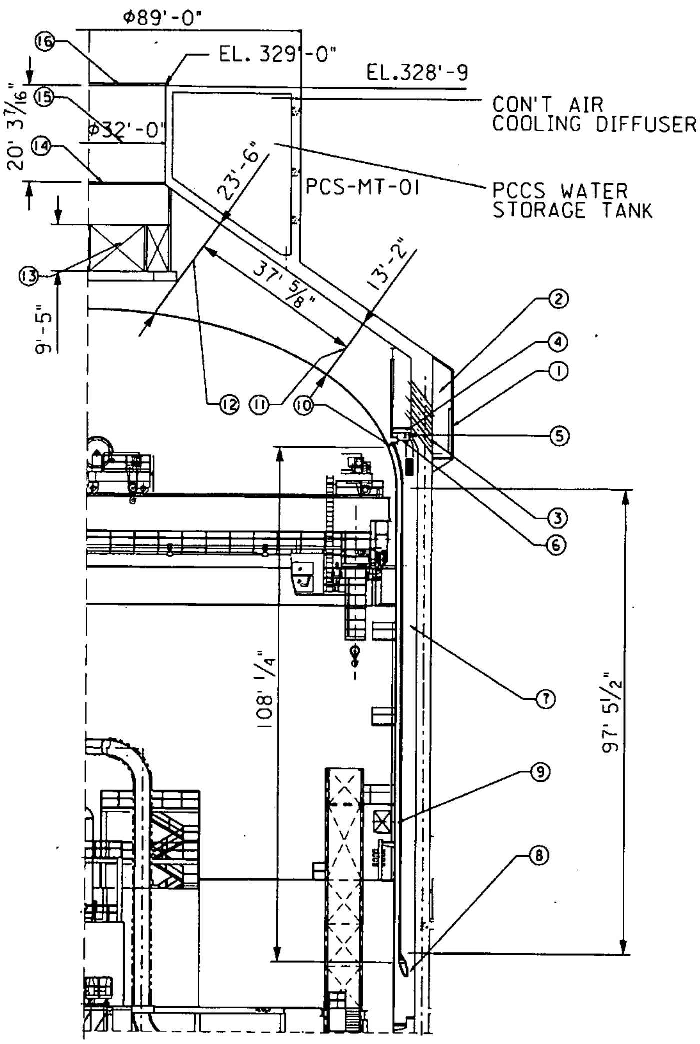
AP1000

PASSIVE CONTAINMENT COOLING SYSTEM

AIR FLOW TEST INPUT DATA

MARCH 3, 2007
J. GORKA

LIST OF FIGURES



NOTE: AIR FLOW AREAS SEE FIG 02

FIG. 01
AIR FLOW AREAS
03.05.07

AREA	DESCRIPTION	FREE AREA	REDUCING FACTOR	NET AREA	LENGTH	REFERENCE
1.	LOUVERS/SCREEN	29X9'X12'=3132 SQ FT	0.4	1253 SQ FT	7.78 IN	FIGURE 09
2.	OUTSIDE SHIELD BLDG PLENUM	N/A			4.0 FT	FIGURE 09
3.	AIR INTAKE DUCTS	16"x16"x384=683 SQ FT	1.0	683 SQ FT	7.33 FT	FIGURE 10
4	GRATING/STRUCTURAL AREA	29.5X39.46=1164 SQ FT	0.73	850 SQ FT	1.75 IN	FIGURE 11
5.	BEAMS AREA	29.5X51.7=1525 SQ FT	0.78	1190 SQ FT	12 IN	FIGURE 12
6.	SEAL AREA	1330 SQ FT	1.0	1330 SQ FT	6 IN	FIGURE 13
7.	AREA OUTSIDE BAFFLE	1280 SQ FT	1.0	1280 SQ FT	97.46 FT	FIGURE 01
8.	BOTTOM BAFFLE AREA	639 SQ FT	1.0	639 SQ FT	1 FT	FIGURE 14
9.	AREA INSIDE BAFFLE	413 SQ FT	1.0	413 SQ FT	108 FT	FIGURE 01
10.	TOP OF BAFFLE	455 SQ FT	1.0	455 SQ FT	1 FT	FIGURE 15
11.	MIN DISTANS BTWN CONT'T AND PCS TANK	4505 SQ FT	1.0	4505 SQ FT	37 FT	FIGURE 01
12.	MAX DISTANS BTWN CONT'T AND PCS TANK	4147 SQ FT	1.0	4147 SQ FT	BETWEEN P11 AND P12	
13.	WIRE MESH	8X118= 944 SQ FT	.473	447 SQ FT	0.050 IN	FIGURE 16
14.	LOWER GRATING EL. 308'-8"	804 SQ FT	.708	569 SQ FT	5 IN	FIGURE 17
15.	DIFFUSER	804 SQ FT	1.0	804 SQ FT	20.3 FT	FIGURE 01
16.	UPPER GRATING EL. 329'-0"	804 SQ FT	.764	617 SQ FT	5 IN	FIGURE 18

FIG. 02
TABLE OF AIR FLOW AREAS
03.07.07

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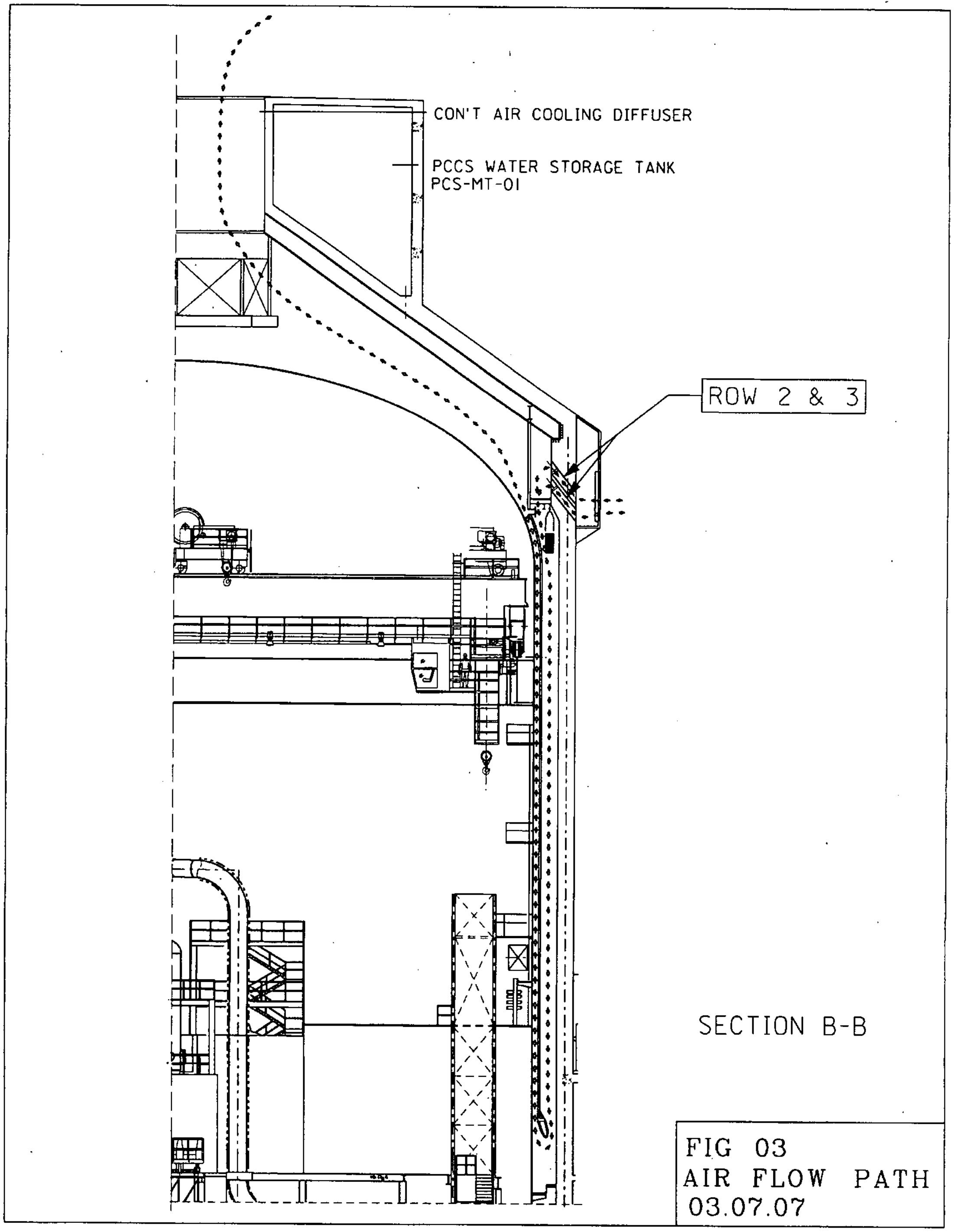

FIG 03
AIR FLOW PATH
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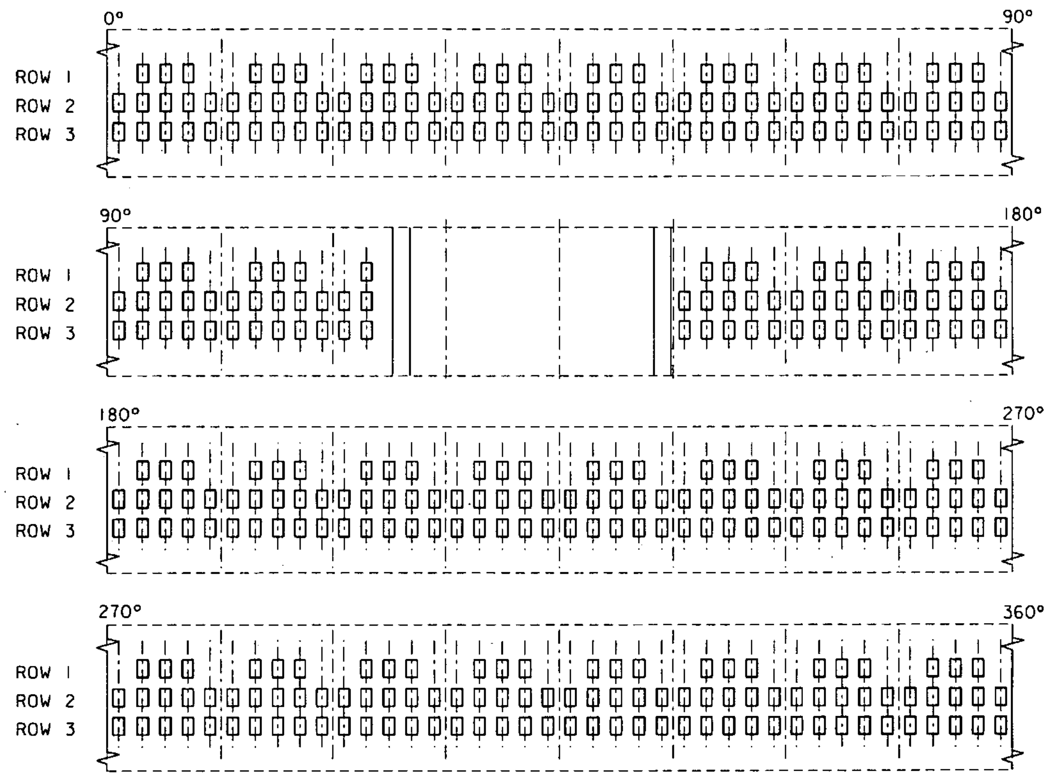

ROW 1 - 90 INLET DUCTS
ROW 2 - 147 INLET DUCTS
ROW 3 - 147 INLET DUCTS
TOTAL - 384 INLET DUCTS

FIG. 04
UNFOLDED AIR INLET DUCTS AREA
03.07.07

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Title: Evaluation of the Effect of Shield Building Changes on Containment Response and Safety Analyses

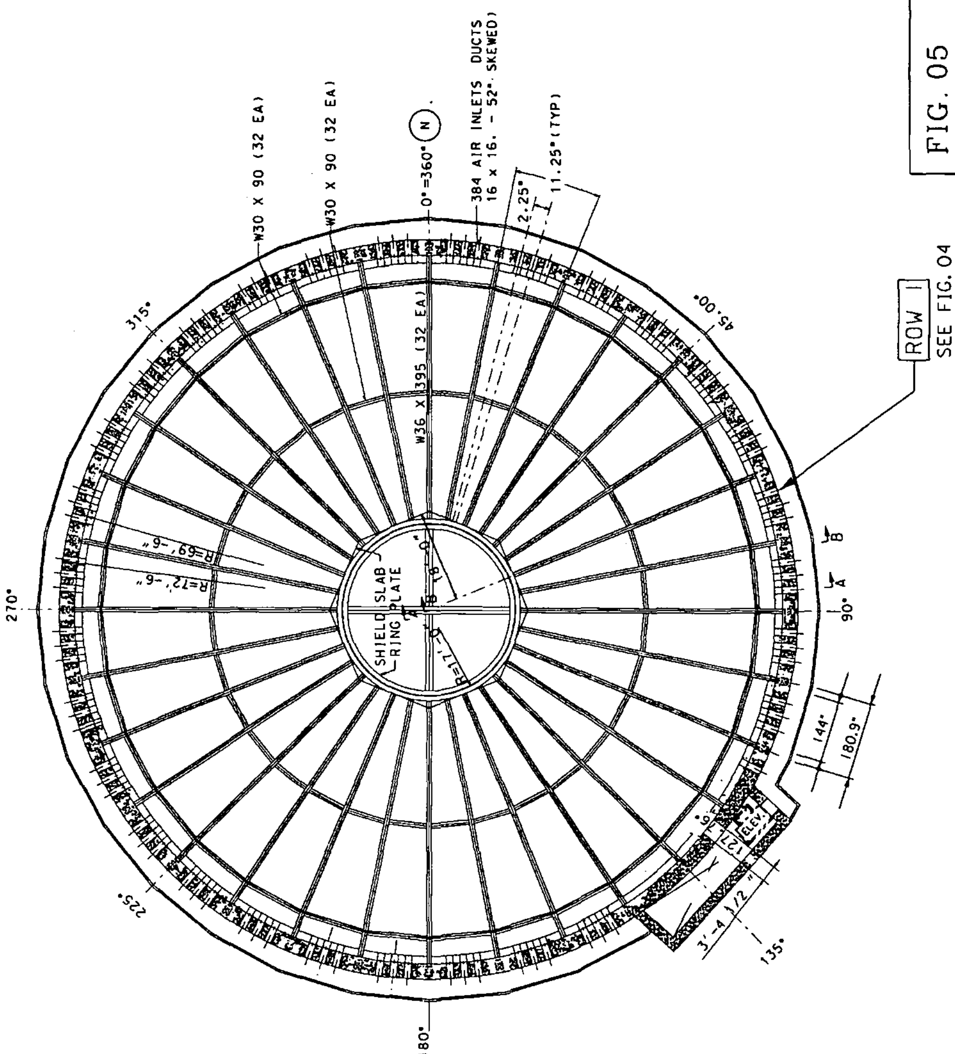

FIG. 05
PLAN VIEW
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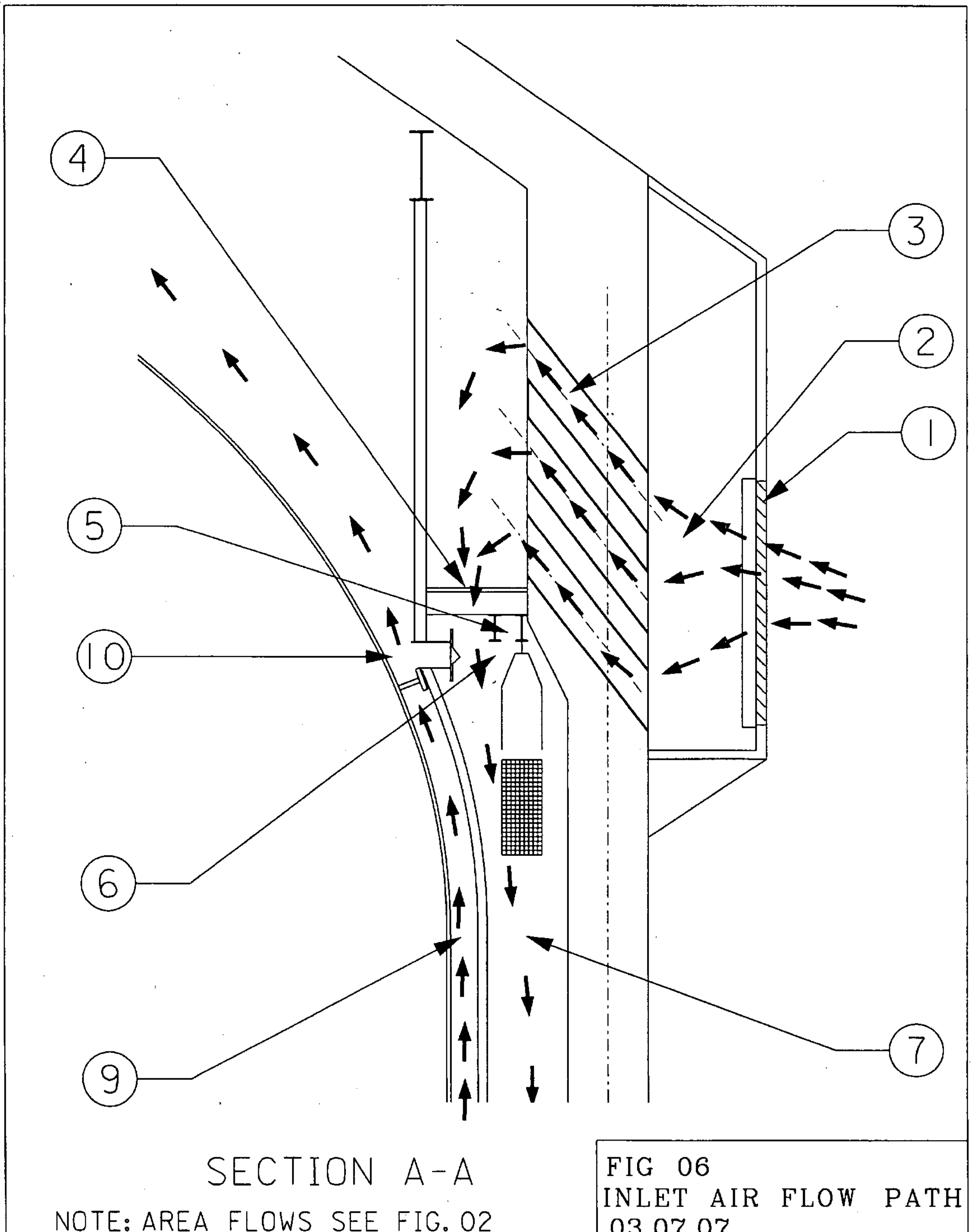


FIG 06
INLET AIR FLOW PATH
03.07.07

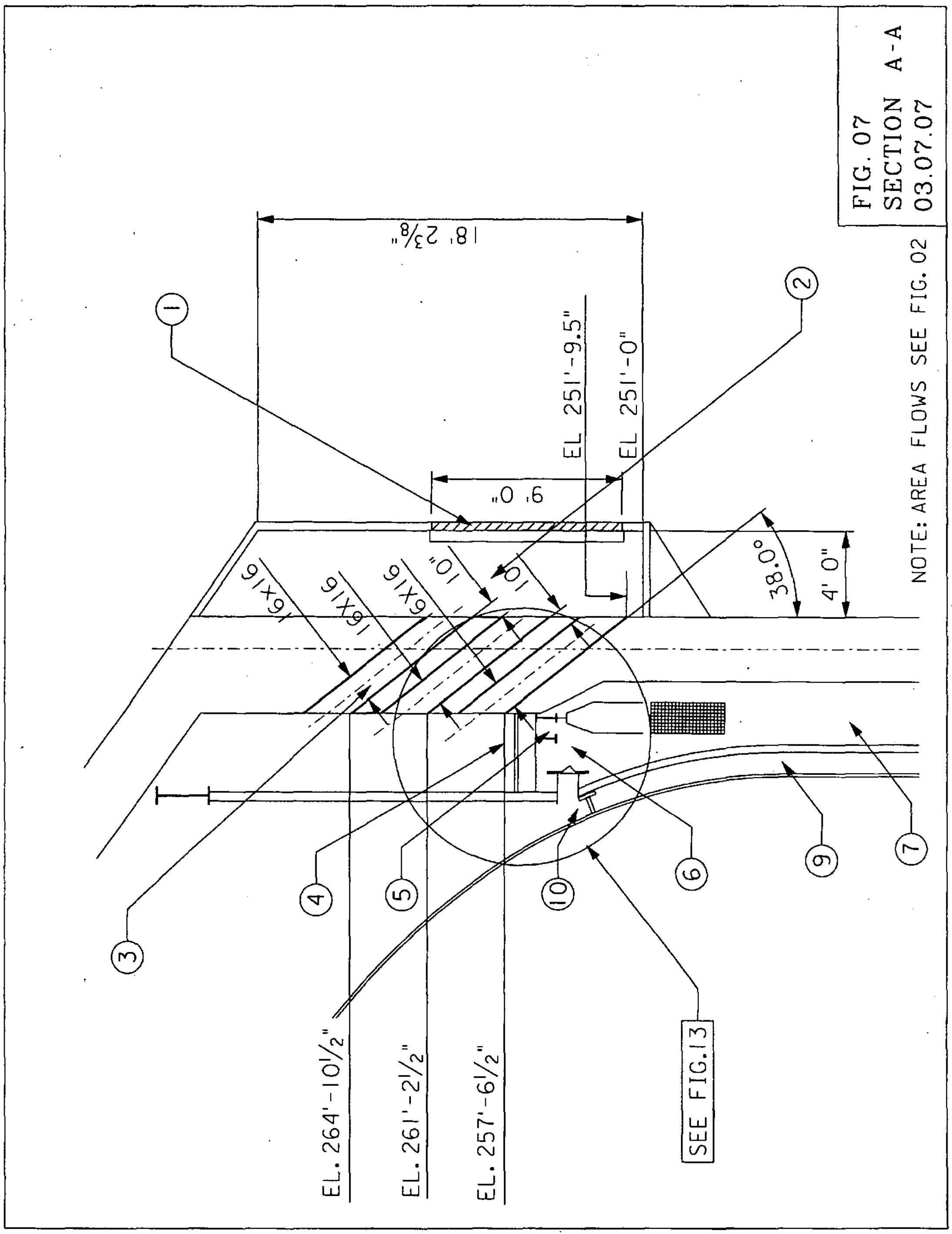
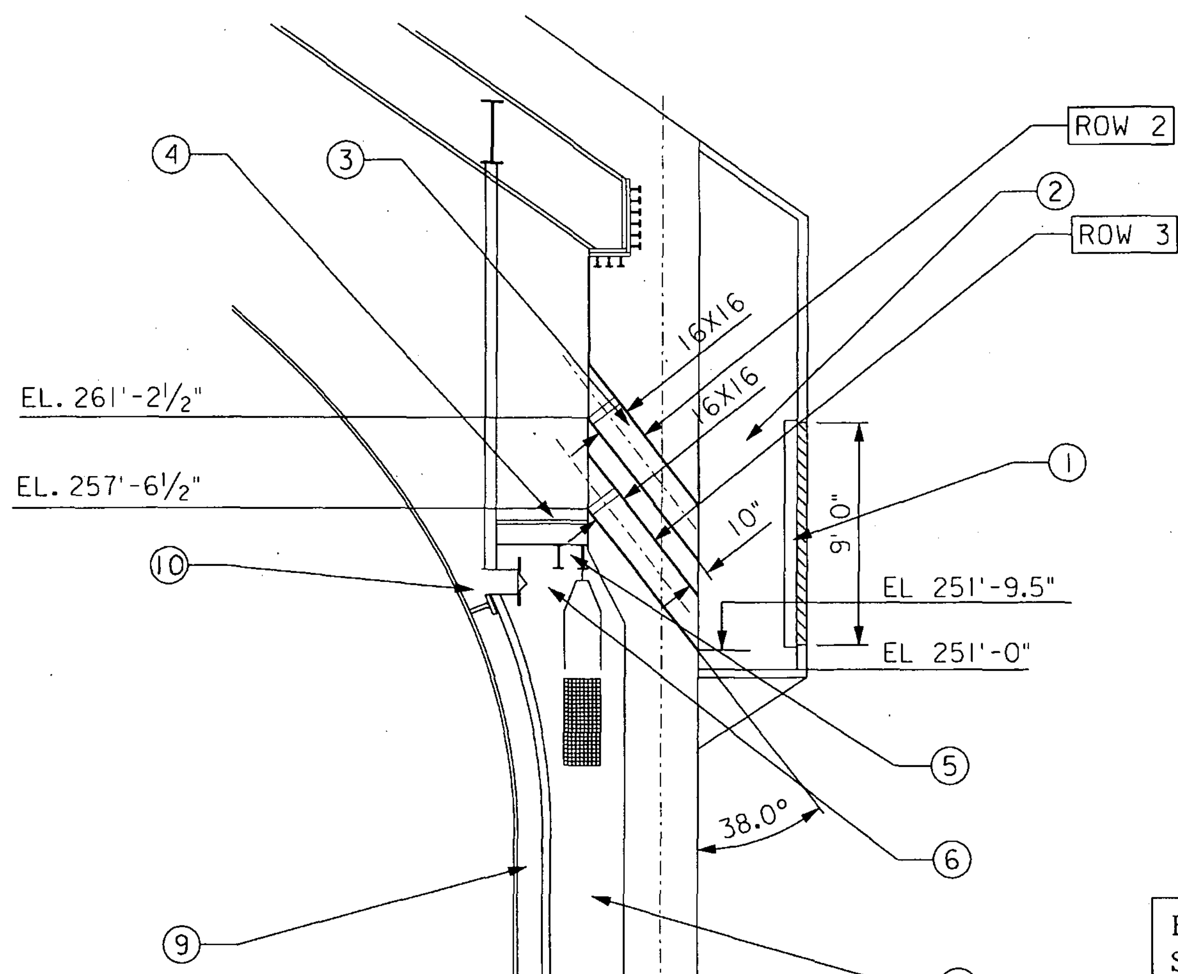
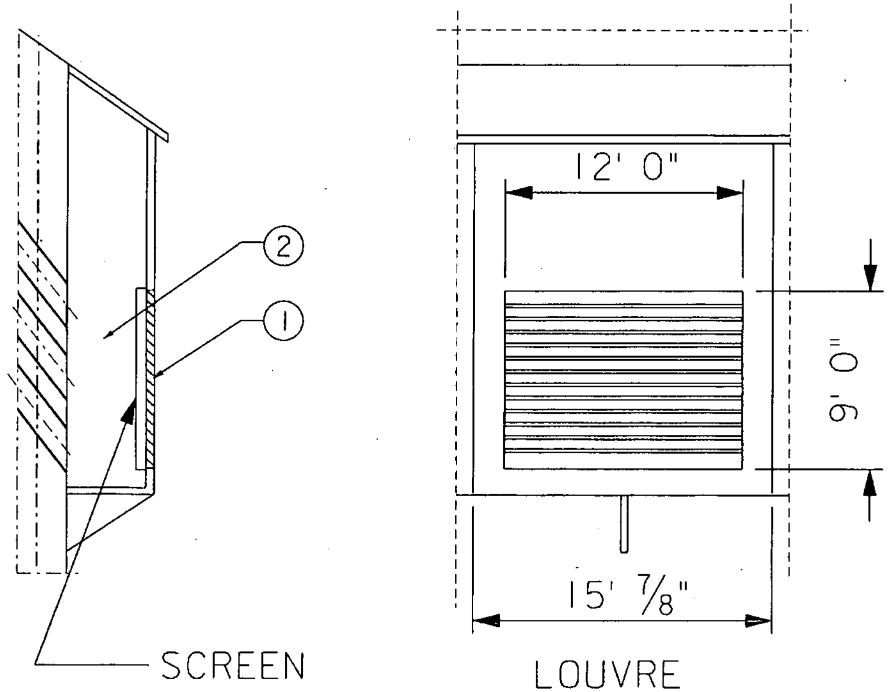


FIG. 07
SECTION A-A
03.07.07



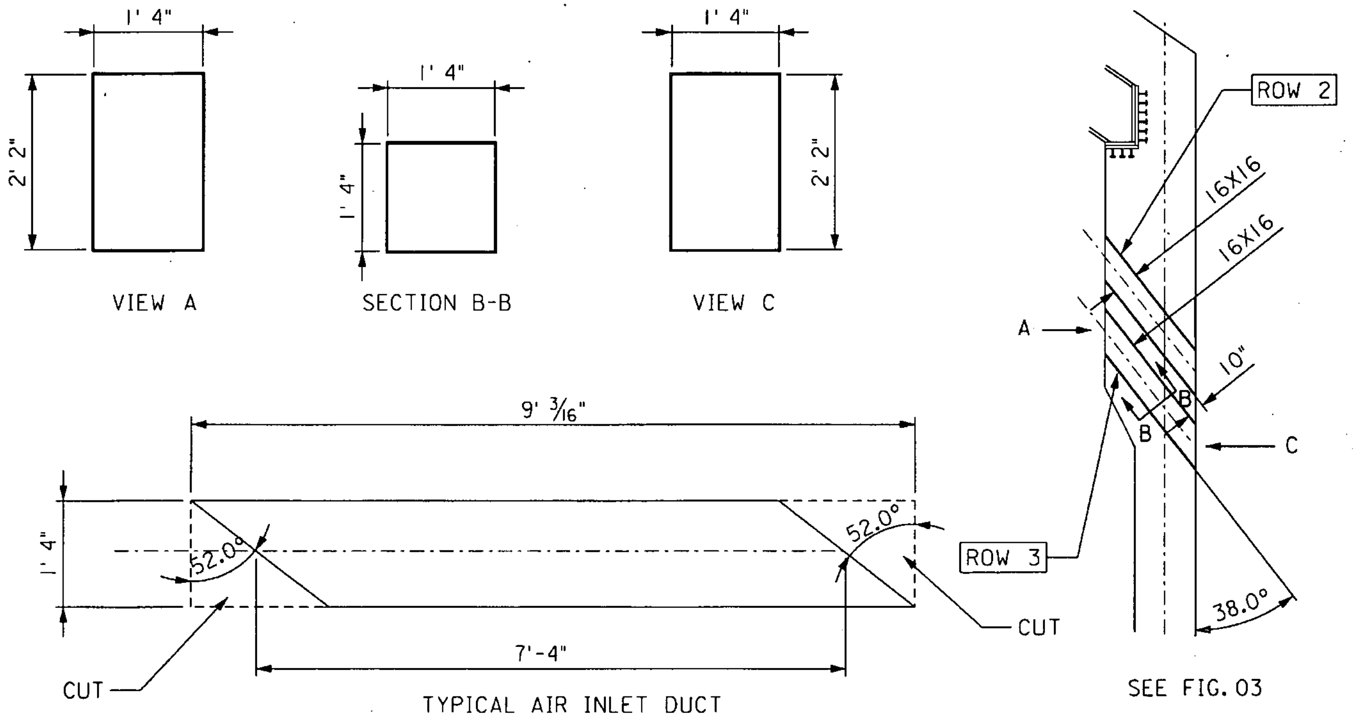
NOTE: AREA FLOWS SEE FIG. 02

FIG. 08
SECTION B-B
03.07.07



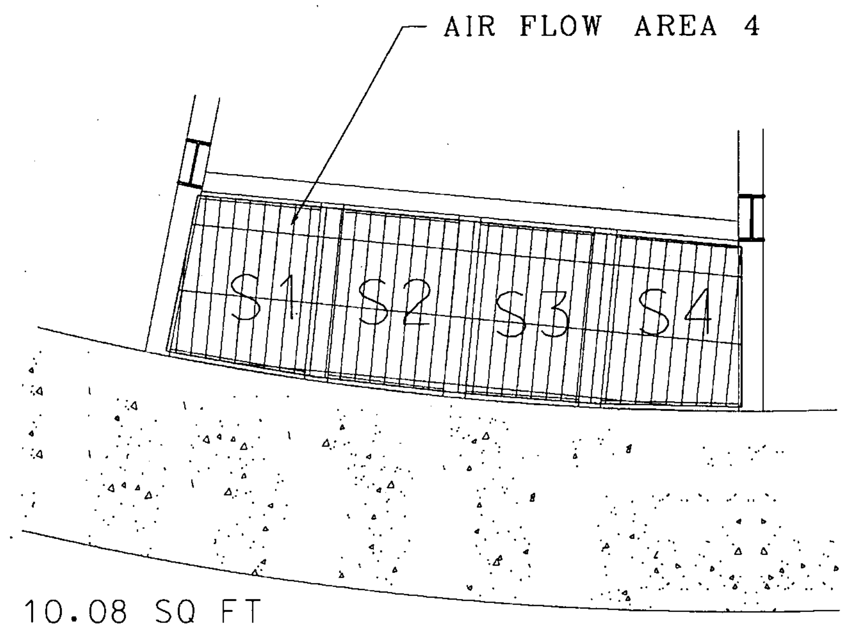
NOTES:
1. FOR TYPICAL LOUVRE PANELS WITH BIRDS SCREEN
   (SEE ATTACHED FIGURES)
   REDUCTION FACTOR IS ASSUMED AS 0.4.
   SO FREE AREA FOR ONE PANEL IS
   SF=12X9X0.4=43.2 SQ FT.
   FOR ALL PANELS
   S=29X43.2=1253 SQ FT
2. THE LENGHT THRU LOUVRES IS 5.5XSIN(45°)=7.78"
3. AIR FLOW AREAS SEE FIG. 02

FIG. 09
LOUVRES AND SCREEN
03.07.07



AIR FLOW AREA 3

FIG. 10
AIR INLET DUCTS
03.05.07



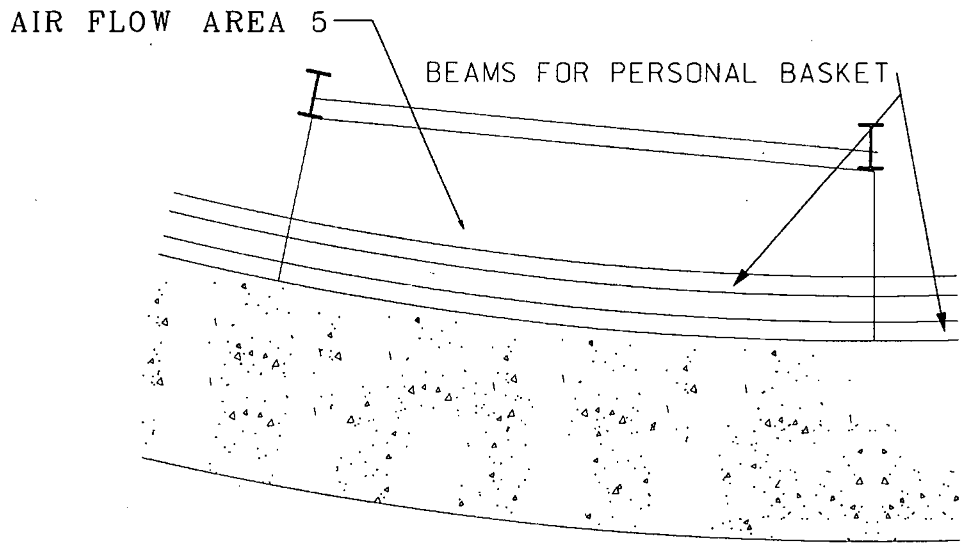
S1= 10.08 SQ FT
S2= 9.65 SQ FT
S3= 9.65 SQ FT
S4= 10.08 SQ FT

S= 39.46 SQ FT

NOTE: ASSUMPTION WAS MADE THAT REDUCING FACTOR IS AS FOR GRATING W19-4 0.73

TOTAL FREE FLOW AREA = 29.5X39.46X0.73=850 SQ FT

FIG. 11
AIR FLOW AREA 4 (THRU GRATING)
03.05.07



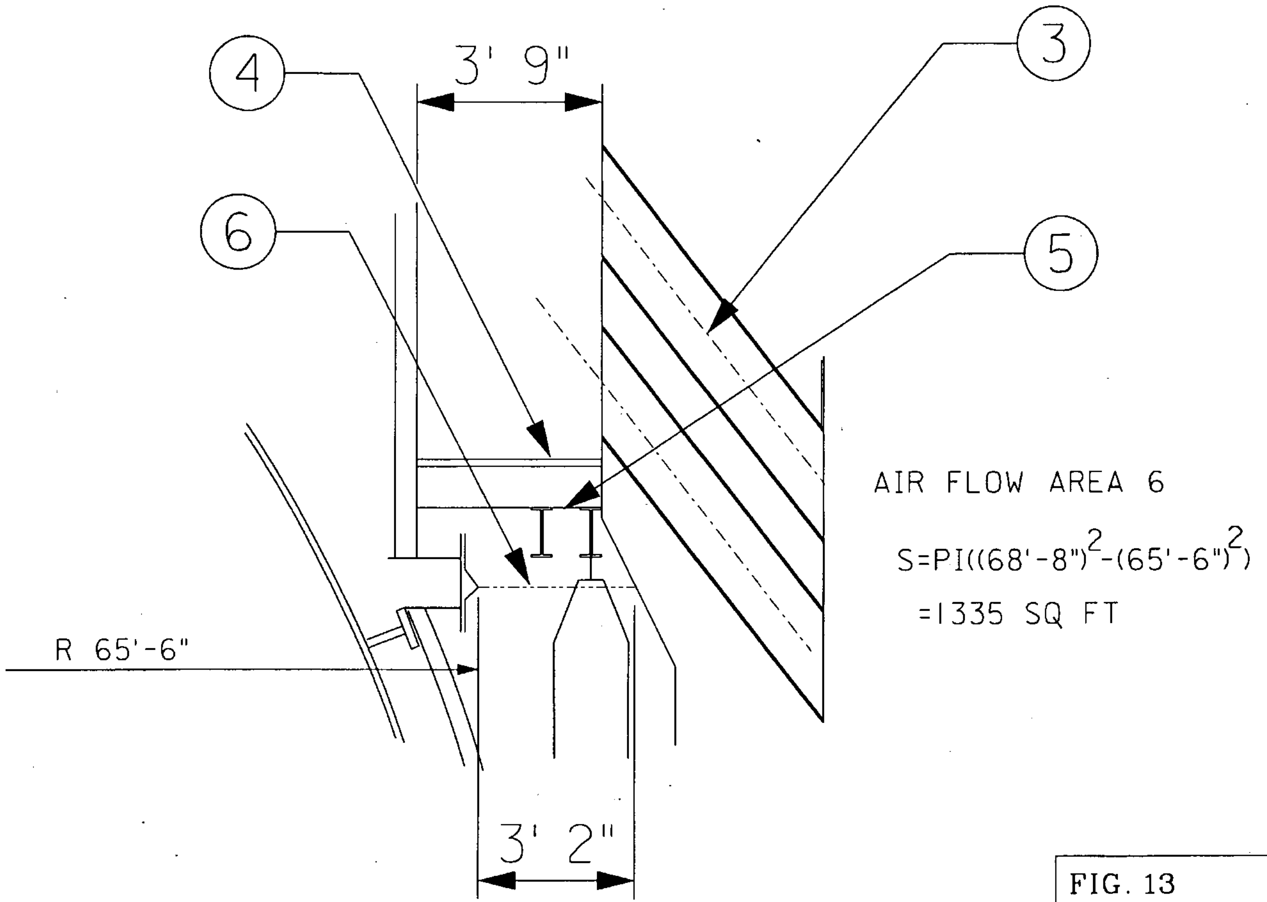
FREE FLOW AREA SF = 51.7 SQ FT

BEAMS AREA SB= SB1+SB2 = 5.63+5.72=11.35

REDUCING FACTOR K=(SF-SB)/SF= (51.7-11.35)/51.7=0.78

TOTAL FREE FLOW AREA =29.5X51.7X0.78=1190 SQ FT

FIG. 12
AIR FLOW AREA 5 (THRU BEAMS)
03.05.07



NOTE: AIR FLOW AREAS SEE FIG. 02

FIG. 13
AIR FLOW AREA 6
03.07.07

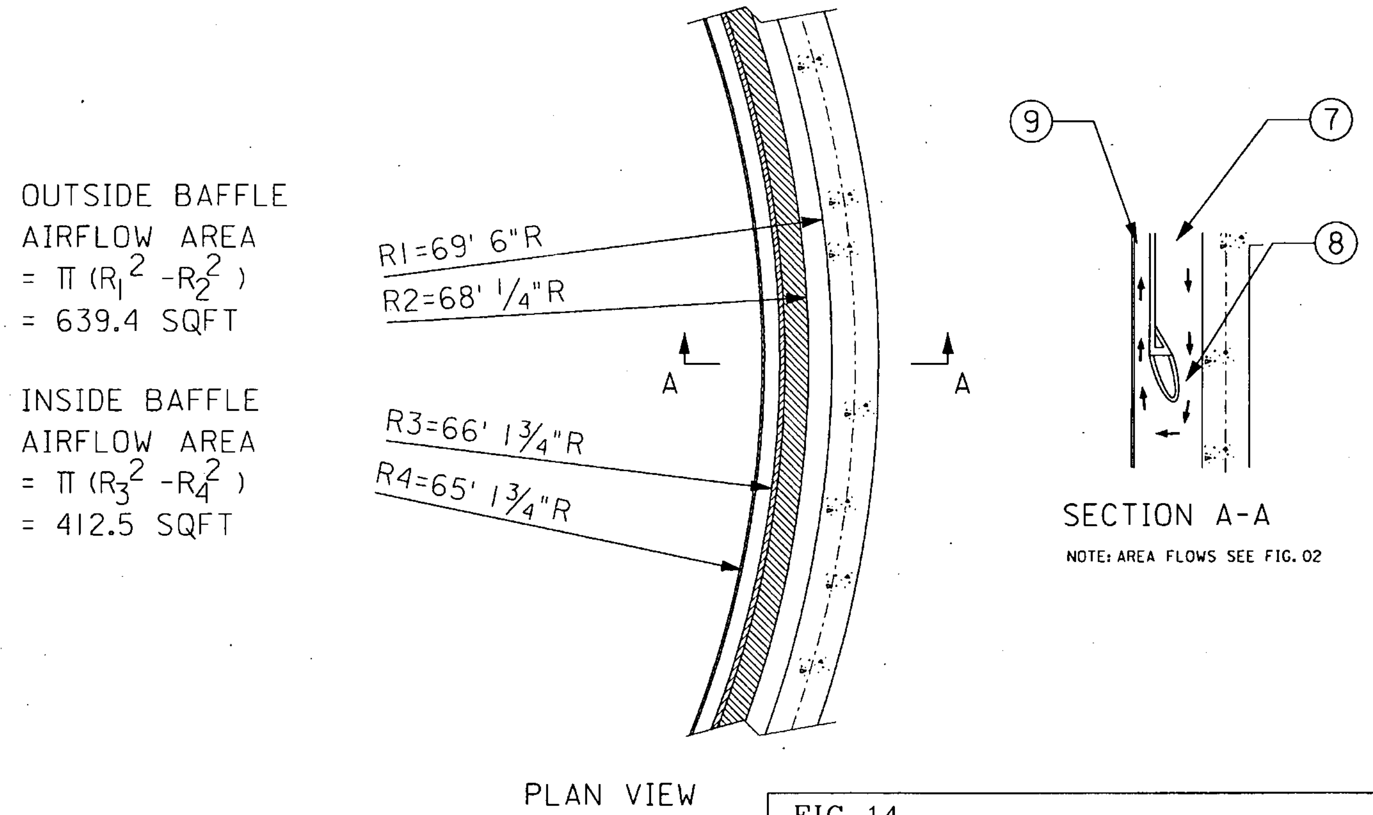


FIG. 14
AIR FLOW AREAS 7, 8 & 9 (AT THE BOTTOM OF THE BAFFLE)
03.07.07

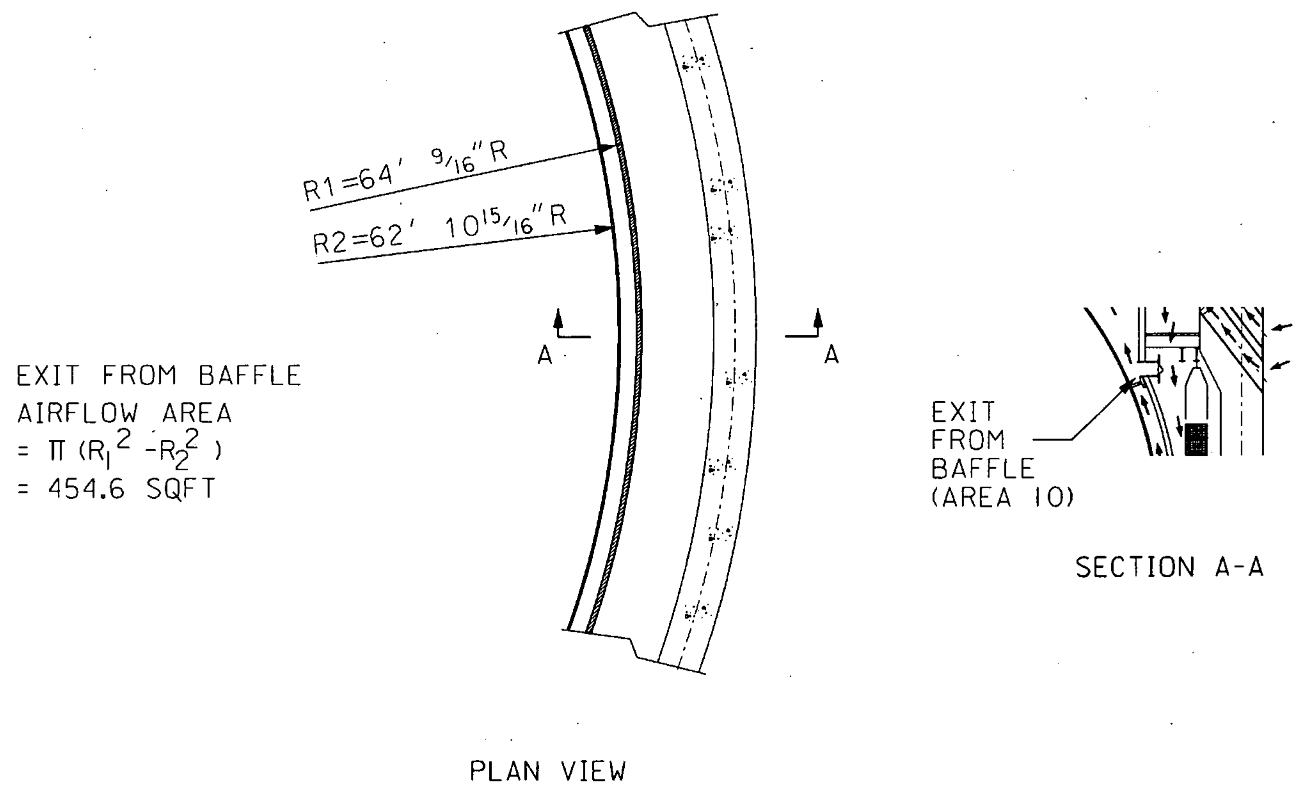
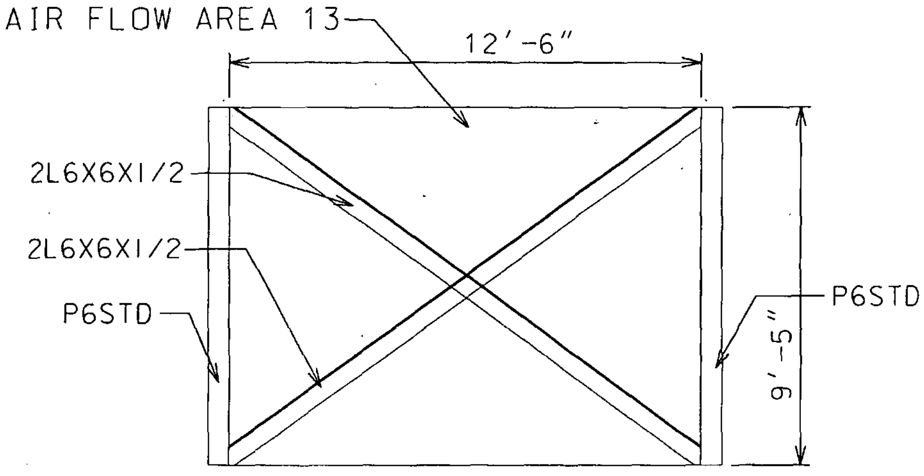


FIG. 15
AIR AREA FLOW 10
(EXIT AREA FROM THE BAFFLE)
03.05.07



VIEW A-A

SF=12.5x9.45=118 SQ FT

S W/OUT STEEL=101.35

K=S/SF=0.86

WIRE MESH: 10 MESH PER INCH WITH DIA 0.025

K=0.55

TOTAL REDUCING FACTOR = 0.473

TOTAL FREE FLOW AREA=8x118X0.473=447 SQ FT

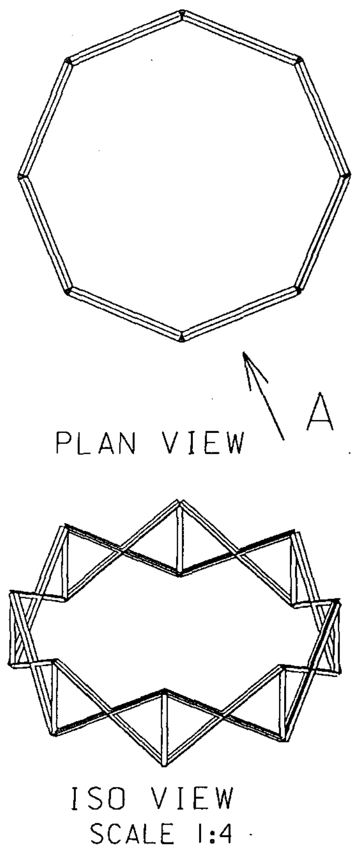


FIG. 16
AIR FLOW AREA 13
(WIRE MESH OUTLET AREA)
03.07.07

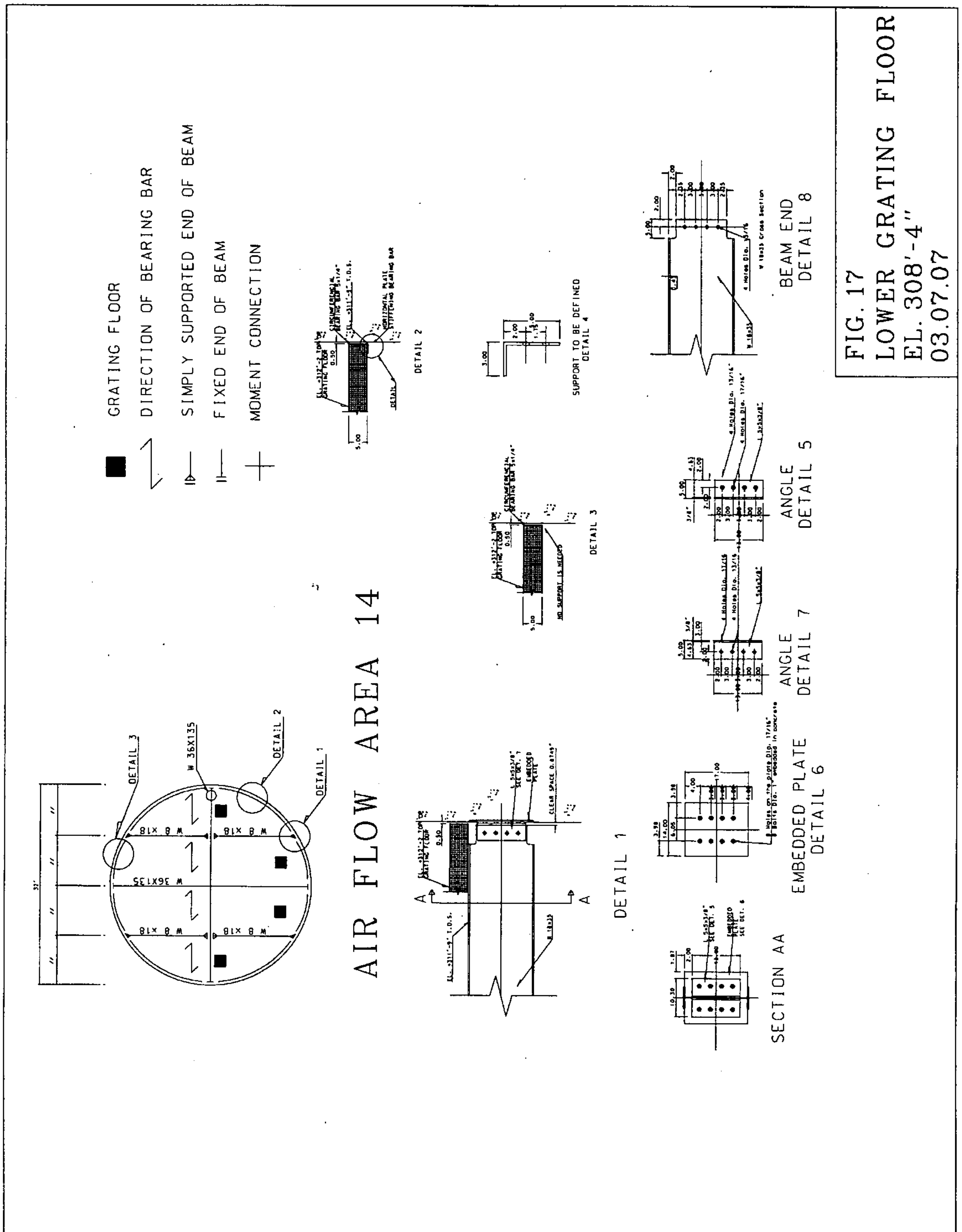


FIG. 17
LOWER GRATING FLOOR
EL. 308'-4"
03.07.07

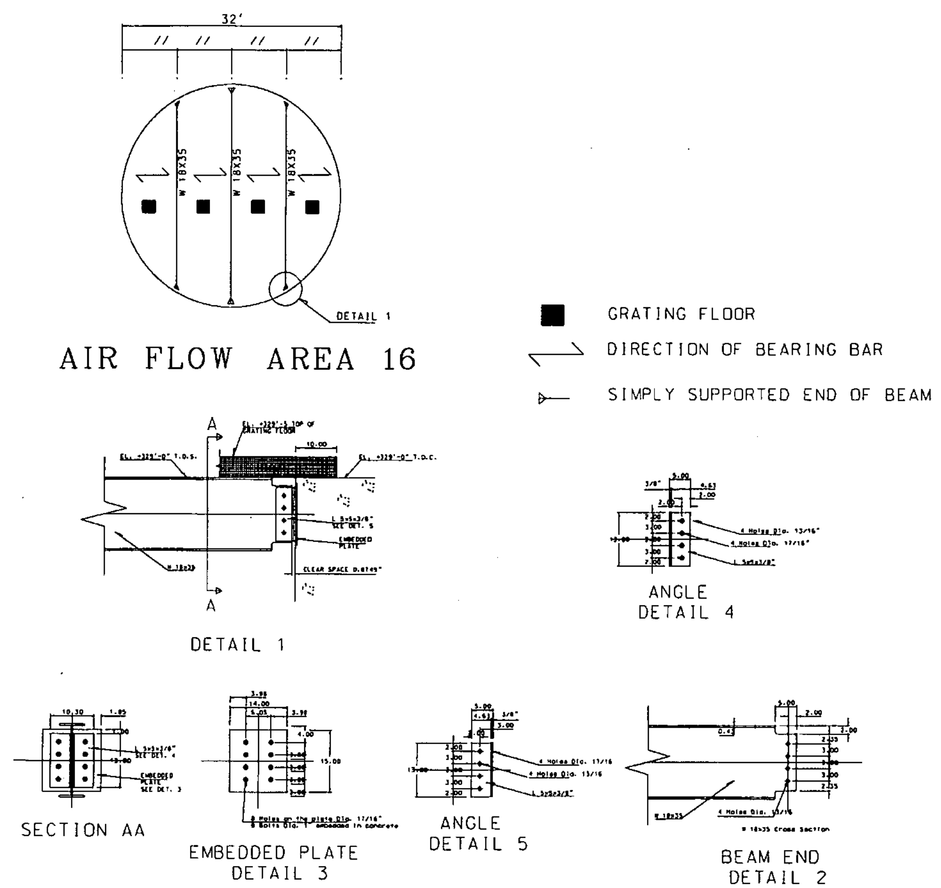


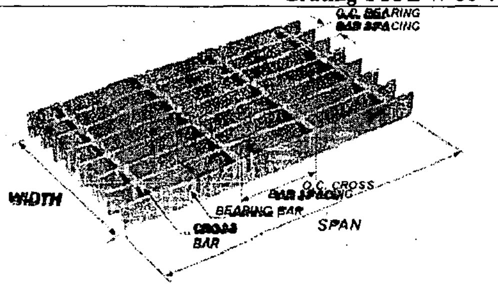
FIG. 18
UPPER GRATING FLOOR
EL. 329'-5"
03.07.07

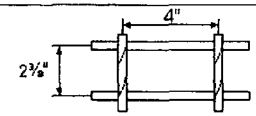
A commercial catalogue issued by Grating Pacific Inc. was used (www.gratingpacific.com) to perform this design.

SB ROOF OPENING, UPPER GRATING FLOOR			
DESCRIPTION	**AREA CALCULATION**	**FREE AREA (SQ-FT)**	**AREA %**
CIRCULAR OPENING 32' DIA.	3.1416 * (16')^2 = 804.25 sq-ft	804.25	100
Area blocked by beam W18X35, 32' Long	32' * (6"/12) = 16.00 sq-ft	— 16.00	— 1.99
Area blocked by 2 beams W18X35, 27.71' Long	2 * 27.71' * (6"/12) = 27.78 sq-ft	— 27.78	— 3.45
Free Area after removing area blocked by beams	804.25 sq-ft - 16.00 sq-ft - 27.78 sq-ft = 760.47 sq-ft		
Grating TYPE W-38-4 blocks 18.9 % of the surface it covers	Hence, blocked area is 18.9% of 760.47 sq-ft, a total of 143.73 sq-ft	— 143.73	— 17.87
TOTAL		**616.74**	**76.44**

SB ROOF OPENING, LOWER GRATING FLOOR			
DESCRIPTION	**AREA CALCULATION**	**FREE AREA (SQ-FT)**	**AREA %**
CIRCULAR OPENING 32' DIA.	3.1416 * (16')^2 = 804.25 sq-ft	804.25	100
Area blocked by beam W36X135, 32' Long	32' * (12"/12) = 32.00 sq-ft	— 32.00	— 3.98
Area blocked by beam W36X135, 31' Long (32' minus W36X135 width, i.e. 12")	31' * (12"/12) = 31.00 sq-ft	— 31.00	— 3.85
Area blocked by 4 beams W18X35, 13.355' Long (13.855' minus half W36X135 width, i.e. 6")	4 * 13.355' * (6"/12) = 26.71 sq-ft	— 26.71	— 3.32
Area blocked by circumferential stiffeners on grating trim band, 3" wide, on 50% of circumferential length, i.e. 2*PI*16'*0.5 = 50.26'	50.26'* (3"/12) = 12.57 sq-ft	— 12.57	— 1.56
Free Area after removing area blocked by beams	804.25 sq-ft - 32.00 sq-ft - 31.00 sq-ft - 26.71sq-ft - 12.57 sq-ft = 701.97 sq-ft		
Grating TYPE W-38-4 blocks 18.9 % of the surface it covers	Hence, blocked area is 18.9% of 701.97 sq-ft, a total of 132.67 sq-ft	— 132.67	— 16.79
TOTAL		**569.30**	**70.79**

Grating TYPE W-38-4





Bearing Bars at 2-3/8" O.C. -
Cross Bars at 4" O.C.
B.B is 5"x1/4"
C.B. is 2"x3/8"

Mesh Opening									
TYPE	Bearing bar spacing	Cross bar spacing	Bearing bar width	Cross bar width	BB Mesh opening	CB Mesh opening	Total Area	Free Area	Percentage of roof opening section that is not blocked
W-38-4	2 3/8"	4"	1/4"	3/8"	2 3/8" – 1/4" = 2.125"	4" – 3/8" = 29/8"	9.50 sq-in	7.703 sq-in	7.703 / 9. 5 = 81.1 %

DESCRIPTION	FREE AREA (SQ-FT)	REDUCTION FACTOR	NET AREA (SQ-FT)	LENGTH (IN)
UPPER GRATING FLOOR	804.25	0.76	**616.74**	5
LOWER GRATING FLOOR	804.25	0.71	**569.30**	5

C. Cantarero (Mar/02/2007)

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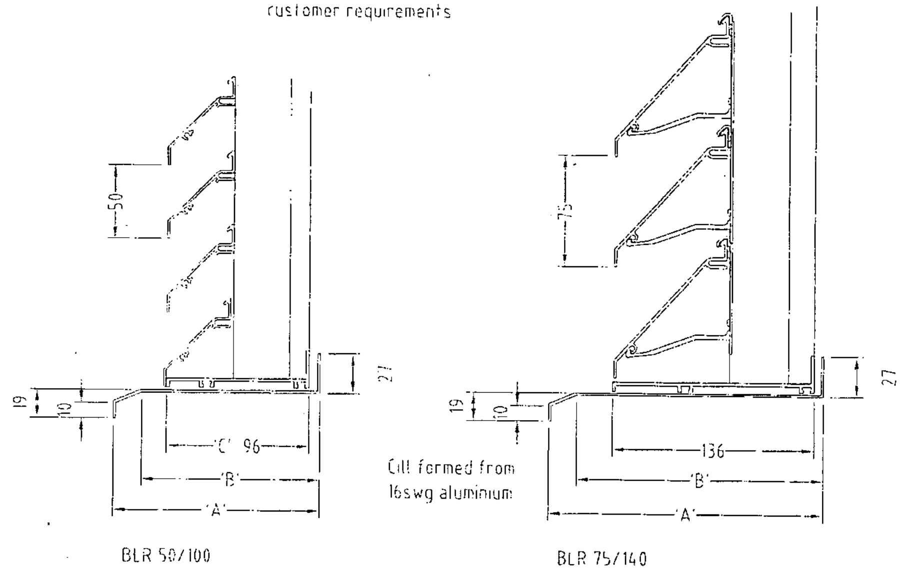
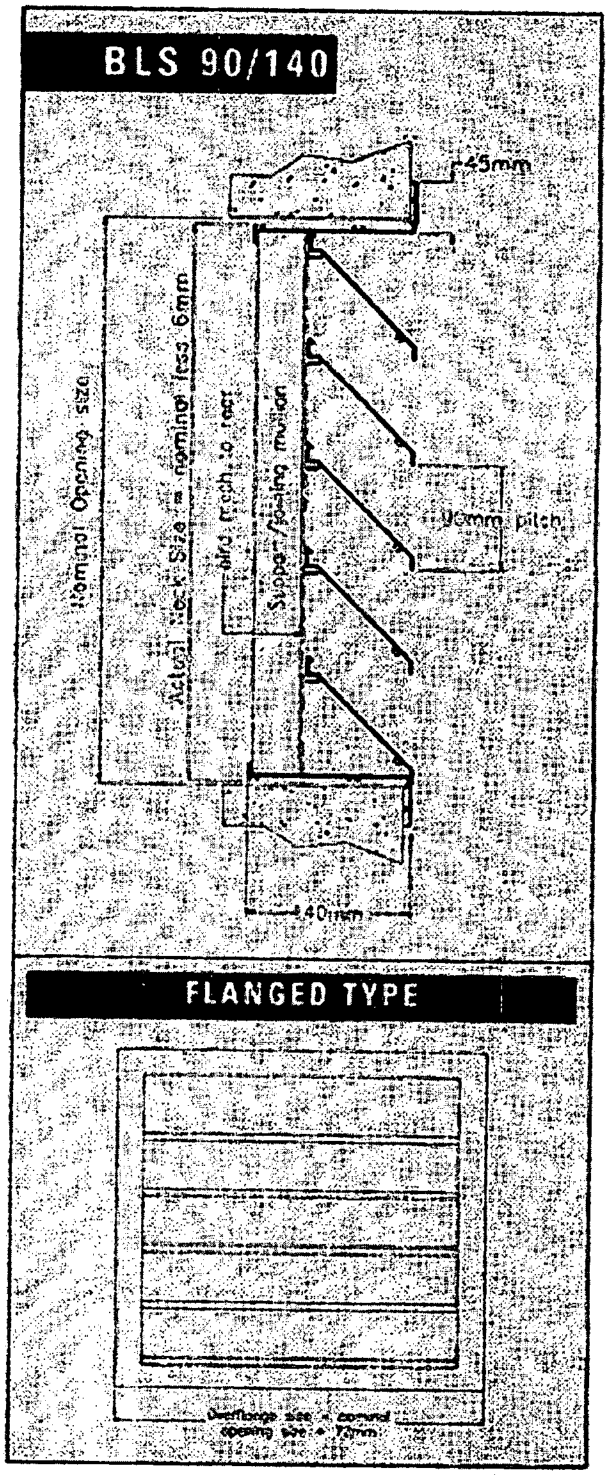
Standard cill details. Dimensions A & B are to suit customer requirements





BLS 90/140
45mm
Nominal Opening Size
Actual Neck Size = nominal less 6mm
Bird mesh to rear
Support/joining mullion
90mm pitch
140mm
FLANGED TYPE

III. DCD MARK-UP

The DCD changes for the design changes evaluated in this report are included in Design Control Document Revision 16. These DCD changes are identified in APP-GW-GLN-105. There are no DCD changes required for the evaluation summarized in this report.

IV. REGULATORY IMPACT

A. FSER IMPACT

The containment heat removal system and shield building functional design are described in FSER Section 6.2.2 and 6.2.3. These write-ups are not altered by the evaluation summarized in this report and the changes to the shield building design. The containment functional design is described in FSER Section 6.2.1. The methodology, assumptions and conclusions described in this section are not are not altered by the evaluation summarized in this report and the changes to the shield building design.

B. SCREENING QUESTIONS (Check correct response and provide justification for that determination under each response)

1. Does the proposed change involve a change to an SSC that adversely affects a DCD described design function? ☐ YES ☒ NO

   The evaluation summarized in this report does not indicate that the performance of the containment cooling is adversely affected. Sufficient cooling is provided to maintain the containment pressure below the design pressure.

2. Does the proposed change involve a change to a procedure that adversely affects how DCD described SSC design functions are performed or controlled? ☐ YES ☒ NO

   The evaluation summarized in this report and the changes to the shield building design do not require an adverse change to procedure to operate or maintain the passive containment cooling system.

3. Does the proposed activity involve revising or replacing a DCD described evaluation methodology that is used in establishing the design bases or used in the safety analyses? ☐ YES ☒ NO

   The evaluation summarized in this report and the changes to the shield building design do not result in a change to the methodology used to evaluate the passive containment cooling system or containment response.

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Title: Evaluation of the Effect of Shield Building Changes on Containment Response and Safety Analyses

4. Does the proposed activity involve a test or experiment not described in the DCD, where an SSC is utilized or controlled in a manner that is outside the reference bounds of the design for that SSC or is inconsistent with analyses or descriptions in the DCD? ☐ YES ☐ NO

   The evaluation summarized in this report and the changes to the shield building design do not require testing to validate the evaluation.

C. EVALUATION OF DEPARTURE FROM TIER 2 INFORMATION (Check correct response and provide justification for that determination under each response)

   10 CFR Part 52, Appendix D, Section VIII. B.5.a. provides that an applicant for a combined licensee who references the AP1000 design certification may depart from Tier 2 information, without prior NRC approval, if it does not require a license amendment under paragraph B.5.b. The questions below address the criteria of B.5.b.

1. Does the proposed departure result in more than a minimal increase in the frequency of occurrence of an accident previously evaluated in the plant-specific DCD? ☐ YES ☒ NO

   The evaluation summarized in this report and the changes to the shield building design do not have an effect on accident precursors.

2. Does the proposed departure result in more than a minimal increase in the likelihood of occurrence of a malfunction of a structure, system, or component (SSC) important to safety and previously evaluated in the plant-specific DCD? ☐ YES ☒ NO

   The evaluation summarized in this report and the changes to the shield building design do not have an adverse the operation of the passive containment cooling system or the pressure boundary integrity of the containment.

3. Does the proposed departure result in more than a minimal increase in the consequences of an accident previously evaluated in the plant-specific DCD? ☐ YES ☒ NO

   The evaluation summarized in this report and the changes to the shield building design do not alter the results of does calculated for postulated accidents.

4. Does the proposed departure result in more than a minimal increase in the consequences of a malfunction of an SSC important to safety previously evaluated in the plant-specific DCD? ☐ YES ☒ NO

   The evaluation summarized in this report and the changes to the shield building design do not alter the results of doses calculated for postulated accidents.

5. Does the proposed departure create a possibility for an accident of a different type than any evaluated previously in the plant-specific DCD? ☐ YES ☒ NO

The evaluation summarized in this report and the changes to the shield building design do not alter the fuel, reactor coolant system, or passive core cooling system and will not add a new failure mechanism.

6. Does the proposed departure create a possibility for a malfunction of an SSC important to safety with a different result than any evaluated previously in the plant-specific DCD? ☐ YES ☒ NO

   The evaluation summarized in this report and the changes to the shield building design do not add a new failure mechanism to the passive containment cooling system, the containment shield building, or containment.

7. Does the proposed departure result in a design basis limit for a fission product barrier as described in the plant-specific DCD being exceeded or altered? ☐ YES ☒ NO

   The evaluation summarized in this report and the changes to the shield building design do not alter the design pressure for the containment.

8. Does the proposed departure result in a departure from a method of evaluation described in the plant-specific DCD used in establishing the design bases or in the safety analyses? ☐ YES ☒ NO

   The evaluation summarized in this report and the changes to the shield building design do not result in a change to the methodology used to evaluate the passive containment cooling system or containment response.

☒ The answers to the evaluation questions above are "NO" and the proposed departure from Tier 2 does not require prior NRC review to be included in plant specific FSARs as provided in 10 CFR Part 52, Appendix D, Section VIII. B.5.b

☐ One or more of the answers to the evaluation questions above are "YES" and the proposed change requires NRC review.

D. IMPACT ON RESOLUTION OF A SEVERE ACCIDENT ISSUE

10 CFR Part 52, Appendix D, Section VIII. B.5.a. provides that an applicant for a combined licensee who references the AP1000 design certification may depart from Tier 2 information, without prior NRC approval, if it does not require a license amendment under paragraph B.5.c. The questions below address the criteria of B.5.c.

1. Does the proposed activity result in an impact to features that mitigate severe accidents. If the answer is Yes answer Questions 2 and 3 below. ☒ YES ☐ NO

2. Is there is a substantial increase in the probability of a severe accident such that a particular severe accident previously reviewed and determined to be not credible could become credible? ☐ YES ☒ NO ☐ N/A

   The evaluation summarized in this report and the changes to the shield building design do not alter accident precursors and do not increase the probability of a severe accident.

3. Is there is a substantial increase in the consequences to the public of a particular severe accident previously reviewed? ☐ YES ☒ NO ☐ N/A

The evaluation summarized in this report and the changes to the shield building design do not adversely affect the response to severe accidents and do not alter the results of doses calculated for postulated severe accidents.

☒ The answers to the evaluation questions above are "NO" or are not applicable and the proposed departure from Tier 2 does not require prior NRC review to be included in plant specific FSARs as provided in 10 CFR Part 52, Appendix D, Section VIII. B.5.c

☐ One or more of the he answers to the evaluation questions above are "YES" and the proposed change requires NRC review.

E. SECURITY ASSESSMENT

1. Does the proposed change have an adverse impact on the security assessment of the AP1000. ☐ YES ☒ NO

The evaluation summarized in this report and the changes to the shield building design will not alter barriers or alarms that control access to protected areas of the plant. The evaluation summarized in this report and the changes to the shield building design will not alter requirements for security personnel.