Westinghouse

Westinghouse Electric Company
Nuclear Power Plants
P.O. Box 355
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USA

U.S. Nuclear Regulatory Commission
ATTENTION: Document Control Desk
Washington, D.C. 20555

Direct tel: 412-374-5355
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e-mail: corletmm@westinghouse.com

Your ref: Docket No. 52-006
Our ref: DCP/NRC1628

September 23, 2003

SUBJECT: Transmittal of Responses to AP1000 DSER Open Items

This letter transmits the Westinghouse responses to Open Items in the AP1000 Design Safety Evaluation Report (DSER). A list of the DSER Open Item responses transmitted with this letter is Attachment 1. The proprietary responses are transmitted as Attachment 2. The non-proprietary responses are provided as Attachment 3 to this letter.

The Westinghouse Electric Company Copyright Notice, Proprietary Information Notice, Application for Withholding, and Affidavit are also enclosed with this submittal letter as Enclosure 1. Attachment 2 contains Westinghouse proprietary information consisting of trade secrets, commercial information or financial information which we consider privileged or confidential pursuant to 10 CFR 2.790. Therefore, it is requested that the Westinghouse proprietary information attached hereto be handled on a confidential basis and be withheld from public disclosures.

This material is for your internal use only and may be used for the purpose for which it is submitted. It should not be otherwise used, disclosed, duplicated, or disseminated, in whole or in part, to any other person or organization outside the Commission, the Office of Nuclear Reactor Regulation, the Office of Nuclear Regulatory Research and the necessary subcontractors that have signed a proprietary non-disclosure agreement with Westinghouse without the express written approval of Westinghouse.

D063

September 23, 2003

Correspondence with respect to the application for withholding should reference AW-03-1708, and should be addressed to Hank A. Sepp, Manager of Regulatory and Licensing Engineering, Westinghouse Electric Company, P.O. Box 355, Pittsburgh, Pennsylvania, 15230-0355.

Please contact me at 412-374-5355 if you have any questions concerning this submittal.

Very truly yours,

M. M. Corletti
Passive Plant Projects & Development
AP600 & AP1000 Projects

/Enclosure

1. Westinghouse Electric Company Copyright Notice, Proprietary Information Notice, Application for Withholding, and Affidavit AW-03-1708.

/Attachments

1. List of the AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses transmitted with letter DCP/NRC1628
2. Proprietary AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses dated September 23, 2003
3. Non-Proprietary AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses dated September 23, 2003

DCP/NRC1628
Docket No. 52-006

September 23, 2003

Enclosure 1

Westinghouse Electric Company
Application for Withholding and Affidavit

Westinghouse

Westinghouse Electric Company
Nuclear Power Plants
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

September 23, 2003

AW-03-1708

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Mr. John Segala

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: Transmittal of Westinghouse Proprietary Class 2 Documents Related to AP1000 Design Certification Review Draft Safety Evaluation Report (DSER) Open Item Response

Dear Mr. Segala:

The application for withholding is submitted by Westinghouse Electric Company, LLC ("Westinghouse") pursuant to the provisions of paragraph (b)(1) of Section 2.790 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject documents. In conformance with 10 CFR Section 2.790, Affidavit AW-03-1708 accompanies this application for withholding setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-03-1708 and should be addressed to the undersigned.

Very truly yours,

M. M. Corletti
Passive Plant Projects & Development
AP600 & AP1000 Projects

/Enclosures

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AW-03-1708

COMMONWEALTH OF PENNSYLVANIA:

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COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared James W. Winters, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company, LLC ("Westinghouse"), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief.

James W. Winters, Manager
Passive Plant Projects & Development
Nuclear Power Plants Business Unit
Westinghouse Electric Company, LLC

Sworn to and subscribed
before me this 23rd day
of September, 2003

Sharon L. Fiori
Notary Public

SHARON L. FIORI
COMMONWEALTH OF PENNSYLVANIA
NOTARY PUBLIC

Notarial Seal
Sharon L. Fiori, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires January 29, 2007
Member, Pennsylvania Association Of Notaries

(1) I am Manager, Passive Plant Projects & Development, in the Nuclear Power Plants Business Unit, of the Westinghouse Electric Company LLC ("Westinghouse"), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Electric Company, LLC.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by the Westinghouse Electric Company, LLC in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in Attachment 2 as Proprietary Class 2 in the Westinghouse Electric Co., LLC document: (1) "AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Response."

This information is being transmitted by Westinghouse's letter and Application for Withholding Proprietary Information from Public Disclosure, being transmitted by Westinghouse Electric Company (W letter AW-03-1708) and to the Document Control Desk, Attention: John Segala, DIPM/NRLPO, MS O-4D9A.

This information is part of that which will enable Westinghouse to:

(a) Provide documentation supporting determination of APP-GW-GL-700, "AP1000 Design Control Document," analysis on a plant specific basis

(b) Provide the applicable engineering evaluation which establishes the Tier 2 requirements as identified in APP-GW-GL-700.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for purposes of meeting NRC requirements for Licensing Documentation.

(b) Westinghouse can sell support and defense of AP1000 Design Certification.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar methodologies and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended for performing and analyzing tests.

Further the deponent sayeth not.

DCP/NRC1628
Docket No. 52-006

September 23, 2003

Attachment 1

List of

Proprietary and Non-Proprietary Responses

Table 1 **"List of Westinghouse's Responses to DSER Open Items Transmitted in DCP/NRC1628"**	
2.5.1-1 Rev 1 2.5.4-1 Rev 1 2.5.4-2 Rev 1 3.3.1-1 Rev 1 3.3.1-2 Rev 1 3.3.2-1 Rev 1 3.3.2-2 Rev 1 3.6.3.4-2 Addendum 1 3.7.1.5-1 Rev 1 3.7.2.16-1 Rev 1 3.8.4.3-1 Rev 1 3.8.4.5-2 Rev 1 3.8.5.1-1 Rev 1	19A.3-3 Rev 2 21.5-3P* Rev 1 21.5-3 Rev 1
*Proprietary	

DCP/NRC1628
Docket No. 52-006

September 23, 2003

Attachment 3

AP1000 Design Certification Review
Draft Safety Evaluation Report Open Item Non-Proprietary Responses

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 2.5.1-1 (Revision 1)

Original RAI Number(s): None

Summary of Issue:

The DCD Tier 2 information, while listing certain site specific aspects of basic geologic and seismic information to be provided by a COL applicant referencing the AP1000 certified design, does not include some of the attributes discussed above. This issue was discussed with the applicant during the April 2-5, 2003 audit. This is Open Item 2.5.1-1.

In telephone discussion on August 22, 2003, it was requested that the DCD specifically identify other items discussed in the DSER such as the dynamic behavior during prior earthquakes.

Westinghouse Response (Revision 1):

This Open Item was addressed by changes to Chapter 2 included in DCD Revision 5. The changes were made in the response to RAI 240.005 transmitted by letter DCP/NRC1586 on May 7, 2003.

The DCD will be revised as shown below to address the comments received from the NRC during the August 22, 2003 telephone call.

Design Control Document (DCD) Revision:

Revise subsection 2.5.1. as follows:

2.5.1 Basic Geological and Seismic Combined License Information

Combined License applicants referencing the AP1000 certified design will address the following regional and site-specific geological, seismological, and geophysical information as well as conditions caused by human activities:

- Structural geology of the site
- Seismicity of the site
- Geological history
- Evidence of paleoseismicity
- Site stratigraphy and lithology
- Engineering significance of geological features
- Site groundwater conditions
- **Dynamic behavior during prior earthquakes**
- **Zones of alteration, irregular weathering, or zones of structural weakness**
- **Unrelieved residual stresses in bedrock**

- **Materials that could be unstable because of their mineralogy or unstable physical properties**
- **Effect of human activities in the area**

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 2.5.4-1 (Revision 1)

Original RAI Number(s): None

Summary of Issue:

The DCD describes the need for establishing a vertical face below the grade with lateral support of the adjoining undisturbed soil or rock and suggests the use of soil nailing to stabilize the vertical soil surface as an alternative method for achieving this provision. The stability of the nailed soil surface will depend on the length and depth of the soil anchors or nails. One result of this proposed construction technique is that the soil immediately surrounding the nuclear island (NI) consists of natural in-situ materials only, which have relatively continuous properties in the horizontal and vertical directions. Because this configuration conforms to the assumptions made in the seismic analyses performed to assess the seismic responses of the NI structures, the proposed excavation method is considered acceptable to the NRC staff. However, during discussions with the applicant during the November 2002 meeting, it was noted that the COL applicant should also show that the existing in-situ soil satisfies the minimum conditions (in terms of soil parameters) assumed for the design of the AP1000 foundation and exterior walls. In addition, if the in-situ soils are not appropriate for the use of soil nailing excavation techniques, the COL applicant should show that any other construction method planned for the excavation satisfies the assumptions of the design of the NI. If any other construction technique that requires excavation and backfill of large areas surrounding the NI is proposed, the procedures and criteria for installing the backfill should also be submitted by the COL applicants for review and approval. In addition, an evaluation of the effect of any alternative construction procedures on the seismic responses of the NI structures should be performed. The amount of lateral passive pressure used in the design of the NI needs to be specified as an interface requirement for the COL applicant. This issue was discussed with the applicant during the April 2-5, 2003, audit. This is Open Item 2.5.4-1.

NRC Comments during telecon on August 22, 2003

Please provide guidance to the Combined License applicant by specifying values for the lateral passive pressure used in the design of the NI.

Westinghouse Response (Revision 1):

This Open Item was addressed by changes to Chapter 2 included in DCD Revision 5. The changes were made in the response to RAI 240.005 transmitted by letter DCP/NRC1586 on May 7, 2003.

The exterior walls of the nuclear island are designed for lateral earth pressure equal to the passive earth pressure as described in DCD subsection 3.8.4.4.1. The passive earth pressure is calculated assuming adjacent soils with the following properties:

ϕ = angle of internal friction of the granular backfill = 35°
γ_{sat} = saturated soil density = 150 pounds/ft^3
γ_{sub} = submerged soil density = 87.6 pounds/ft^3

The passive earth pressure is conservatively specified as one design load case for the exterior walls because it is included in subsection 3.8.5.5.3 as part of the resistance against sliding. The minimum passive earth pressure to provide the required factor of safety against sliding corresponds to the soil properties specified in DCD subsection 2.5.4.6.2.

The lateral earth pressure is less than the passive earth pressure unless sliding occurs. Design for the full passive earth pressure calculated using the soil properties shown above is conservative. Soils that would result in a higher passive earth pressure would be acceptable since the factor of safety against sliding meets the acceptance criterion of 1.1 using the minimum soil properties specified in subsection 2.5.4.6.2.

The AP1000 exterior walls are designed for At-Rest pressure distributions that will envelop all of the soil properties that could be used by the applicant from medium sand to hard rock. It is also noted that these walls are also designed for hydrostatic pressure distributions associated with probable maximum flood levels at ground elevation of 100' 0". Therefore, it is not necessary to provided additional information than that provided by subsection 2.5.4.6.2.

A second design load case is also specified for the exterior walls as described in DCD subsection 3.8.4.4.1. For this case the dynamic earth pressure is calculated in accordance with ASCE 4-98. It is calculated with conservative soil properties (saturated soil density = 160 pounds/ ft^3 and Poisson's ratio of 0.40). These loads will bound those using site specific properties.

The lateral pressures used in the design of the nuclear island is sufficient to assure an adequate factor of safety against sliding and no additional information needs to be included in the DCD.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 2.5.4-2 (Revision 1)

Original RAI Number(s): None

Summary of Issue:

The bearing capacity of the subgrade is a fundamental design parameter for this standard design. In the design of the foundation of a large structure it is important to ensure that under normal operating conditions, the average pressure on the subgrade is less than the allowable average bearing capacity of the foundation material, and that the peak subgrade pressure caused by the load combination with the SSE imposing the largest toe pressure at the edge of the foundation is also within the allowable capacity of the subgrade. The allowable bearing capacity of the subgrade is governed by settlement or crushing. Under relatively soft soil conditions, short term soil movement due to water table fluctuation and long term settlement due to the super imposed loading affect the allowable bearing capacity. Under hard rock subgrade conditions, the bedding direction of rock layers and the level of cracking and other discontinuities in the matrix of the rock material can limit the allowable average and allowable peak bearing capacity. The response to the RAIs indicates that the bearing capacity at a hard rock site will exceed 21.55MPa (450,000 pounds per square ft). During the April 2 through 5, 2003 audit, the staff requested the applicant to clearly specify, in the DCD, that this standard design is based on an allowable average and an allowable peak bearing capacity, and should specify what these values are. This is Open Item 2.5.4-2.

In a telephone discussion on August 22, 2003, it was requested that additional information be provided on the bearing demand and the determination of the allowable bearing capacity by the Combined License applicant.

Westinghouse Response (Revision 1):

This Open Item was addressed by changes to Chapter 2 included in DCD Revision 5. The changes were made in the response to RAI 240.005 transmitted by letter DCP/NRC1586 on May 7, 2003.

A revision to the DCD is shown below to address the additional comments from the NRC in the August 22 telephone call. The revisions also include a correction to the required bearing capacity (120,000 pounds per square foot) based on the latest revision of the nuclear island basemat analyses. This bearing demand replaces the demand of 450,000 pounds per square ft. which was given in the earlier revision of the DCD prior to completion of the basemat analyses.

Typical allowable bearing capacities for rock were provided in the revision 1 response to RAI 241.001. Allowable bearing pressures for rock given in Reference 2.5.4-2-1 range from 80 ksf to in excess of 200 ksf (Boston, Denver, Newark, New York, Philadelphia, and New York city).

It is recognized that it is difficult to establish a generic methodology to determine the allowable bearing capacity since this is site dependent. As stated by Terzaghi and Peck (Reference 2.5.4-2-1): "Because of the great variety of soils and combinations of soils encountered in practice, no single method for determining the allowable soil pressure can be developed that would be suitable under all circumstances. The procedure must always be adapted to the soil conditions revealed by the exploratory borings. ..." Therefore, the COL applicant is referred to the acceptance criteria given in the Standard Review Plan 2.5.4 in the DCD.

References:

2.5.4-2-1 Terzaghi, Karl, and Ralph B. Peck, <u>Soil Mechanics in Engineering Practice</u>, John Wiley & Sons, Inc., New York, 1948, p 418.

Design Control Document (DCD) Revision:

Revise soil bearing parameters in Table 5.0-1 of Tier 1 and Table 2-1 of Tier 2 as follows:

Soil		
	Average Allowable Static Bearing Capac~~bil~~ity	Greater than or equal to 8,600 lb/ft^2 over the footprint of the nuclear island at its excavation depth
	Maximum Allowable Dynamic Bearing Capacity for Normal Plus SSE	Greater than or equal to ~~85~~120,000 lb/ft^2 at the edge of the nuclear island at its excavation depth
	Shear Wave Velocity	Greater than or equal to 8,000 ft/sec based on low-strain best-estimate soil properties over the footprint of the nuclear island at its excavation depth
	Liquefaction Potential	None

Revise subsection 2.5.4.2 as follows:

2.5.4.2 Bearing Capacity

The maximum bearing reaction on the hard rock determined from the analyses described in subsection 3.8.5.1 is less than ~~85,~~120,000 pounds per square foot under all combined loads including the safe shutdown earthquake. Bearing capacity at a hard rock site will exceed this demand.

The maximum bearing reaction on the hard rock specified in Table 2-1 is determined from the analyses described in subsection 3.8.5.1. These analyses consider the foundation as a very stiff semi-infinite elastic medium. This results in high bearing reactions below the stiff walls of the nuclear island. Where the rock is unable to support these high local bearing pressures, loads will redistribute to the adjacent rock. The key attribute for acceptability of the site for an AP1000 is the structural capacity of the mat to resist the bearing pressure. The mat has substantial margin to accommodate a redistribution of the bearing reactions. Evaluation criteria are defined to evaluate sites that do not satisfy the site parameters directly.

If the shear wave velocity or the allowable bearing capacity are outside the range evaluated for AP1000 design certification, a site specific evaluation can be performed using the AP1000 basemat model and methodology described in subsection 3.8.5. The safe shutdown earthquake loads are those from the AP1000 analyses described therein. Alternatively, bearing pressures may be determined from a site-specific analysis using site specific inputs as described in subsection 2.5.2.3. For the site to be acceptable the bearing pressures from the site-specific analyses including static and dynamic loads need to be less than the capacity of each portion of the basemat.

Revise subsection 2.5.4.6.7 as follows:

2.5.4.6.7 Bearing Capacity – The Combined License applicant will verify that the site-specific allowable soil bearing capacities for static and dynamic loads are equal to or greater than the values documented in Table 2-1 **or will provide a site specific evaluation as described in subsection 2.5.4.2. The acceptance criteria for this evaluation are those of Standard Review Plan 2.5.4 as follows:**

- **The static and dynamic loads, and the stresses and strains induced in the soil surrounding and underlying the nuclear island are conservatively and realistically evaluated**
- **The consequences of the induced soil stresses and strains, as they influence the soil surrounding and underlying the nuclear island have been conservatively assessed.**

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 3.3.1-1 (Revision 1)

Original RAI Number(s): None

Summary of Issue:

Pressure generated from the design wind velocity is further dependent on exposure and gust response factors corresponding to the exposure categories. The applicant has used exposure Category C which is consistent with open shoreline and flat open country exposure. Category C exposure is suitable for most sites in the Eastern United States; however, it is not suitable for sites near open inland waterways, the Great Lakes and coastal areas of California, Oregon, Washington and Alaska. The wind load design for AP1000 makes it unsuitable for sites that fall under the exposure Category D. Seismic Category I structures for AP1000 are robust and their lateral load resistance is generally governed by seismic and tornado loading. It may be feasible to demonstrate that the AP1000 wind design is adequate for exposure Category D. Without such a demonstration, the use of wind exposure category is an open issue. This issue is Open Item 3.3.1-1.

NRC requested further clarification of the applicability of Exposure Categories C and D in this response during the telephone calls on August 22 and September 9, 2003.

Westinghouse Response (Revision 1):

The basic wind speed of 145 mph selected for design is the maximum anywhere in the United States and occurs on the Eastern seaboard in hurricane prone areas in the Eastern United States. Exposure Category C is specified for design of the AP1000 in Section 3.3 because it is specifically identified in ASCE 7-98 as applicable to shoreline locations in hurricane prone areas. **The Exposure Category for such locations was revised from D in ASCE 7-95 to C in ASCE 7-98 based on studies described by Vickery and Skerlj in Reference 3.3.1-1-1.**

Exposure Category D excludes shore lines in hurricane prone areas. It is applicable for sites near open inland waterways, the Great Lakes and coastal areas of California, Oregon, Washington and Alaska. For such locations the basic wind speed is less than the 145 mph used for design of the AP1000. Loads on the structures are based on the product of the square of the basic wind speed and coefficients based on the exposure category. At grade the velocity pressure exposure coefficients for exposure Category D are 21% greater than those for exposure Category C. At 200 feet above grade they are 10% higher. Thus, the AP1000 can be sited at sites with exposure Category D when the basic wind speed is equal to or less than 130 mph. The Combined License applicant will be able to demonstrate that the loads on the structure at these sites are lower than those used in design.

Reference 3.3.1-1-1: Vickery, P.J and Skerlj, P.F., "Elimination of Exposure D along Hurricane Coastline in ASCE 7", Journal of Structural Engineering, ASCE, April 2000.

Design Control Document (DCD) Revision:

Revise Section 2.3 as follows **(this revision was included in DCD Revision 7):**

The AP1000 is designed for air temperatures, humidity, precipitation, snow, wind, and tornado conditions as specified in Table 2-1. The Combined License applicant must provide information to demonstrate that the site parameters are within the limits specified for the standard design.

The design wind is specified as a basic wind speed of 145 mph with an annual probability of occurrence of 0.02. Wind loads are calculated for exposure C, which is applicable to shorelines in hurricane prone areas. The site parameters for the design wind may be demonstrated to be acceptable for other exposures or topographic factors by comparison of the wind loads on the structures. For example, for a site at a location with exposure Category D, the wind speed should be equal to or less than 130 mph.

Subsection 3.3.1.1 will be revised as follows:

3.3.1.1 Design Wind Velocity

The design wind is specified as a basic wind speed of 145 mph with an annual probability of occurrence of 0.02 based on the most severe location identified in Reference 1. This wind speed is the 3 second gust speed at 33 feet above the ground in open terrain (Reference 1, exposure C). The basic wind speed of 145 mph is the 3 second gust speed that has become the basis of wind design codes since 1995. It corresponds to the 110 mph fastest mile wind used as the basis for the AP600 design in accordance with the 1988 edition of Reference 1.

Higher winds with a probability of occurrence of 0.01 are used in the design of seismic Category I structures by using an importance factor of 1.15. This is obtained by classifying the AP1000 seismic Category I structures as essential facilities and using the design provisions for Category IV of Reference 1.

Velocity pressure exposure coefficients and gust response factors are calculated according to Reference 1 for exposure C, which is applicable to shorelines in hurricane prone areas in the 1998 edition of Reference 1. The topographic factor is taken as unity.

The design wind loads calculated as described above exceed those required at other locations in the United States where the more severe Exposure Category D is specified in Reference 1. Exposure Category D is applicable for sites near open inland waterways, the Great Lakes and coastal areas of California, Oregon, Washington and Alaska. For such locations the basic wind speed is less than 130 mph.

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 3.3.1-2 (Revision 1)

Original RAI Number(s): None

Summary of Issue:

In order to calculate the pressure loadings on structures for the design tornado wind velocity and the associated vertical distribution of wind pressures and gust factors, the applicant has used ASCE 7-98. The shape coefficients for the shield building, however, are calculated using American Society of Civil Engineers (ASCE) Paper No.3269, "Wind Forces on Structures," Vol. 126, Part II (1961). ASCE Paper 3269 is a reference in the Standard Review Plan in Section 3.3.1. It is not clear why the applicant used the latest ASCE standard for the basic wind velocity, importance category and exposure category, but did not use the recommendations of ASCE 7-98 for the velocity pressure and the corresponding pressure and force coefficients. AP1000 structures are dynamically rigid and the use of pressure coefficients different from those recommended by ASCE 7-98 is not likely to produce an unacceptable design, since the lateral strength of the AP1000 structures is likely to be governed by seismic and tornado loads. Nevertheless, the applicant should clarify its inconsistent use of the ASCE 7-98 recommendations for wind load design. This issue is Open Item 3.3.1-2.

NRC requested further clarification of the shape factors in this response during the telephone call on August 22, 2003.

Westinghouse Response (Revision 1):

The ASCE Paper 3269 is used for design of the shield building because it provides detailed shape coefficients for chimneys, tanks and similar structures. The simplified coefficients given in ASCE 7-98 do not specify the variation around the circumference. The detailed coefficients of the ASCE paper give total loads that are consistent with those specified in ASCE 7-98.

The report of the AP600 wind tunnel tests (see DCD Reference 6 below) concluded that "the distribution of pressures with azimuths is much as would be expected for a circular cylinder, with a relatively large positive pressure peak for angles where the wind is pointing directly at the inlet" and negative pressures at other azimuths. These pressure distributions are plotted in Appendix C of the report and are similar to the pressure distributions shown in Table 4(f) of the ASCE paper # 3269.

Design Control Document (DCD) Revision:

Based on the revised response, the second paragraph of DCD subsection 3.3.1.2 will be revised as follows:

Effective pressures applied to interior and exterior surfaces of the buildings and corresponding shape coefficients are calculated according to Reference 1 for exposure C. Shape coefficients

defining the variation around the circumference of ~~for~~ the shield building are calculated using ASCE Paper No. 3269 (Reference 2). **These shape coefficients are consistent with those observed in the model tests described in Reference 6.**

In subsection 3.3.4 add Reference 6:

6. WCAP-13294-P and WCAP-13295-NP, "Phase I Wind Tunnel Testing for the Westinghouse AP600 Reactor," April 1992.

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 3.3.2-1 (Revision 1)

Original RAI Number(s): None

Summary of Issue:

The procedures used to calculate pressure loads from the tornado wind velocity are the same as those used for wind, as discussed in Section 3.3.1 of this report. The tornado missile effects are determined using procedures discussed in DCD Tier 2 Section 3.5, and the acceptability of these procedures is given in Section 3.5 of this report. Tornado loading includes tornado wind pressure, internal pressure by tornado-created atmospheric pressure drop, and forces generated by the impact of tornado missiles. These loads are combined with other loads as described in DCD Tier 2 Section 3.8.4. The acceptability of these loads and load combinations is discussed in Section 3.8.4 of this report. The applicant has indicated that a maximum pressure drop of 13.8 kPa (2 psi) is used for non-vented structures, unless a lower value is justified by a detailed analysis using the provisions of ASCE 7-98 for partially vented structures. However, the applicant has not identified any structure within the scope of the AP1000 standard design for which a lower pressure drop has been used. Design certification is a final decision by the NRC subject to provisions of changes through rule making; consequently, the applicant needs to identify all the structures for which it has used a pressure drop lower than 13.8 kPa (2 psi). Therefore, the use of a tornado pressure drop of less than 13.8 kPa (2 psi) for vented structures in the future is an open issue. This issue is Open Item 3.3.2-1.

NRC requested during the telephone call on August 22, 2003 that the revision 0 response be included in the DCD

Westinghouse Response (Revision 1):

AP1000 nuclear island structures with the exception of the shield building have been designed as non-vented structures using a differential pressure equal to the maximum pressure drop of 2 psi. The portion of the shield building surrounding the upper annulus is designed as fully vented (zero differential pressure) due to the large area of the air inlets and discharge stack. Tornado loads on this portion of the shield building are only those due to the wind load.

Design Control Document (DCD) Revision:

Based on NRC additional comment, r Revise last paragraph of subsection 3.3.2.2 as follows:

The maximum pressure drop of 2.0 psi, applicable to a nonvented structure, is used for W_p **for all structures except the upper portion of the shield building. The portion of the shield building surrounding the upper annulus is designed as fully vented (zero differential pressure) due to the large area of the air inlets and discharge stack**~~unless a lower value is justified by detailed analysis, using the provisions of Reference 1, for partially vented structures.~~ Figure 3.3-1 shows the velocity pressure variation with the radius from the center of the tornado. When the tornado loading includes the missile load, the structure locally may go into the plastic

range because of missile impact. Subsection 3.5.3 discusses the procedure for analyzing local missile effects.

PRA Revision: None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 3.3.2-2 (Revision 1)

Original RAI Number(s): None

Summary of Issue:

The applicant states in DCD Tier 2 Section 3.3.2.3 that the failure of structures not designed for tornado loadings does not affect the capability of seismic Category I structures or the performance of safety-related systems because the applicant has either:

- designed the adjacent non-safety-related structure to the design-basis tornado loading
- investigated the effect of failure of adjacent structures on seismic Category I SSCs to determine that no impairment of safety function results, or
- designing a structural barrier to protect seismic Category I SSCs from adjacent structural failure

The applicant has stated in DCD Tier 2 Section 3.3.3 that COL applicants referencing the AP1000 certified design will address site interface criteria for wind and tornado. The site interface criteria for wind and tornado do not make it clear that the COL applicant needs to follow the three acceptable criteria described in DCD Tier 2 Section 3.3.2.3 to ensure that structures outside the scope of the certified design do not compromise the function of safety-related structures or systems of the AP1000 plant. Although DCD Tier 2 Table 1.8-2 mentions DCD Tier 2 Section 3.3.3 for the wind and tornado site interface criteria, neither DCD Tier 2 Section 3.3, nor DCD Tier 2 Table 1.8-2 clearly specifies that the COL applicant ensure that a tornado initiated failure of structures and components within the COL scope will not compromise the safety of AP1000 safety related structures and components. Identification of wind and tornado site interface criteria remains an open issue. This is Open Item 3.3.2-2.

NRC requested further clarification of the COL item in this response during the telephone call on August 22, 2003.

Westinghouse Response (Revision 1):

Due to the definition of the certification boundary for AP1000, its site plan and its required security provisions, there are no structures close enough to certified structures that their tornado or wind induced collapse could affect safety-related structures or systems. This leaves the potential for tornado or wind induced missiles generated by structures outside the certification boundary. Evaluation for these types of missiles is covered by Section 3.5.4 of the Tier 2 portion of the DCD. It is repeated here for information:

> The Combined License applicant will demonstrate that the site satisfies the interface requirements provided in Section 2.2. This requires an evaluation for those external events that produce missiles that are more

energetic than the tornado missiles postulated for design of the AP1000, or additional analyses of the AP1000 capability to handle the specific hazard.

Design Control Document (DCD) Revision:

Revise COL Item in subsection 3.3.3 as follows:

Combined License applicants referencing the AP1000 certified design will address site interface criteria for wind and tornado. **The Combined License applicant will ensure that a tornado initiated failure of structures and components within the Combined License applicant's scope will not compromise the safety of AP1000 safety related structures and components (see also subsection 3.5.4).**

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 3.6.3.4-2 Addendum 1

Original RAI Number(s): 251.004

Summary of Issue:

In RAI 251.005, the staff requested that the applicant provide values of crack morphology parameters, e.g., surface roughness, number of 45 degree and 90 degree turns, etc., that were used in generating the BACs for LBB. The NRC staff also asked for a comparative study, using the values of crack morphology parameters associated with transgranular stress corrosion cracking (TGSCC). This information and the study were requested to evaluate the BACs and to understand the sensitivity of the AP1000 LBB analyses to a crack morphology similar to PWSCC. In its response to RAI 251.005, the applicant provided the values of crack morphology parameters used in generating the BACs. However, since chlorides will be controlled at minimum levels in the AP1000 LBB candidate piping systems water environment and the hydrogen overpressure will keep the oxygen levels to near zero, the applicant discounted the possibility of TGSCC and considered the comparative study using the crack morphology parameters associated with TGSCC not necessary. The applicant's argument does not address the intent of RAI 251.005. The NRC staff performed an independent sensitivity study to assess the impact on the BACs due to a consideration of a TGSCC type of crack in the LBB analysis as a surrogate for PWSCC. The NRC staff's independent sensitivity study shows that the BACs might not be easily met by the most limiting piping. DCD Tier 2 Appendix 3B.3.3.4 does not rule out the possibility of a LBB candidate piping system not meeting the BAC limit either, as evidenced by the statement: "[i]f the point falls above the bounding analysis curve, the leak-before-break analysis criteria are not satisfied and the pipe layout or support configuration needs to be revised to meet the leak-before-break bounding analysis."

The information provided by the applicant has not been sufficient to address the staff position in SECY-93-087, discussed in DSER Section 3.6.3.1, on demonstrating that adequate margins on leakage, loads, and flaw sizes are available for AP1000 LBB candidate piping systems. In addition, the information provided is not sufficient to understand the degree to which PWSCC may affect LBB margins. Therefore, the staff is evaluating the appropriate analyses the applicant should perform to resolve these issues. The staff expects to issue a supplemental DSER on LBB. This is Open Item 3.6.3.4-2.

Westinghouse Response:

Westinghouse provided a response to this DSER Open Item in Westinghouse letter DCP/NRC1611 dated 8/13/2003. This addendum provides our assessment of the AP1000 piping systems designated as Leak-Before-Break (LBB), and provides the basis for the staff to complete the FSER on LBB.

AP1000 Evaluation of Candidate LBB Piping Systems

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1.0 INTRODUCTION

For AP1000 piping design, Westinghouse proposes to use a DAC/ITAAC approach similar to what was used for previous Design Certifications. Following the proposed DAC/ITAAC approach, the staff reviews and approves the methodology, design criteria, and analysis acceptance criteria that would be used to perform the detailed piping design. The methods, design criteria, and analysis acceptance criteria are referenced as Tier 2* information in the AP1000 Design Control Document (DCD). Westinghouse has also committed that a COL applicant would be required to complete the piping analyses for the piping systems designated as Leak-Before-Break (LBB) lines at the time of a COL application. These analyses would be completed as a condition of the COL. Similar to the other certified designs, the final piping design and analysis for the as-built piping are subject to ITAAC verification.

In the AP1000 Draft Safety Evaluation Report, the staff has indicated that additional information should be provided by Westinghouse to provide high confidence that the piping systems designated as LBB will be able to meet the LBB acceptance criteria at the time of a COL. To accomplish this, the staff requested Westinghouse to complete a piping stress analysis of one LBB candidate piping system and demonstrate that the piping stress analysis results are within the limits of the AP1000 LBB Bounding Analysis Curves included in the DCD. Westinghouse presented analysis results of the direct vessel injection line A (DVI-A) subsystem previously to the staff and these results are included in this report. Westinghouse plans to complete this analysis with the final AP1000 seismic response spectra included in the DCD and will provide updated results to the staff when they are available. The technical basis for the determination that the DVI-A subsystem represents a limiting analysis for AP1000 LBB is provided in this addendum.

The staff also indicated that Westinghouse should perform a qualitative assessment of other LBB candidate subsystems to demonstrate feasibility to qualify the lines for LBB, and provide reasonable assurance that the other LBB candidate subsystems will be within their respective BACs. This report describes the feasibility assessment for application of the LBB methodology to the high energy piping systems in the AP1000. The LBB feasibility assessment is based on comparisons between the AP1000 piping and the corresponding piping in the AP600 standard plant. Westinghouse completed the LBB analysis for the AP600 piping systems designated as LBB in support of AP600 design Certification. An assessment of the feasibility of successfully qualifying the AP1000 LBB lines that have not been analyzed is performed by applying correction factors to the piping analysis results for the AP600 plant. The AP600 lines are generally similar to the AP1000 plant lines. Factors are developed that account for the AP1000 seismic floor response spectra, the changes in the elevations of the pipe/equipment supports, and the changes in pipe diameter. Section 2 describes the assessment methodology. Section 3 discusses the results for each candidate LBB piping line. A brief summary is given in Section 4.

2.0 ASSESSMENT METHODOLOGY

The candidate pipe lines for Leak-Before-Break for the AP1000 plant are listed in Table 1. The AP1000 pipe lines are generally similar to the corresponding AP600 lines. The lines are the same lines that were identified and analyzed for LBB for the AP600. A comparison of the AP1000 and AP600 LBB pipe lines was provided to the NRC in Westinghouse letter DCP/NRC1516, dated August 5th, 2002. In addition, the NRC staff visited Westinghouse and reviewed the detailed AP1000 piping arrangement including the three dimensional electronic model. Several of the AP1000 lines have larger pipe diameters. The normal operating temperatures and pressures are similar. The in-structure seismic response spectra for the AP1000 plant are different from the AP600 plant primarily because of the taller shield building and the taller walls for the steam generator and pressurizer subcompartments. The AP1000 spectra used are based on the most recent seismic analysis documented in Section 3.7 of Revision 6 to the DCD. The seismic analysis includes the impact of reduced shear wall stiffness as requested in DSER open item 3.7.2.3-1. The Bounding Analysis Curves (BACs) in the AP1000 Design Control Document are based on a reliable leak detection capability of 0.5 gallons per minute and ASME Code minimum values for material strength. DCD Subsection 5.2.5 provides a description of the leak detection monitors for AP1000. RCS leakage detection instrumentation is also addressed in Technical Specification 3.4.10. The Bounding Analysis Curve for the Main Steam line incorporates the material tensile and fracture toughness properties that were measured from material testing for the design of the AP600 plant. The following methodology addresses the differences between the AP1000 and the AP600 and uses the estimated stresses in the piping system in combination with the corresponding AP1000 LBB Bounding Analysis Curve to evaluate the feasibility of LBB for each pipe line.

TABLE 1
CANDIDATE LBB PIPE LINES

LINE	DESCRIPTION (AP1000)
1A	Primary Loop Hot Leg - 31"
1B	Primary Loop Cold Leg - 22"
2	Pressurizer Surgeline - 18"
3A	ADS Stage 2,3 - 14"
3B	ADS Stage 2,3 - 8"
3C	Pressurizer Safety - 6"
4A	ADS Stage 4 East - 18"
4B	ADS Stage 4 East - 14" (610F)
4C	ADS Stage 4 East - 14" (120F)
5A	ADS Stage 4 West - 18"
5B	ADS Stage 4 West - 14" (610F)
5C	ADS Stage 4 West - 14" (120F)
6A	Normal RHR Suction - 20"
6B	Normal RHR Suction - 12"
6C	Normal RHR Suction - 10"
7	Passive RHR Return - 14"
8A	DVI-A - 8" 316 (537F)
8B	DVI-A - 8" 316 (120F)
8C	DVI-A - 8" 304
8D	DVI-A - 8" schedule 40S
8E	DVI-A RNS - 6"
8F	DVI-A PXS - 8"
9A	DVI-B - 8" 316 (537F)
9B	DVI-B - 8" 316 (120F)
9C	DVI-B - 8" 304
9D	DVI-B - 8" schedule 40S
9E	DVI-B RNS - 6"
9F	DVI-B PXS - 8"
10	CMT-A (West) -8"
11	CMT-B (East) -8"
12	Main Steam - A (West) -38"
13	Main Steam - B (East) - 38"

2.1 SEISMIC PIPE STRESSES

The AP1000 pipe/equipment support elevations are used to select the AP1000 response spectra curves. These elevations are generally higher than the corresponding elevations for the AP600 plant. The AP600 pipe lines have been analyzed for seismic loading using the envelope response spectra methodology or the time history methodology (for the reactor coolant loop hot leg and cold leg lines). The AP600 seismic analysis models include the equipment and equipment supports. The seismic stresses for the AP1000 pipe lines are estimated by applying a seismic multiplication factor to the AP600 seismic stress. This multiplication factor is based on the horizontal in-structure seismic response spectra at the elevation of the highest pipe line support or equipment support for each particular pipe line model. The vertical response spectra are generally lower and have less of an effect on the seismic pipe stress. For each horizontal direction the peak of the AP1000 spectrum is divided by the peak of the AP600 spectrum. These ratios are shown on the seismic response spectrum curves in Figures 1 through 8. The largest of these two ratios from the two horizontal seismic response spectra is then used as the seismic multiplication factor. The factors are summarized in Table 2. The estimated seismic stress is then modified to account for the changes in pipe diameter as required. This is described in Section 2.2.

Table 2 SEISMIC MULTIPLICATION FACTORS				
LINE	DESCRIPTION (AP1000)	MAXIMUM SEISMIC ELEVATION (FT) AP600	AP1000	AP1000 SEISMIC FACTOR
1A	Primary Loop Hot Leg - 31"	135	153	1.74
1B	Primary Loop Cold Leg - 22"	135	153	1.74
2	Pressurizer Surgeline - 18"	158	169	2.71
2	Pressurizer Surgeline - 18"	158	multi-point	1.36
3A	ADS Stage 2,3 - 14"	158	169	2.71
3B	ADS Stage 2,3 - 8"	158	169	2.71
3C	Pressurizer Safety - 6"	158	169	2.71
4A	ADS Stage 4 East - 18"	135	153	1.42
4B	ADS Stage 4 East - 14" (610F)	135	153	1.42
4C	ADS Stage 4 East - 14" (120F)	135	153	1.42
5A	ADS Stage 4 West - 18"	135	153	1.74
5B	ADS Stage 4 West - 14" (610F)	135	153	1.74
5C	ADS Stage 4 West - 14" (120F)	135	153	1.74
6A	Normal RHR Suction - 20"	135	153	1.42
6B	Normal RHR Suction - 12"	135	153	1.42
6C	Normal RHR Suction - 10"	135	153	1.42
7	Passive RHR Return - 14"	135	153	1.74
8A	DVI-A - 8" 316 (537F)	107	107	1.28 (1)
8B	DVI-A - 8" 316 (120F)	107	107	1.28 (1)
8C	DVI-A - 8" 304	107	107	1.28 (1)
8D	DVI-A - 8" schedule 40S	107	107	1.28 (1)
8E	RNS - 6"	107	107	1.28 (1)
8F	PXS - 8"	107	107	1.28 (1)
9A	DVI-B - 8" 316 (537F)	107	107	1.28
9B	DVI-B - 8" 316 (120F)	107	107	1.28
9C	DVI-B - 8" 304	107	107	1.28
9D	DVI-B - 8" schedule 40S	107	107	1.28
9E	RNS - 6"	107	107	1.28
9F	PXS - 8"	107	107	1.28
10	CMT-A (West) -8"	135	153	1.74
11	CMT-B (East) -8"	135	153	1.42
12	Main Steam - A (West) -38"	135	153	1.74
13	Main Steam - B (East) - 38"	135	153	1.74 (2)

Notes (1) Results are provided for DVI-A based piping stress analysis per Section 2.5.

(2) Assessment of the Main Steam – B (East) system is based on the results from the Main Steam – A (West) evaluation due to the similarity of the two systems.

2.2 PIPE LINE DIAMETER AFFECTS

Several of the AP1000 pipe lines have larger pipe diameters than the corresponding AP600 pipe line. The larger diameter results in a stiffer line for thermal expansion loads and a higher section modulus. For an applied thermal displacement, the moment in the pipe is proportional to moment of inertia and therefore proportional to the diameter cubed. Since the pipe section modulus is proportional to the diameter squared, the thermal stress in the pipe (stress equals moment/section modulus) is proportional to the pipe diameter. The diameter ratio approach is valid when the ratio of the pipe diameter to wall thickness remains the same while the diameter is increased. The thermal stress is caused by restraining the thermal growth of the pipe. The thermal stress is equal to the moment divided by the section modulus. The moment in the pipe is approximately proportional to the stiffness of the pipe which is represented by the moment of inertia. The piping system consists of straight section and elbows. The moment of inertia for an elbow can be taken as the moment of inertia of the straight pipe divided by the elbow flexibility factor. The affect on the thermal stresses in the pipe due to increasing the pipe diameter can be assessed by calculating the following ratios: (moment of inertia of pipe)/(section modulus of pipe), and (moment of inertia of bend/section modulus of bend). Based on these ratios, the following table shows that the thermal stress increases approximately in proportion to the pipe diameter.

DESCRIPTION	DIAM IN	LONG RADIUS ELBOW			3D BEND		
		FLEX FACTOR	I/S(PIPE) IN	I/S(BEND) IN	FLEX FACTOR	I/S(PIPE) IN	I/S(BEND) IN
AP600	10.75	2.11	5.38	2.55	1.05	5.38	5.10
AP1000	14.00	2.22	7.00	3.16	1.11	7.00	6.32
RATIO AP1000/AP600	1.30		1.30	1.24		1.30	1.24
AP600	12.75	2.15	6.38	2.96	1.08	6.38	5.93
AP1000	18.00	2.26	9.00	3.99	1.13	9.00	7.98
RATIO AP1000/AP600	1.41		1.41	1.35		1.41	1.35

For seismic and deadweight loads, the moment in the pipe is proportional to weight of the pipe plus its contents. Since the ratio of the pipe diameter to the wall thickness is essentially the same for AP1000 and AP600, the seismic and deadweight moments are proportional to the pipe diameter. The seismic or deadweight stress in the pipe (stress equals moment/section modulus) is therefore proportional to 1.0/diameter. Based on these ratios, the following table shows that the seismic stress decreases approximately in proportion to the pipe diameter.

DESCRIPTION	DIAM IN	WEIGHT PIPE+WATER LBS/FT	S(PIPE) IN^3	WEIGHT/S LBS/FT/IN^3	1.0/DIAM IN^(-1)
AP600	10.75	141	74.3	1.89	0.093
AP1000	14.00	231	160	1.45	0.071
RATIO AP1000/AP600				0.77	0.77
AP600	12.75	195	123	1.59	0.078
AP1000	18.00	380	336	1.13	0.056
RATIO AP1000/AP600				0.71	0.71

The total (maximum LBB) pipe stress is the sum of the stresses due to internal pressure, thermal expansion, deadweight, and seismic loads, where deadweight, thermal, and seismic loads are combined by absolute summation. The corresponding normal LBB stress is the sum of the stresses due to internal pressure, thermal expansion, and deadweight loads, where the deadweight and thermal loads are combined by algebraic summation. When the diameter increases the thermal stress should increase and the deadweight and seismic stresses should decrease. The deadweight stress from the AP600 pipe stress analysis is not readily available in the Stress Reports which provide the total normal condition stress (pressure plus deadweight plus thermal). The deadweight plus thermal stress for AP600 is readily calculated by subtracting out the pressure stress. The deadweight plus thermal stress for AP1000 can be obtained by applying a factor to the AP600 stress. In order to obtain a high estimated or maximum value for the total stress, the deadweight plus thermal stress is assumed to be proportional to the pipe diameter. This is not a large affect since the deadweight stresses are usually smaller than the thermal stress. Therefore, in order to obtain a conservative estimate of the total pipe stress the following relations are used:

- Pressures stress is same as AP600.
- Deadweight and thermal stresses are proportional to the pipe diameter.
- Seismic stresses are proportional to 1.0/diameter.
- Seismic stresses are increased by the ratio of the AP1000 to AP600 peak acceleration per Section 2.1.

2.3 MATERIAL STRENGTH AFFECTS

When the estimated maximum pipe stress is above the BAC (in the region of the material flow stress) in the AP1000 Design Control Document, consideration is given to higher material strength properties that are more representative of the actual values obtained from test data for specific material heats. This raises the magnitude of the BAC in the region of the Curve that corresponds to the material flow stress. Westinghouse reviewed the certified material test reports of 316 type stainless steel material of auxiliary lines in operating plants for samples of 169 Heats. The average (mean value) of the flow stress for these material tests was 23.7% higher than the ASME Code minimum flow stress. The summary of the certified material test report review as well as the calculated mean values are provided in Appendix A. Westinghouse therefore adjusted the BAC wherever necessary to reflect a 20% to 23.7% increase in the flow stress. The flow

stress or the $3S_m$ values, whichever is the minimum, has been used. LBB analysis is typically performed using actual tested material properties of the piping system. Using approximately average material properties for the AP1000 assessment is appropriate given the high probability of reducing the piping stresses in the actual piping analysis. At worst, it is possible to specify easily obtainable new minimum material properties for the AP1000 pipe, should they be required by the results of the detailed piping analyses.

The use of certified material properties test reports has been accepted by the NRC on plant specific applications of LBB.

2.4 LEAK RATE AFFECTS

When the estimated maximum pipe stress is above the BAC in the AP1000 Design Control Document consideration is given to increasing the leak detection capability. This raises the magnitude of the BAC in the region of the Curve that is below the material flow stress. Lower leak rate detection capability has been reviewed and accepted by the NRC on operating plant specific applications of LBB. It is not expected that lowering the leak detection rate will be required for the AP1000. It is relatively easy to move the piping analysis stress points to the right in the BAC assessment by increasing the normal stress in the piping system based on piping system support modifications.

2.5 AP1000-SPECIFIC PIPE STRESS ANALYSIS

Westinghouse has performed a detailed pipe stress analysis of one piping system. The Direct Vessel Injection – A system was selected to be analyzed because it represents a limiting piping analysis considering the following criteria:

Complexity of piping system - The DVI-A piping system is complex, and was particularly challenging to qualify for the AP600. TheAP600 design and analysis of the DVI-A subsystem was performed over several iterations that included perturbations in the piping layout, support configuration, and piping analysis. Figure 9 shows isometric views of both the AP600 and AP1000 DVI-A piping system.

Low Margin to BAC for AP600 - The AP600 analysis results for the DVI-A line exhibited low margin to the AP600 BAC limits. In addition, the limit for one particular line segment actually exceeded the BAC. (For that segment, engineering judgement was used to determine that modification of the final support configuration would result in reducing the stress limits to below the BAC for that line segment). Therefore it is expected that the DVI-A would be one of the most difficult piping systems to qualify for LBB for the AP1000.

Minimum line size qualified for LBB - The DVI-A piping subsystem contains the smallest size line segment qualified for leak before break. Typically smaller lines are the most challenging to qualify for LBB. The DVI-A contains 6-inch piping, which is the smallest pipe size designated as LBB for the AP1000.

Potential for subcompartment pressurzation impact - The DVI-A traverses several subcompartments in the AP1000 containment. These subcompartments are not designed for the break of a high energy line of the size included in the DVI-A piping system. Therefore, if the DVI-A piping system were not qualified for LBB, additional subcompartment pressurization analyses would be required to demonstrate that the subcompartments are adequate.

Based on these considerations, Westinghouse decided to perform the detailed piping analysis of the DVI-A piping system to demonstrate that this limiting piping subsystem could be qualified for LBB. Results from the preliminary analyses for the DVI-A system are summarized in Table 3 and provided in Figures 10 through 15. The calculated stresses for the various line segments included in the DVI-A piping subsystem are below the BACs. The following table summarizes the results.

Table 3
Summary of DVI-A Preliminary Piping Stress Analysis Results

Pipe Segment	Maximum Calculated Stress (ksi)	Bounding Analysis Curve Limit (ksi)	Report Figure
8-inch, 316SS, 537F	23.9	41.6	Fig. 10
8-inch, 316SS, 120F	22.0	44.0	Fig. 11
8-inch, 304	13.8	14.4	Fig. 12
8-inch, Sch 40S	11.7	22.7	Fig. 13
6-inch, RNS	14.5	22.9	Fig. 14
8-inch, PXS	22.3	44.5	Fig. 15

These preliminary analysis results demonstrate the feasibility that the DVI-A piping subsystem can be qualified for LBB at the time of a COL application. The final analysis results for the DVI-A piping system will be made available to the NRC when they are completed.

3.0 ASSESSMENT RESULTS

This section provides the results of the AP1000 LBB assessment for each candidate line.

3.1 Primary Loop Hot Leg (31") – (Reference AP1000 DCD Figure 3B-2)

The Hot Leg pipe diameter is the same as AP600. The seismic multiplication factor is 1.74. This includes the affect of the higher elevation of the steam generator upper lateral support. The maximum stress is 29.5 ksi which is less than the BAC stress of 40.7 ksi. Figure 16 shows the BAC and the estimated stresses for the AP1000 plant. Feasibility of LBB for AP1000 is confirmed.

3.2 Primary Loop Cold Leg (22") – (Reference AP1000 DCD Figure 3B-3)

The Cold Leg pipe diameter is the same as AP600. The seismic multiplication factor is 1.74. This includes the affect of the higher elevation of the steam generator upper lateral support. The maximum stress is 42.6 ksi which is lower than the modified BAC stress of 49.9 ksi. Figure 17 shows the BAC and the estimated stresses for the AP1000 plant. Therefore, the feasibility of LBB for AP1000 is confirmed.

3.3 Pressurizer Surgeline (18") – (Reference AP1000 DCD Figure 3B-6)

The Surgeline pipe diameter is the same as AP600. The seismic multiplication factor is 1.36. This includes the affect of the higher elevation of the pressurizer center of gravity and the use of multiple input point seismic response spectra analysis. Applying the multiple input method in place of the envelope response spectra method reduces the SSE factor from 2.71 to 1.36. The damping value for the multiple input method is taken as 3% for the Surgeline. For the multiple input method an equivalent uniform acceleration is needed to apply to the AP600 SSE stresses. The equivalent uniform input is taken to be the peak spectral acceleration at the elevation of the center of gravity of the AP1000 Pressurizer Tank. This acceleration is higher than the AP600 peak spectral acceleration, which is at the top of the Pressurizer subcompartment walls. The maximum stress is 32.7 ksi which is less than the BAC stress of 40.3 ksi. Figure 18 shows the BAC and the estimated stresses for the AP1000 plant. Feasibility of LBB for AP1000 is confirmed.

3.4 ADS Stage 2 and 3 (14") – (Reference AP1000 DCD Figure 3B-10)

The Stage 2 and 3 pipe diameter is the same as AP600. The seismic multiplication factor is 2.71. This includes the affect of the higher elevation of the pressurizer upper lateral support. The maximum stress is 31.8 ksi which is less than the BAC stress of 40.3 ksi. Figure 19 shows the BAC and the estimated stresses for the AP1000 plant. Feasibility of LBB for AP1000 is confirmed.

3.5 ADS Stage 2 and 3 (8") – (Reference AP1000 DCD Figure 3B-16)

The Stage 2 and 3 pipe diameter is the same as AP600. The seismic multiplication factor is 2.71. This includes the affect of the higher elevation of the pressurizer upper lateral support. The maximum stress is approximately 48 ksi which is more than the BAC stress of 40 ksi. Using more realistic material strength the modified BAC stress limit can be increased to 48 ksi. Figure 20 shows the BAC and the estimated stresses for the AP1000 plant. Therefore, the feasibility of LBB for AP1000 is confirmed.

3.6 Pressurizer Safety (6") – (Reference AP1000 DCD Figure 3B-19)

The Pressurizer Safety pipe diameter is the same as AP600. The seismic multiplication factor is 2.71. This includes the affect of the higher elevation of the pressurizer upper lateral support. The maximum stress is 61.9 ksi which is higher than the BAC stress of 40.4 ksi. Figure 21 shows the BAC and the estimated stresses for the AP1000 plant. This stress is calculated based on the

conservative methods previously described in Section 2. Utilizing detailed time-history seismic analysis methods as opposed to response spectra methods previously utilized for AP600, it is anticipated that the analytical results will be significantly lower than those obtained by the conservative ratios developed. In the event that the results from the detailed time-history seismic results still exceed the BAC limits, the affects of postulated high energy line pipe breaks in the two 6" Safety lines would need to be evaluated. These pipe breaks are above the top of the Pressurizer subcompartment walls, and do not effect the design for subcompartment pressurization. Therefore the breaks would not have any adverse impact on the structural design of the Containment Internal Structure. Pipe whip restraints can be installed on the ADS pressurizer platforms at the locations shown in Figure 22 to ensure that the adjacent components that are needed to mitigate the pipe break (i.e. ADS Stage 1, 2, and 3 valves and piping)are not compromised.

3.7 ADS Stage 4 East (18") – (Reference AP1000 DCD Figure 3B-7)

The ADS Stage 4 pipe diameter is larger than the AP600 (12"). The seismic multiplication factor is 1.42. This includes the affect of the higher elevation of the steam generator upper lateral support in the East Subcompartment. The maximum stress is 26.3 ksi before adjustment for pipe diameter and 30.9 ksi after adjustment. The adjusted stress is less than the BAC stress of 40.7 ksi. Figure 23 shows the BAC and the estimated stresses for the AP1000 plant. Feasibility of LBB for AP1000 is confirmed.

3.8 ADS Stage 4 West (18") – (Reference AP1000 DCD Figure 3B-7)

The ADS Stage 4 pipe diameter is larger than the AP600 (12"). The seismic multiplication factor is 1.74. This includes the affect of the higher elevation of the steam generator upper lateral support in the West subcompartment. The maximum stress is 20.4 ksi before adjustment for pipe diameter and 23.2 ksi after adjustment. The adjusted stress is less than the BAC stress of 40.7 ksi. Figure 23 shows the BAC and the estimated stresses for the AP1000 plant. Feasibility of LBB for AP1000 is confirmed.

3.9 ADS Stage 4 East (14"- 610F) - (Reference AP1000 DCD Figure 3B-8)

The ADS Stage 4 pipe diameter is larger than the AP600 (10"). The seismic multiplication factor is 1.42. This includes the affect of the higher elevation of the steam generator upper lateral support. The maximum stress is 31.4 ksi before adjustment for pipe diameter and 34.8 ksi after adjustment. The adjusted stress is less than the BAC stress of 40.7 ksi. Figure 24 shows the BAC and the estimated stresses for the AP1000 plant. Feasibility of LBB for AP1000 is confirmed.

3.10 ADS Stage 4 West (14"- 610F) – (Reference AP1000 DCD Figure 3B-8)

The ADS Stage 4 pipe diameter is larger than the AP600 (10"). The seismic multiplication factor is 1.74. This includes the affect of the higher elevation of the steam generator upper lateral support. The maximum stress is 32.7 ksi before adjustment for pipe diameter and 27.0 ksi after adjustment. The adjusted stress is less than the corresponding BAC stress of 31.6 ksi. Figure 24

shows the BAC and the estimated stresses for the AP1000 plant. Feasibility of LBB for AP1000 is confirmed.

3.11 ADS Stage 4 East (14"- 120F) – (Reference AP1000 DCD Figure 3B-9)

The ADS Stage 4 pipe diameter is larger than the AP600 (10"). The seismic multiplication factor is 1.42. This includes the affect of the higher elevation of the steam generator upper lateral support. The maximum stress is 30.4 ksi before adjustment for pipe diameter and 32.9 ksi after adjustment. The adjusted stress is less than the BAC stress of 51.9 ksi. Figure 25 shows the BAC and the estimated stresses for the AP1000 plant. Feasibility of LBB for AP1000 is confirmed.

3.12 ADS Stage 4 West (14"- 120F) – (Reference AP1000 DCD Figure 3B-9)

The ADS Stage 4 pipe diameter is larger than the AP600 (10"). The seismic multiplication factor is 1.74. This includes the affect of the higher elevation of the steam generator upper lateral support. The maximum stress is 26.7 ksi before adjustment for pipe diameter and 24.4 ksi after adjustment. The adjusted stress is less than the BAC stress of 51.9 ksi. Figure 25 shows the BAC and the estimated stresses for the AP1000 plant. Feasibility of LBB for AP1000 is confirmed.

3.13 Normal RHR Suction (20") – (Reference AP1000 DCD Figure 3B-5)

The Normal RHR Suction pipe diameter is the same as AP600. The seismic multiplication factor is 1.42. This includes the affect of the higher elevation of the steam generator upper lateral support in the East subcompartment. The maximum stress is 17.9 ksi which is less than the BAC stress of 40.7 ksi. Figure 26 shows the BAC and the estimated stresses for the AP1000 plant. Feasibility of LBB for AP1000 is confirmed.

3.14 Normal RHR Suction (12") – (Reference AP1000 DCD Figure 3B-20)

The Normal RHR Suction pipe diameter is the same as AP600. The seismic multiplication factor is 1.42. This includes the affect of the higher elevation of the steam generator upper lateral support in the East subcompartment. The maximum stress is 30.0 ksi which is less than the BAC stress of 40.7 ksi. Figure 27 shows the BAC and the estimated stresses for the AP1000 plant. The feasibility of LBB for AP1000 is confirmed.

3.15 Normal RHR Suction (10") – (Reference AP1000 DCD Figure 3B-21)

The Normal RHR Suction pipe diameter is the same as AP600. The seismic multiplication factor is 1.42. This includes the affect of the higher elevation of the steam generator upper lateral support in the East subcompartment. The maximum stress is 38.9 ksi which is less than the BAC stress of 40.7 ksi. Figure 28 shows the BAC and the estimated stresses for the AP1000 plant. The feasibility of LBB for AP1000 is confirmed.

3.16 Passive RHR Return (14") – (Reference AP1000 DCD Figure 3B-11)

The Passive RHR Return pipe diameter is larger than the AP600 (10"). The seismic multiplication factor is 1.74. This includes the affect of the higher elevation of the steam

generator upper lateral support in the West subcompartment. The maximum stress is 59.1 ksi before adjustment for pipe diameter and 51.4 ksi after adjustment. The adjusted stress is higher than the BAC stress of 41.6 ksi. Using more realistic material strength the modified BAC stress limit is 51.4 ksi. Figure 29 shows the BAC and the estimated stresses for the AP1000 plant. Therefore, the feasibility of LBB for AP1000 is confirmed.

3.17 Direct Vessel Injection (DVI) – B (8", (316SS, 537F)) – (Reference AP1000 DCD Figure 3B-14)

The DVI-B (8", 316SS, 537F) pipe diameter is the same as AP600. The seismic multiplication factor is 1.28. This includes the elevation of the reactor vessel support. The maximum stress is 30.3 ksi which is less than the BAC stress of 41.6 ksi. Figure 30 shows the BAC and the estimated stresses for the AP1000 plant. The feasibility of LBB for AP1000 is confirmed.

3.18 Direct Vessel Injection (DVI) – B (8", (316SS, 120F)) – (Reference AP1000 DCD Figure 3B-15)

The DVI-B (8", 316SS, 120F) pipe diameter is the same as AP600. The seismic multiplication factor is 1.28. This includes the elevation of the reactor vessel support. The maximum stress is 23.7 ksi which is less than the corresponding BAC stress of 48.6 ksi. Figure 31 shows the BAC and the estimated stresses for the AP1000 plant. The feasibility of LBB for AP1000 is confirmed.

3.19 Direct Vessel Injection (DVI) – B (8", (304)) – (Reference AP1000 DCD Figure 3B-17)

The DVI-B (8", 304) pipe diameter is the same as AP600. The seismic multiplication factor is 1.28. This includes the elevation of the reactor vessel support. The maximum stress is 8.7 ksi which is less than the corresponding BAC stress of 10.5 ksi. Figure 32 shows the BAC and the estimated stresses for the AP1000 plant. The feasibility of LBB for AP1000 is confirmed.

3.20 Direct Vessel Injection (DVI) – B (8", (Sch 40S)) – (Reference AP1000 DCD Figure 3B-13)

The DVI-B (8", Sch 40S) pipe diameter is the same as AP600. The seismic multiplication factor is 1.28. This includes the elevation of the reactor vessel support. The maximum stress is 16.2 ksi which is less than the corresponding BAC stress of 21.3 ksi. Figure 33 shows the BAC and the estimated stresses for the AP1000 plant. The feasibility of LBB for AP1000 is confirmed.

3.21 Direct Vessel Injection (DVI) – B (6", RNS) – (Reference Figure 3B-18)

The DVI-B (6", RNS) pipe diameter is the same as AP600. The seismic multiplication factor is 1.28. This includes the elevation of the reactor vessel support. The maximum stress is 17.2 ksi which is less than the corresponding BAC stress of 27.0 ksi. Figure 34 shows the BAC and the estimated stresses for the AP1000 plant. The feasibility of LBB for AP1000 is confirmed.

3.22 Direct Vessel Injection (DVI) – B (8", PXS) – (Reference AP1000 DCD Figure 3B-15)

The DVI-B (8", PXS) pipe diameter is larger than the AP600. The seismic multiplication factor is 1.28. This includes the elevation of the reactor vessel support. The maximum stress is 26.6 ksi before adjustment for pipe diameter and 23.8 ksi after adjustment. The adjusted stress is less than the corresponding BAC stress of 35.2 ksi. Figure 35 shows the BAC and the estimated stresses for the AP1000 plant. The feasibility of LBB for AP1000 is confirmed.

3.23 Core Makeup Tank Supply – West (8") – (Reference AP1000 DCD Figure 3B-14)

The Core Makeup Tank Supply–West pipe diameter is the same as AP600. The seismic multiplication factor is 1.74. This includes the affect of the higher elevation of the steam generator upper lateral support in the West subcompartment. The maximum stress is 43.1 ksi which is higher than the BAC stress of 41.6 Using more realistic material strength the modified BAC stress limit is 50.0 ksi. Figure 36 shows the BAC and the estimated stresses for the AP1000 plant. The feasibility of LBB for AP1000 is confirmed.

3.24 Core Makeup Tank Supply – East (8") – (Reference AP1000 DCD Figure 3B-14)

The Core Makeup Tank Supply–East pipe diameter is the same as AP600. The seismic multiplication factor is 1.42. This includes the affect of the higher elevation of the steam generator upper lateral support in the East subcompartment. The maximum stress is 41.0 ksi which is higher than the corresponding BAC stress limit. Using more realistic material strength and the lower leak detection capability of 0.25 gpm the modified BAC stress limit of 42.8 ksi. Figure 36 shows the BAC and the estimated stresses for the AP1000 plant. The feasibility of LBB for AP1000 is confirmed.

3.25 Main Steam – A – West (38") – (Reference AP1000 DCD Figure 3B-4)

The Main Steam – A-West pipe diameter is larger than the AP600. The seismic multiplication factor is 1.74. This includes the affect of the higher elevation of the steam generator upper lateral support in the West subcompartment. The maximum stress is 27.7 ksi before adjustment for pipe diameter and 24.5 ksi after adjustment. The adjusted stress is higher than the corresponding BAC stress limit of 21.0 ksi. Using a lower leak detection capability of 0.25 gpm, the modified BAC stress limit is 25.9 ksi. Figure 37 shows the BAC and the estimated stresses for the AP1000 plant. The feasibility of LBB for AP1000 is confirmed. An alternative approach is to modify the pipe support configuration to shift the frequency response of the piping system away from the peak response spectra accelerations, thus producing a lower maximum stress point below the original BAC stress limit. Additionally, if required, detailed time-history seismic analysis methods could be used as opposed to envelope response spectra methods to obtain further reduction in the corresponding seismic stresses.

3.26 Main Steam – B – East (38") – (Reference AP1000 DCD Figure 3B-4)

The Main Steam – B-East pipe is similar to the West pipe. Stress estimates were not specifically calculated for this line. By similarity, the feasibility of LBB for AP1000 is confirmed.

4.0 SUMMARY

This report summarizes an assessment of applying Leak-Before-Break methodology to the candidate AP1000 plant pipe lines listed in Table 1. Feasibility is demonstrated for the LBB candidate piping systems with one possible exception of the Pressurizer Safety Valve inlet piping (6"). For these two lines, the high energy pipe breaks can be mitigated by the installation of protection devices (whip restraints) as shown at the locations in Figure 22 if required.

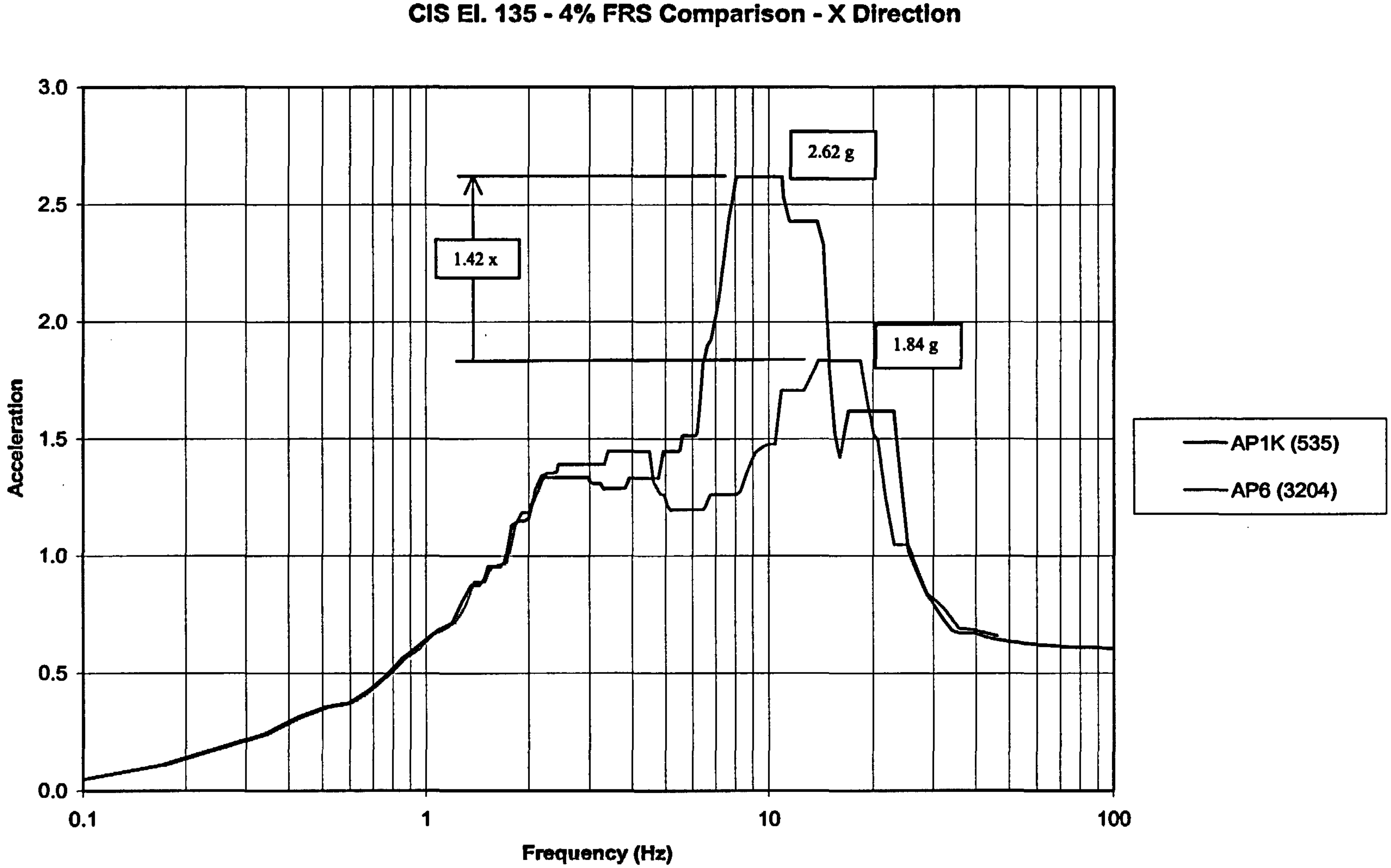


Figure 1 - In-Structure Seismic Response Spectra, Steam Generator Support Elev. 135', (North-South)

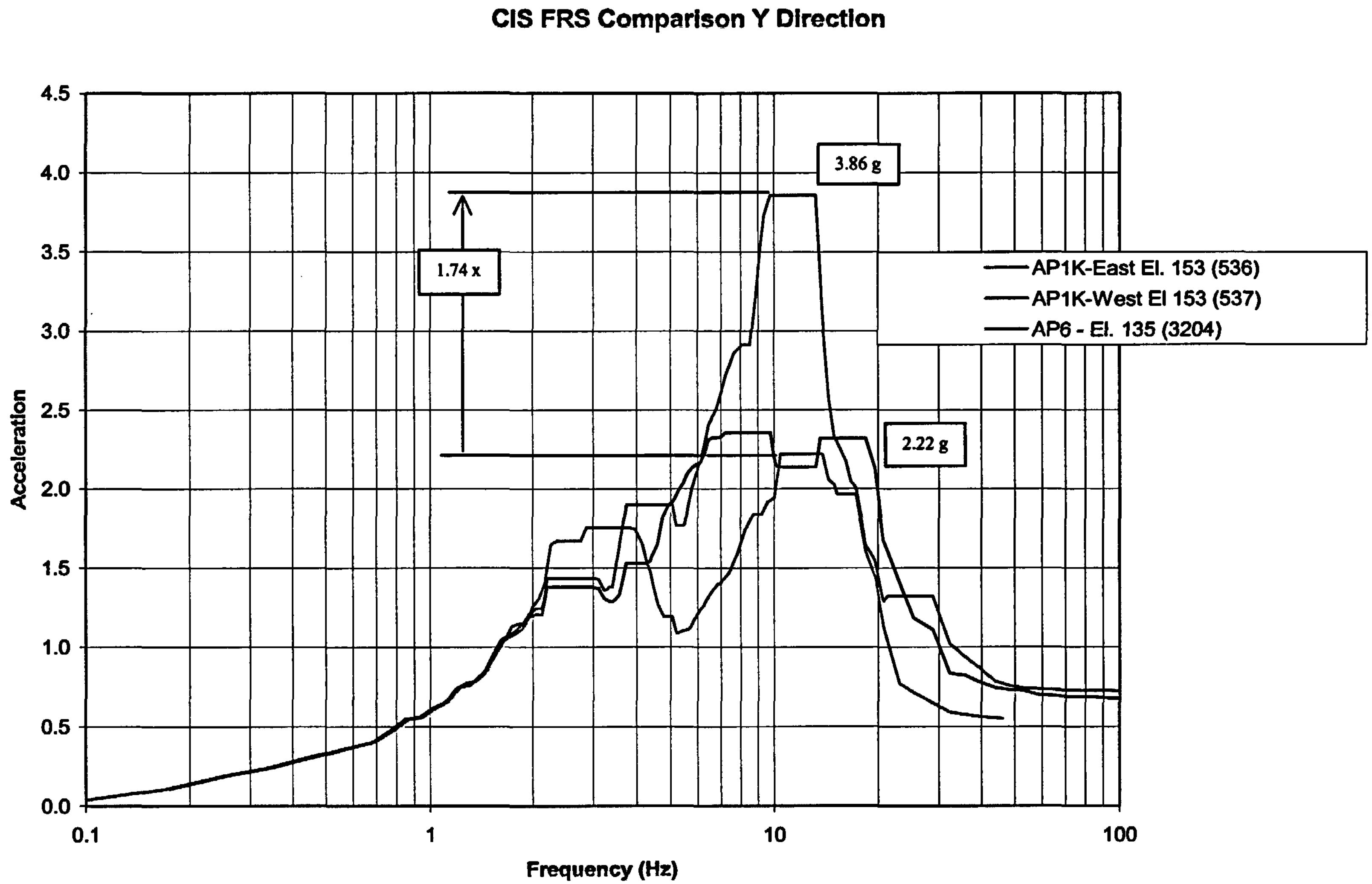


Figure 2 - In-Structure Seismic Response Spectra, Steam Generator Support Elev. 153', (East-West)

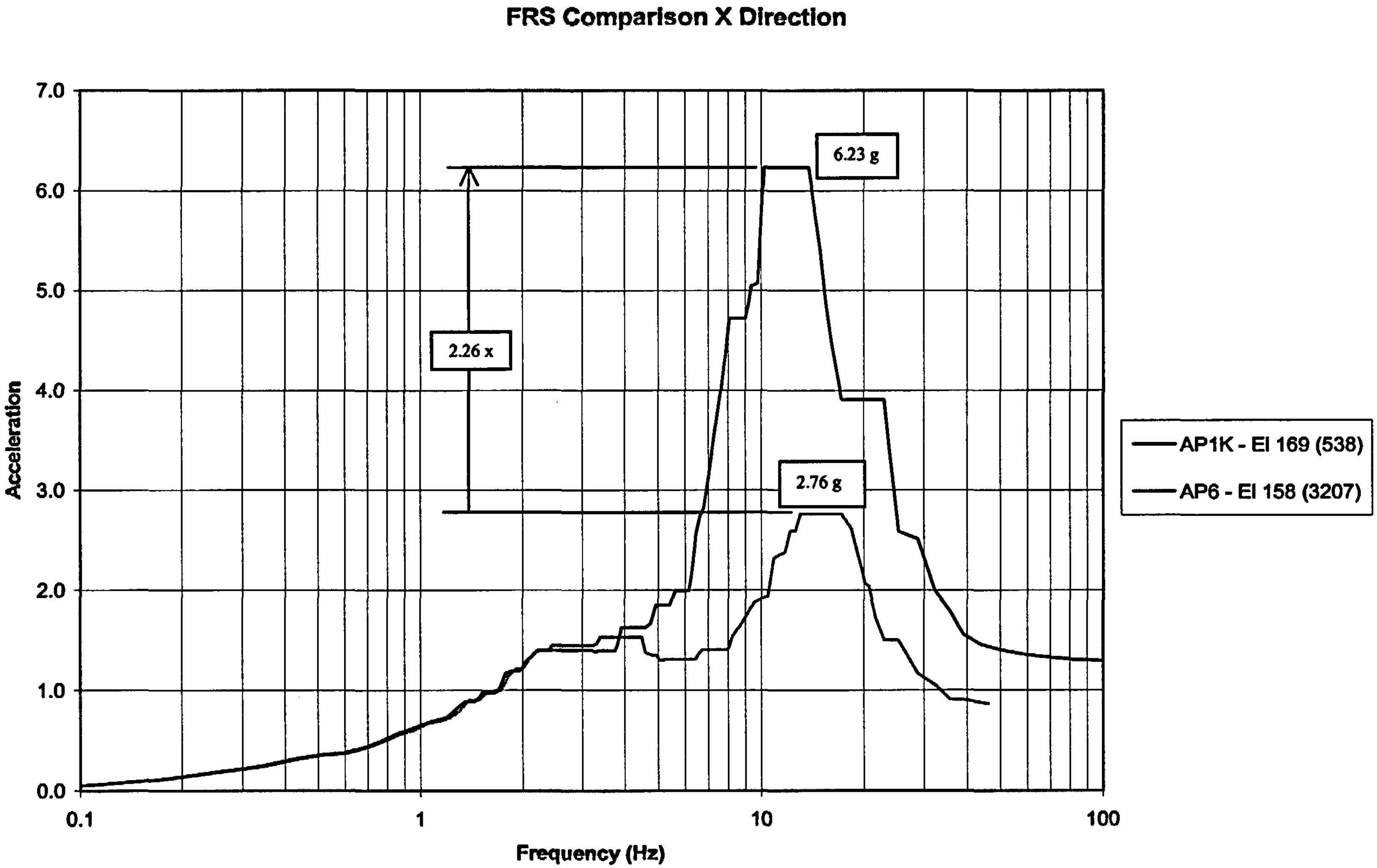


Figure 3 - In-Structure Seismic Response Spectra, Pressurizer Support, (North-South)

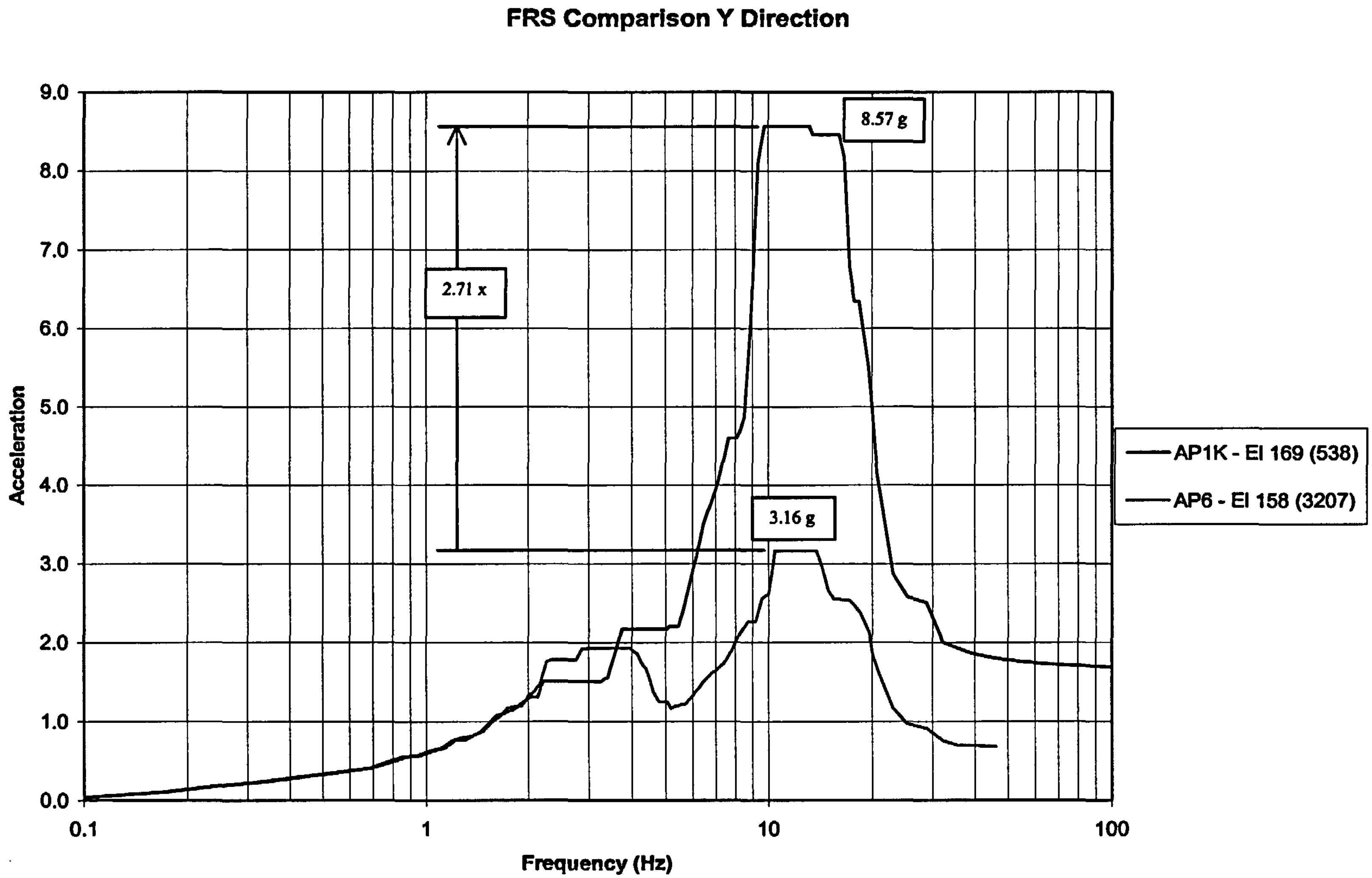


Figure 4 - In-Structure Seismic Response Spectra, Pressurizer Support, (East-West)

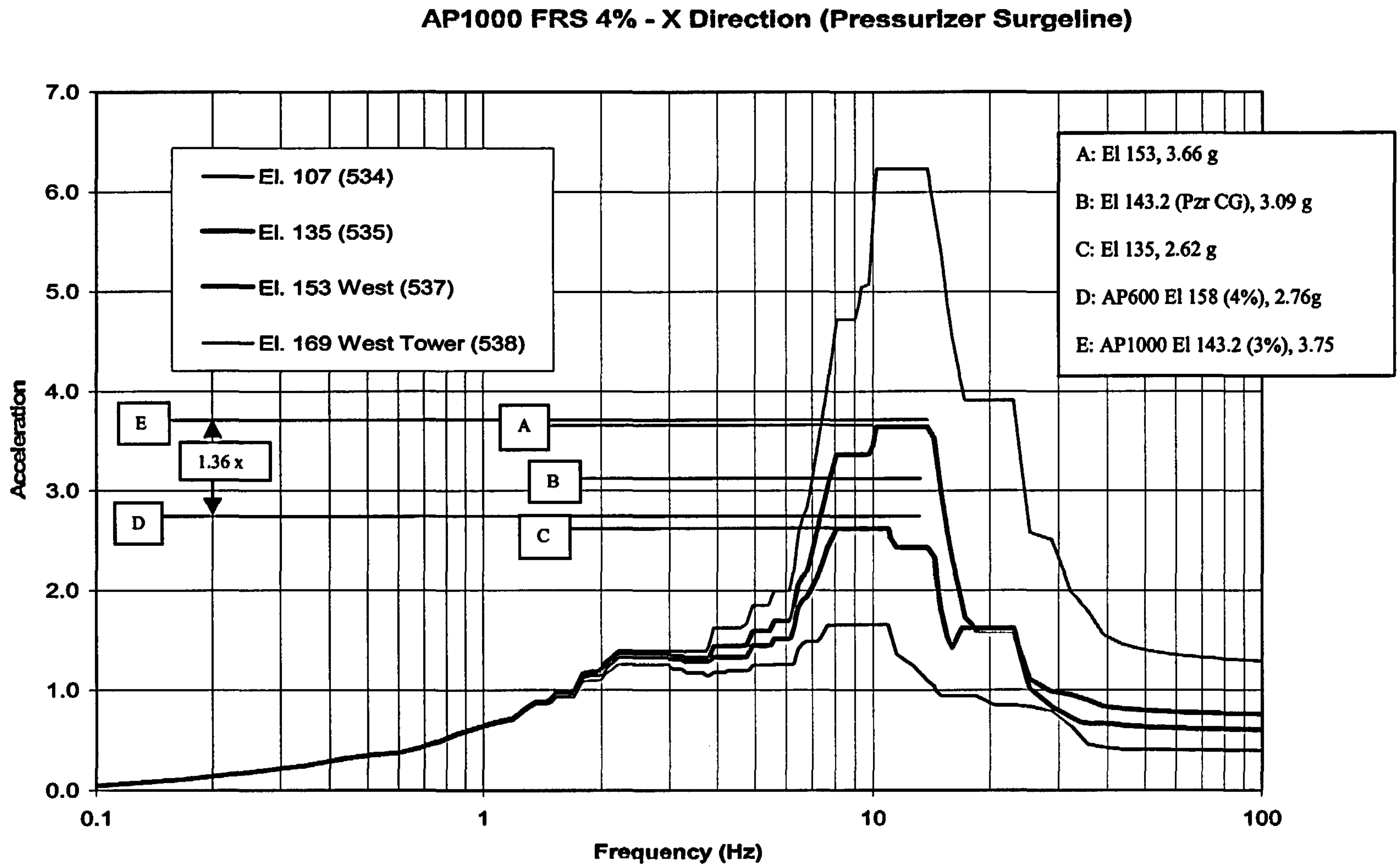


Figure 5 - In-Structure Seismic Response Spectra, Pressurizer Center of Gravity, (North –South)

AP1000 FRS 4% - Y Direction (Pressurizer Surgeline)

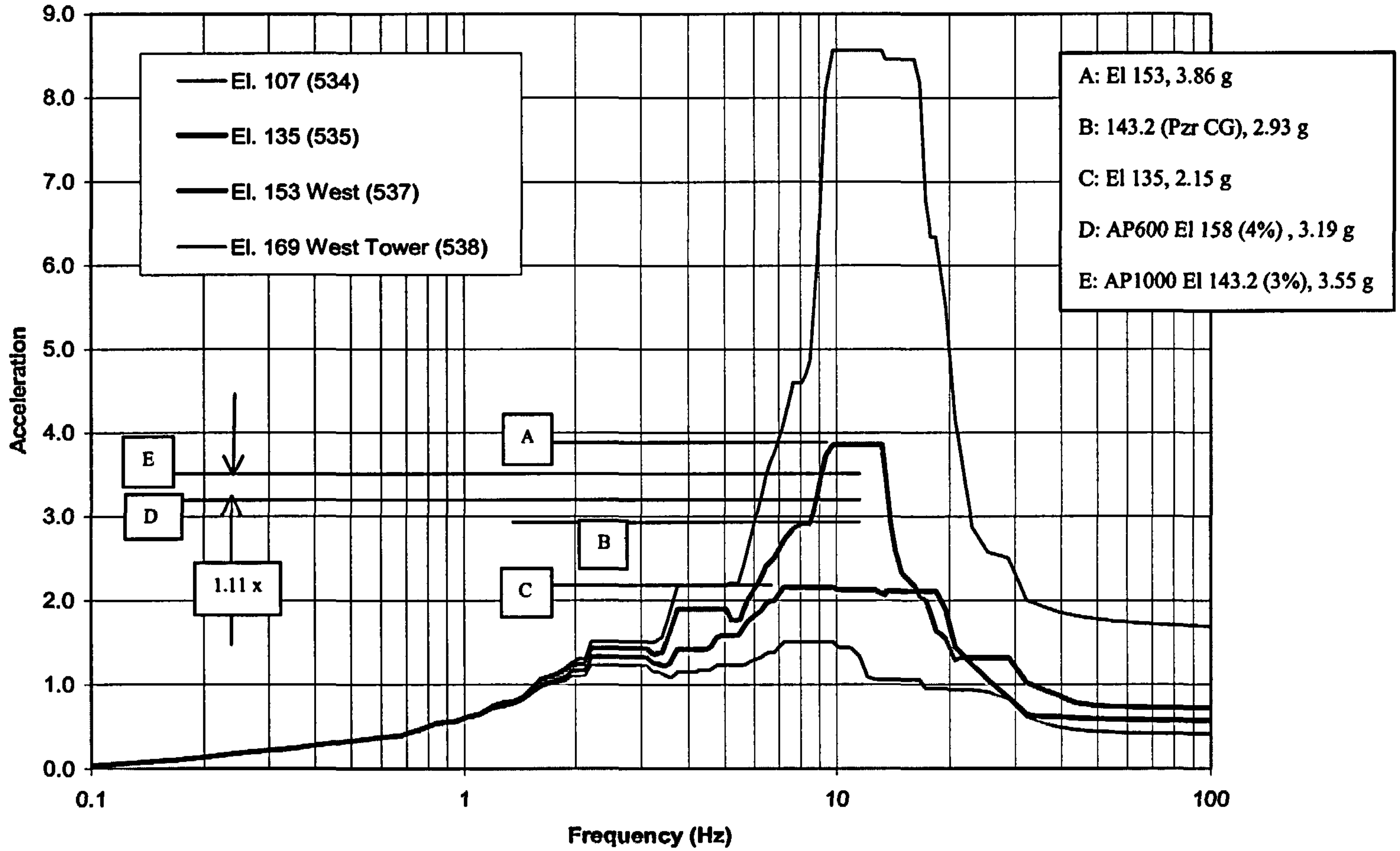


Figure 6 - In-Structure Seismic Response Spectra, Pressurizer Center of Gravity, (East-West)

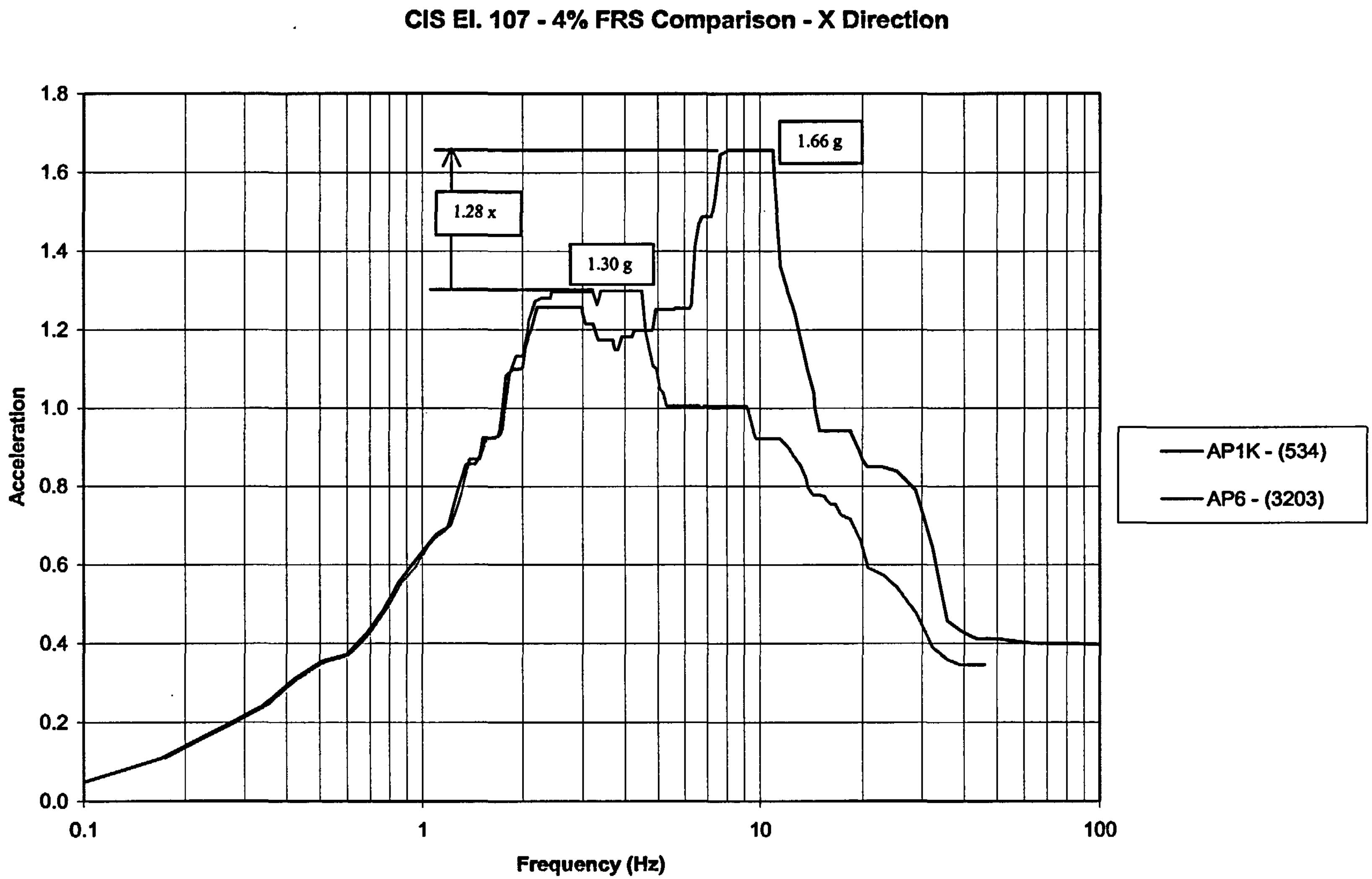


Figure 7 - In-Structure Seismic Response Spectra, Reactor Vessel Support, (North-South)

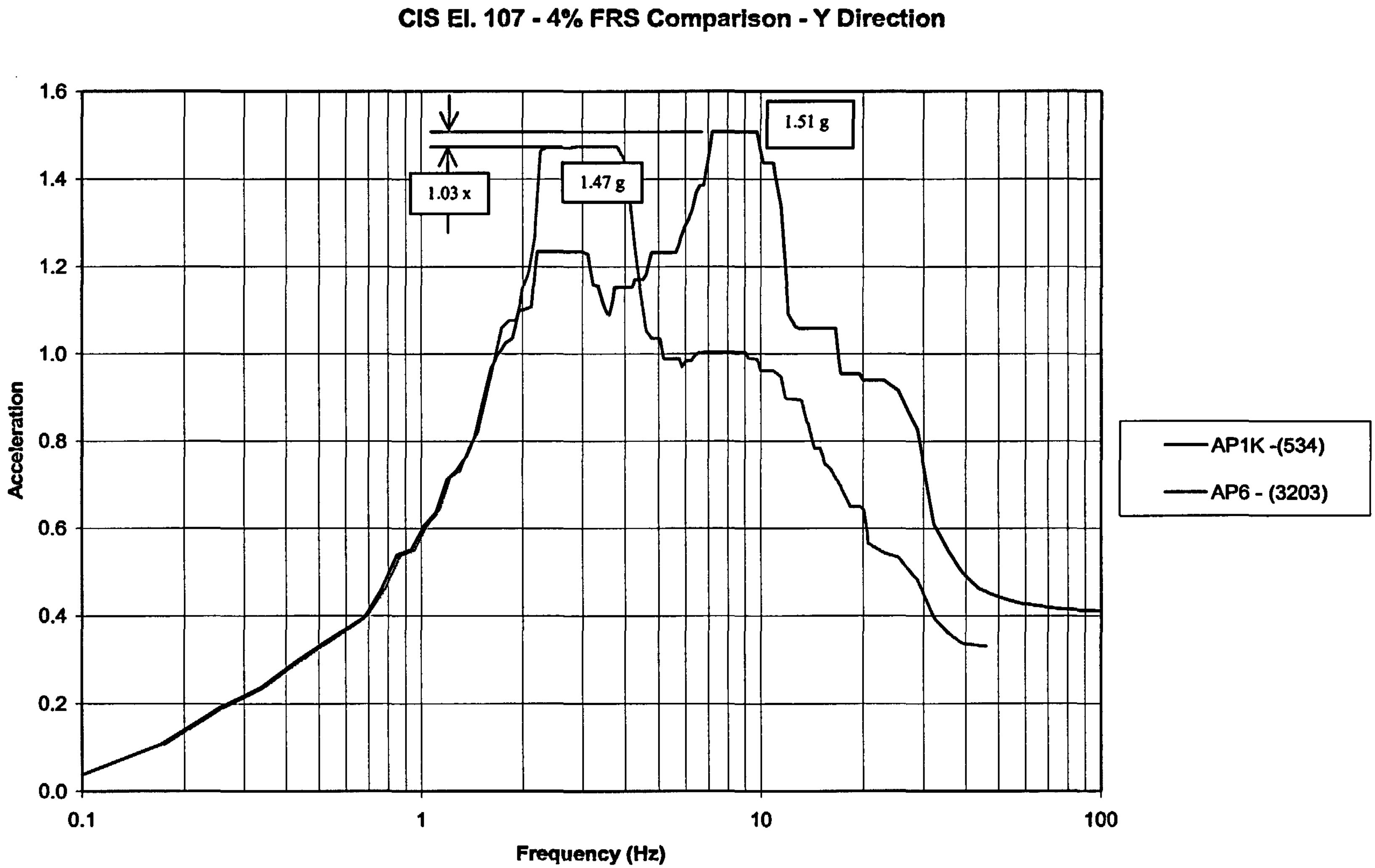


Figure 8 - In-Structure Seismic Response Spectra, Reactor Vessel Support, (East-West)

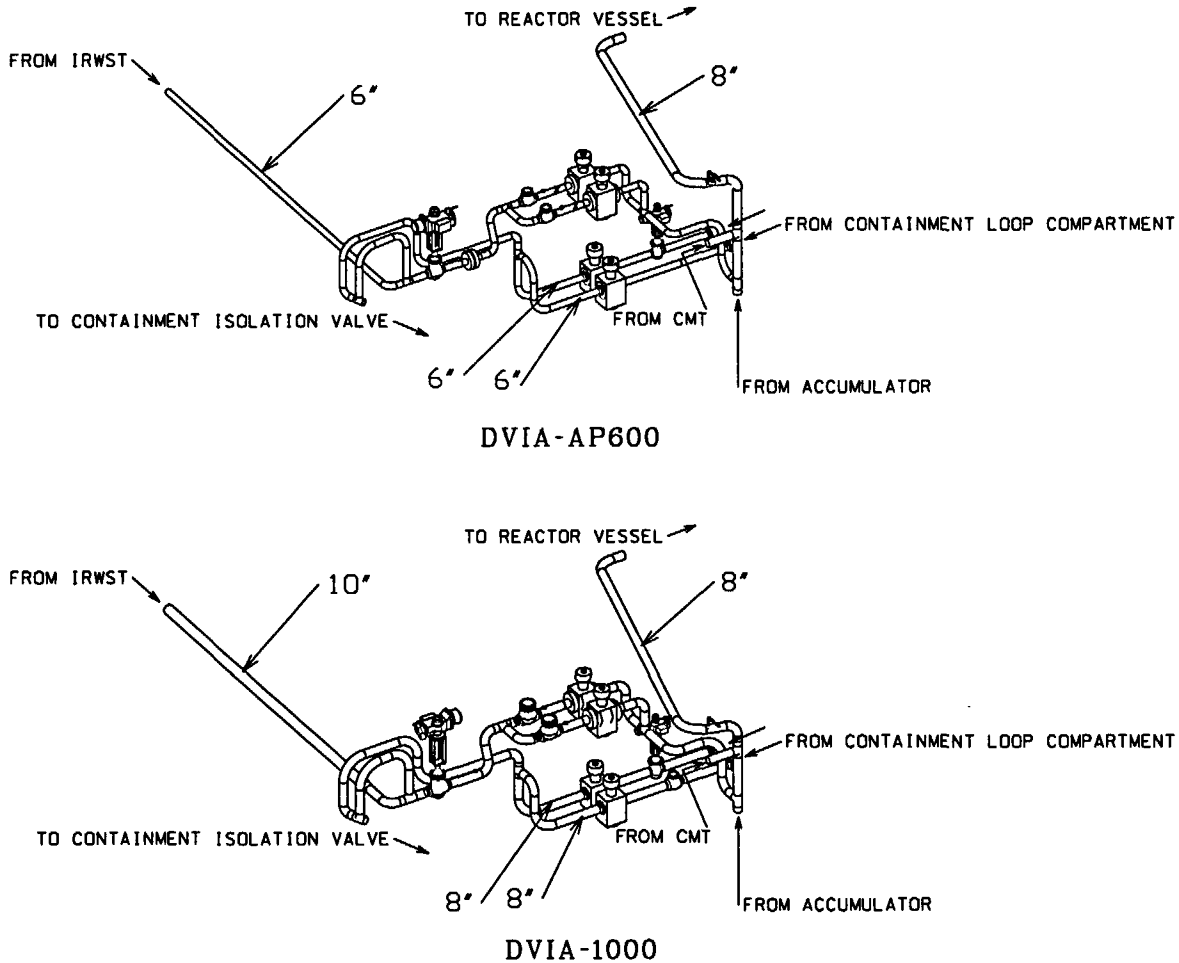


Figure 9 – Isometric View: Comparison of AP600 and AP1000 DVI-A Piping System

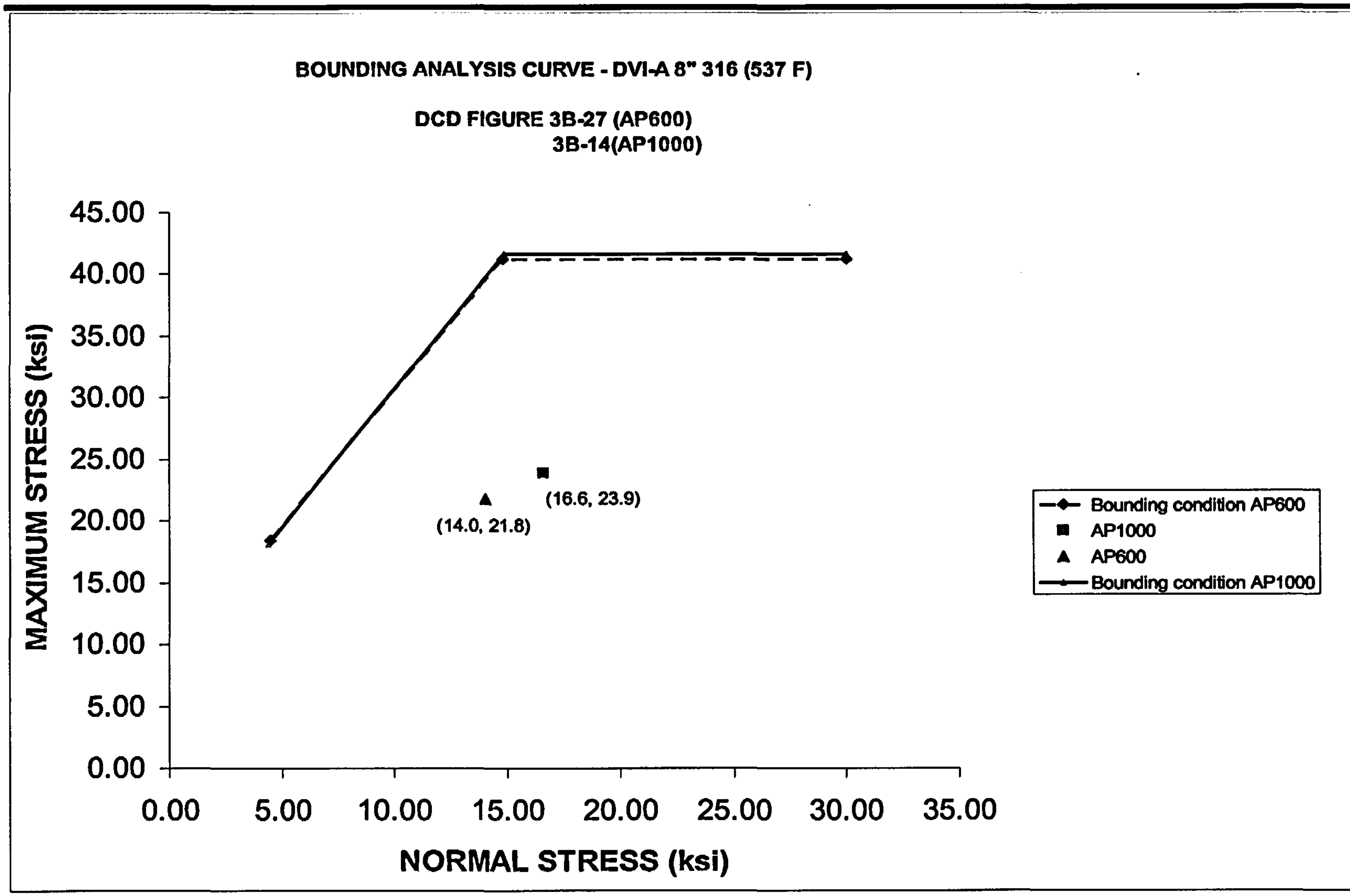


Figure 10 - Bounding Analysis Curve – DVI-A – 8" (316 SS, 537 °F)

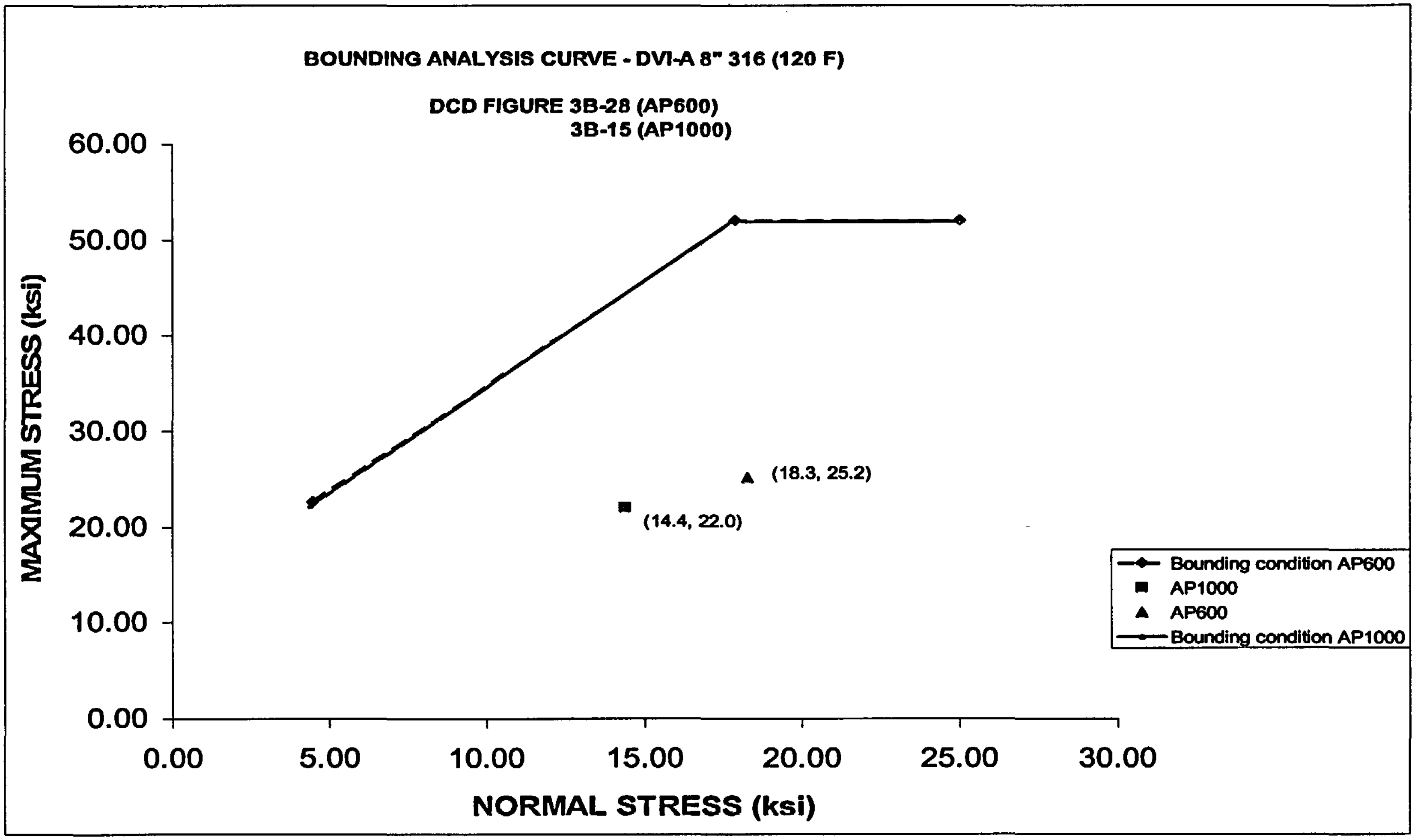


Figure 11 - Bounding Analysis Curve – DVI-A – 8" (316 SS, 120 °F)

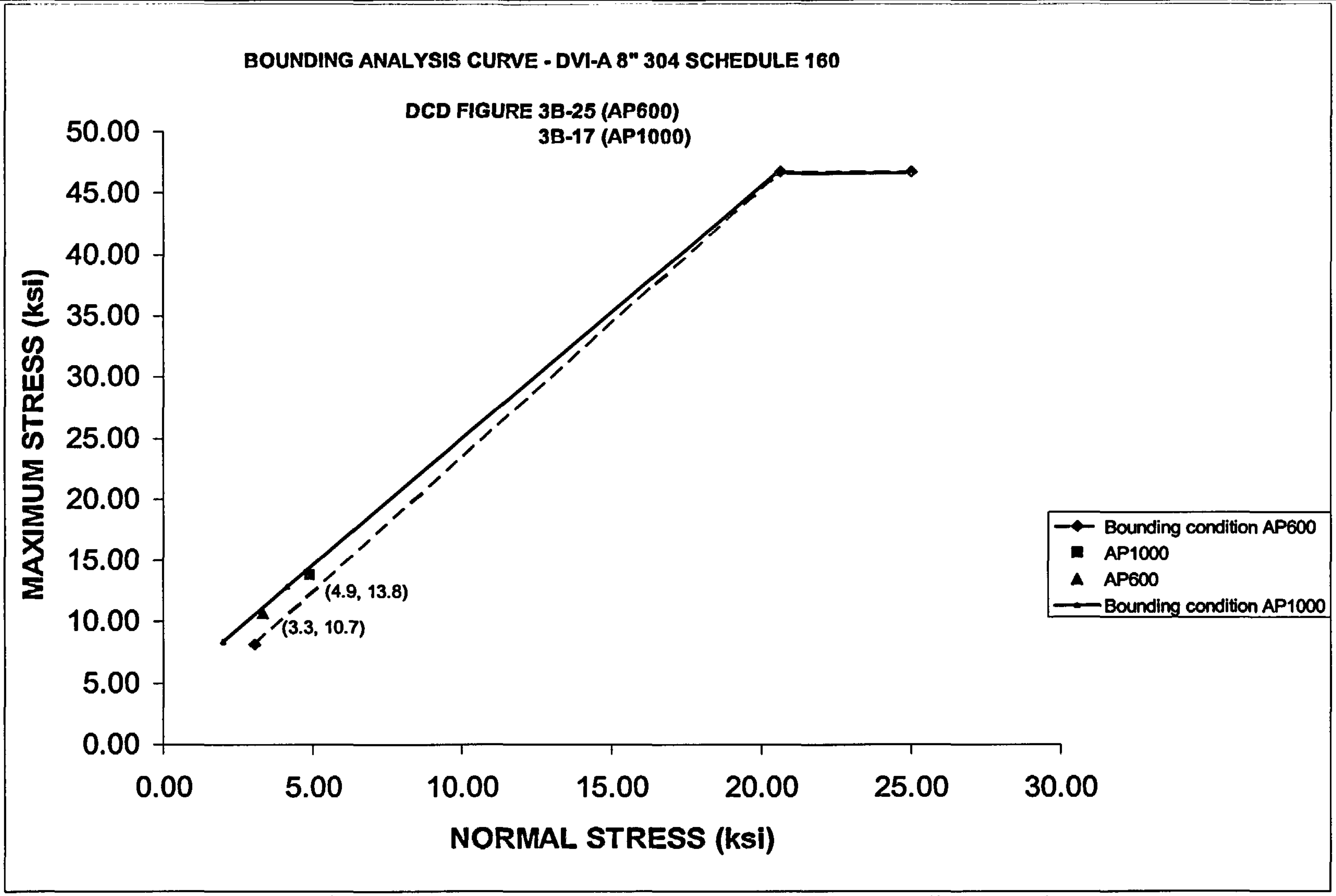


Figure 12 - Bounding Analysis Curve – DVI-A – 8" (304 SS)

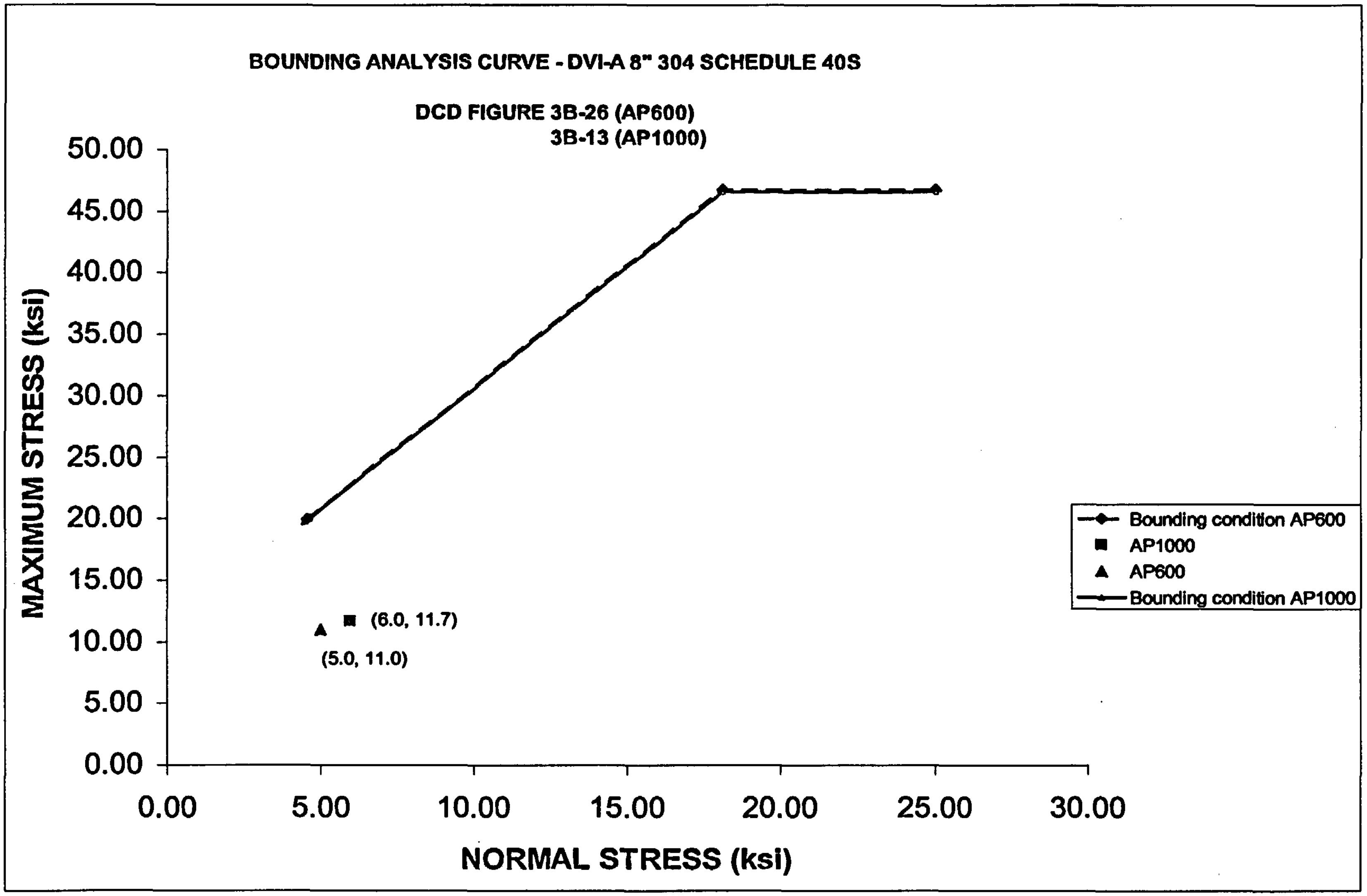


Figure 13 - Bounding Analysis Curve – DVI-A – 8" (Sch 40S)

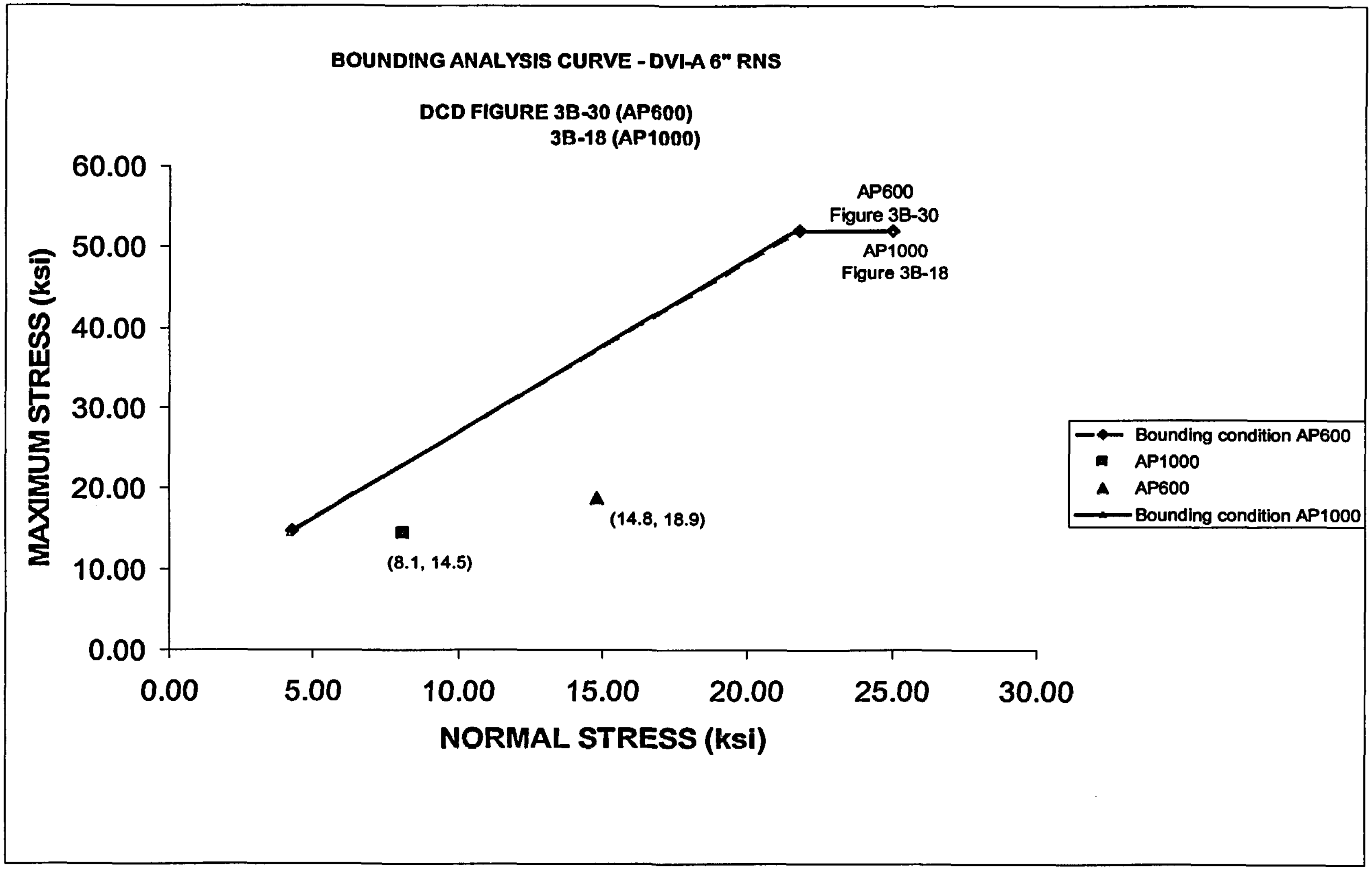


Figure 14 - Bounding Analysis Curve – DVI-A – 6" RNS

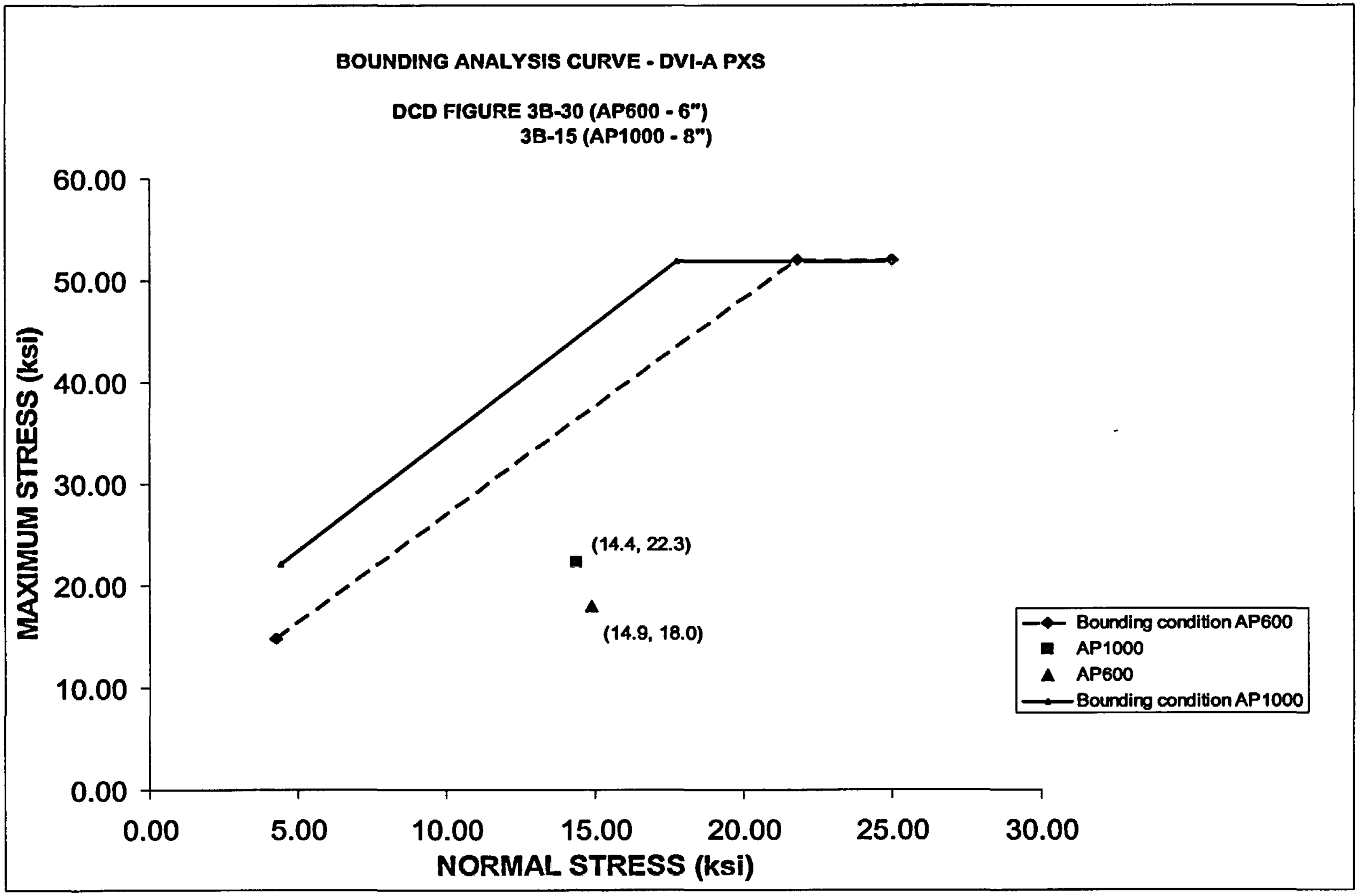


Figure 15 - Bounding Analysis Curve – DVI-A – 8" PXS

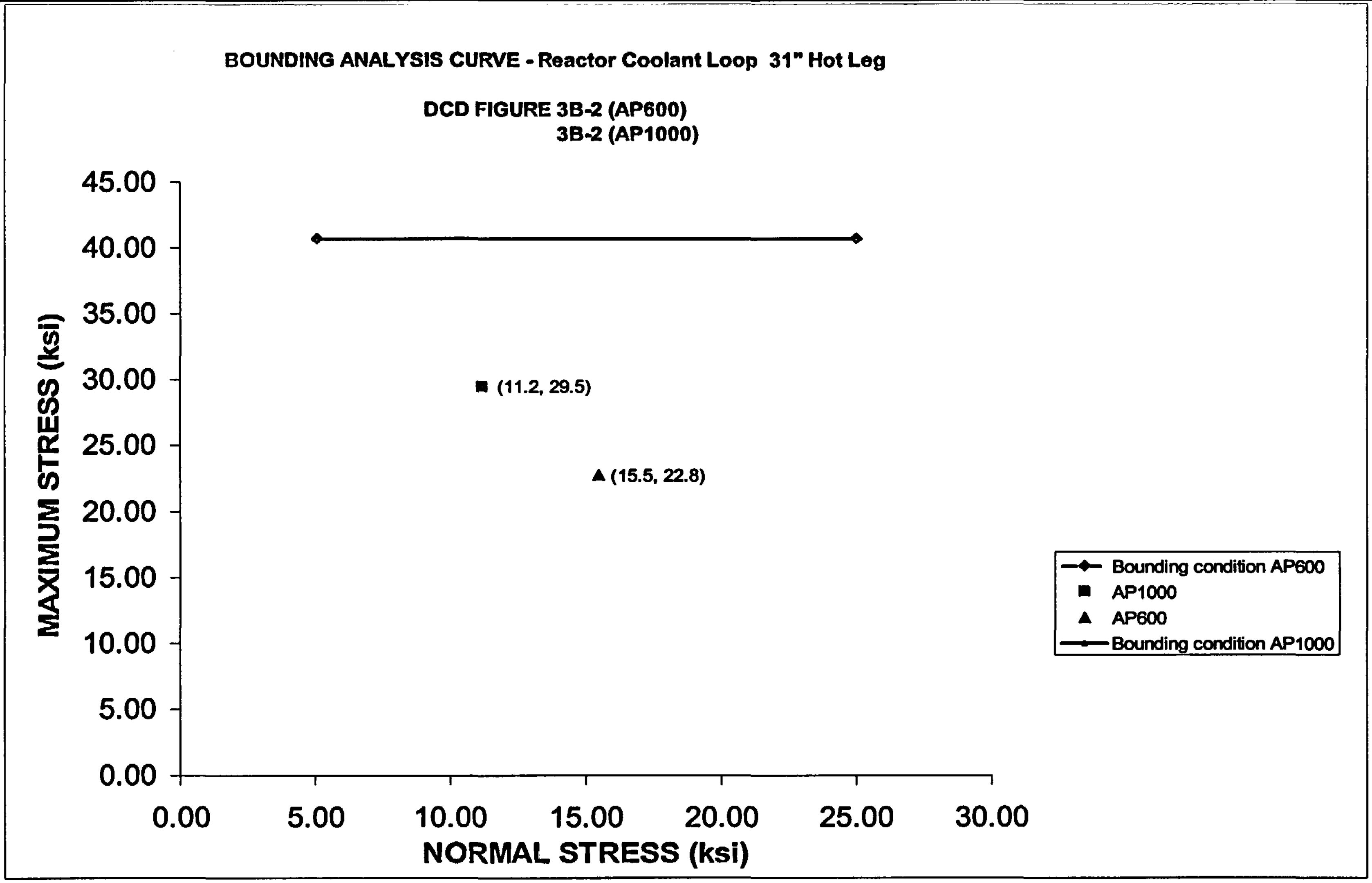


Figure 16 - Bounding Analysis Curve – Primary Loop Hot Leg – 31"

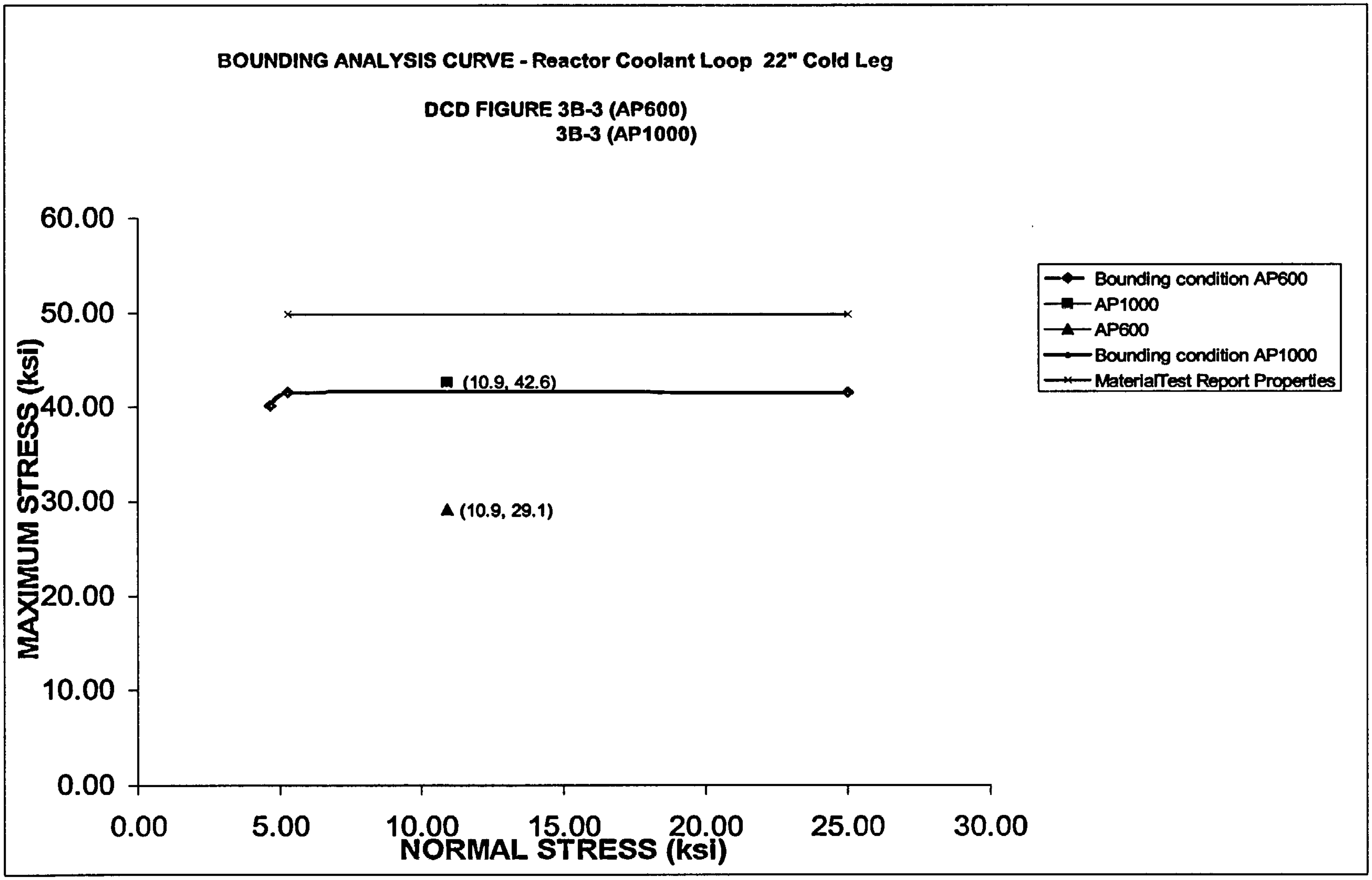


Figure 17 - Bounding Analysis Curve – Primary Loop Cold Leg – 22"

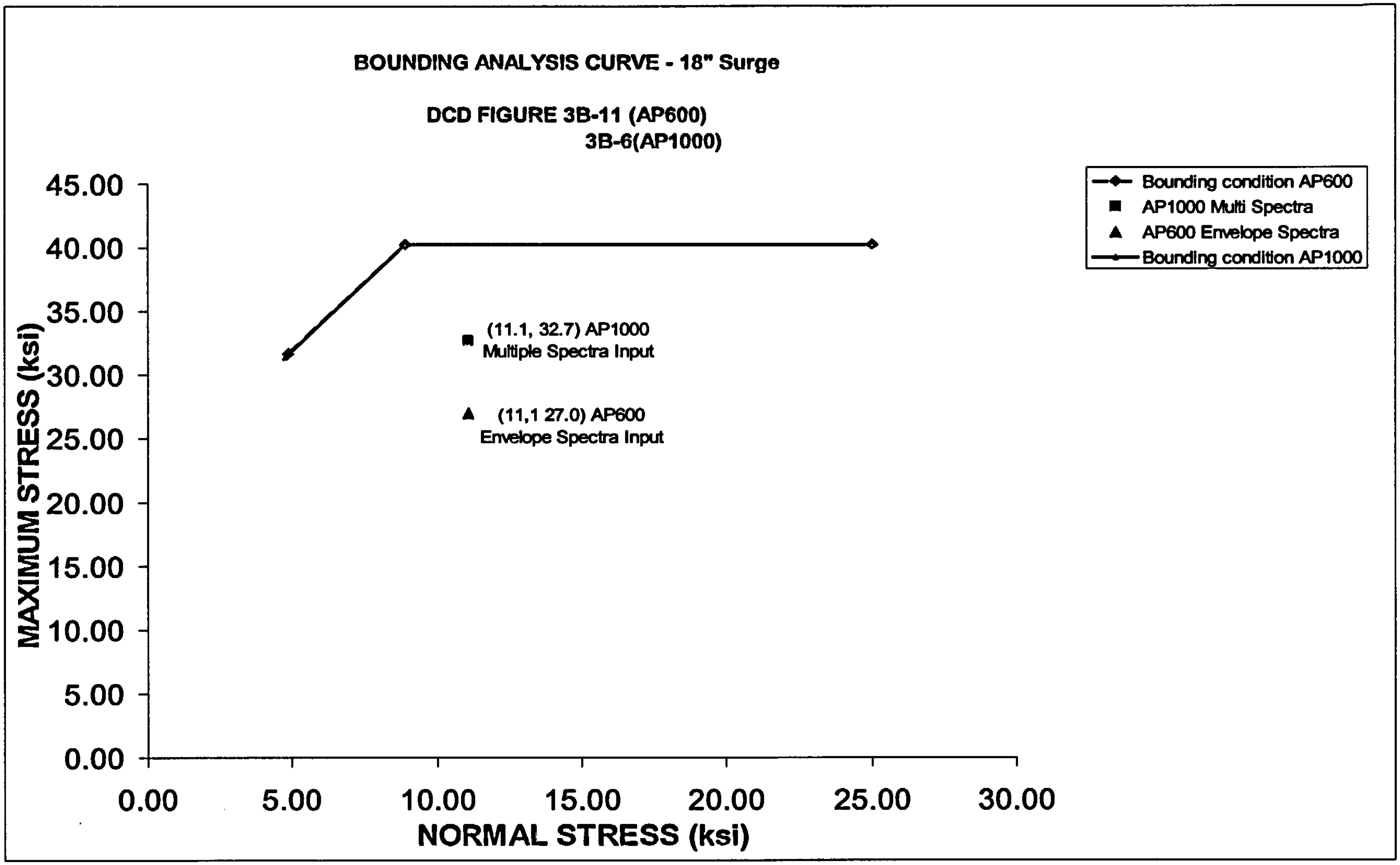


Figure 18 - Bounding Analysis Curve – Pressurizer Surgeline – 18"

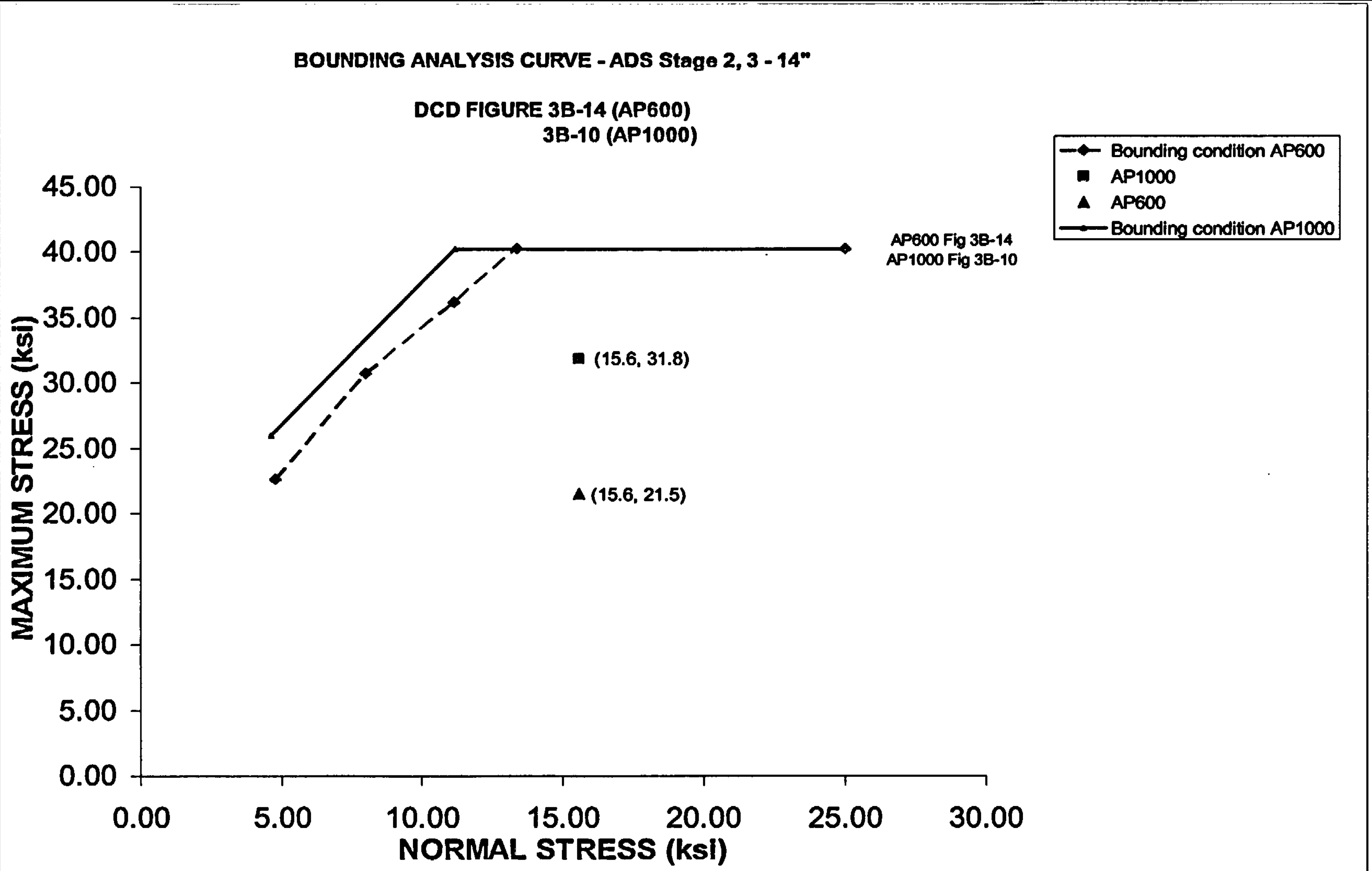


Figure 19 - Bounding Analysis Curve – ADS Stage 2 and 3 – 14”

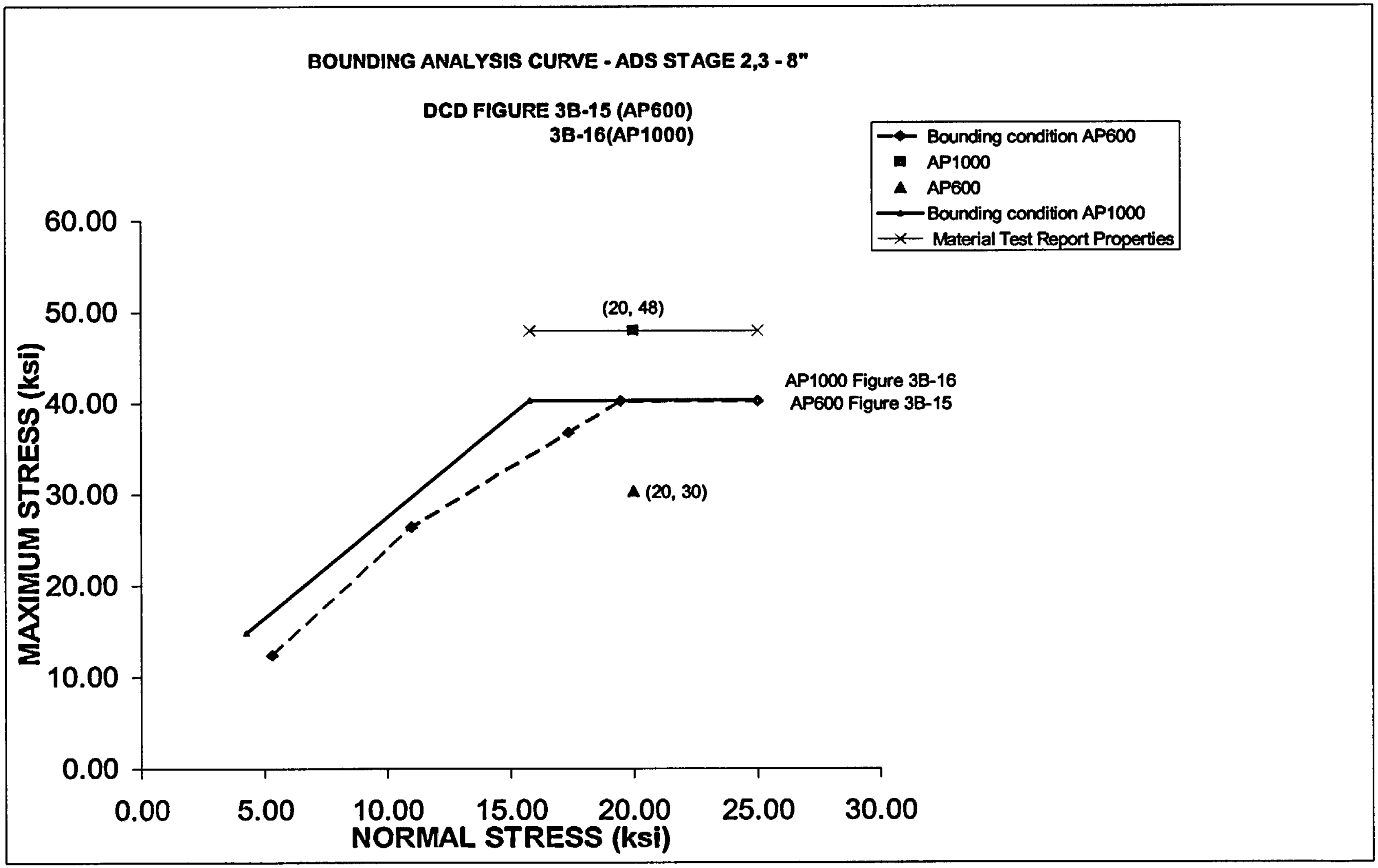


Figure 20 - Bounding Analysis Curve – ADS Stage 2 and 3 – 8"

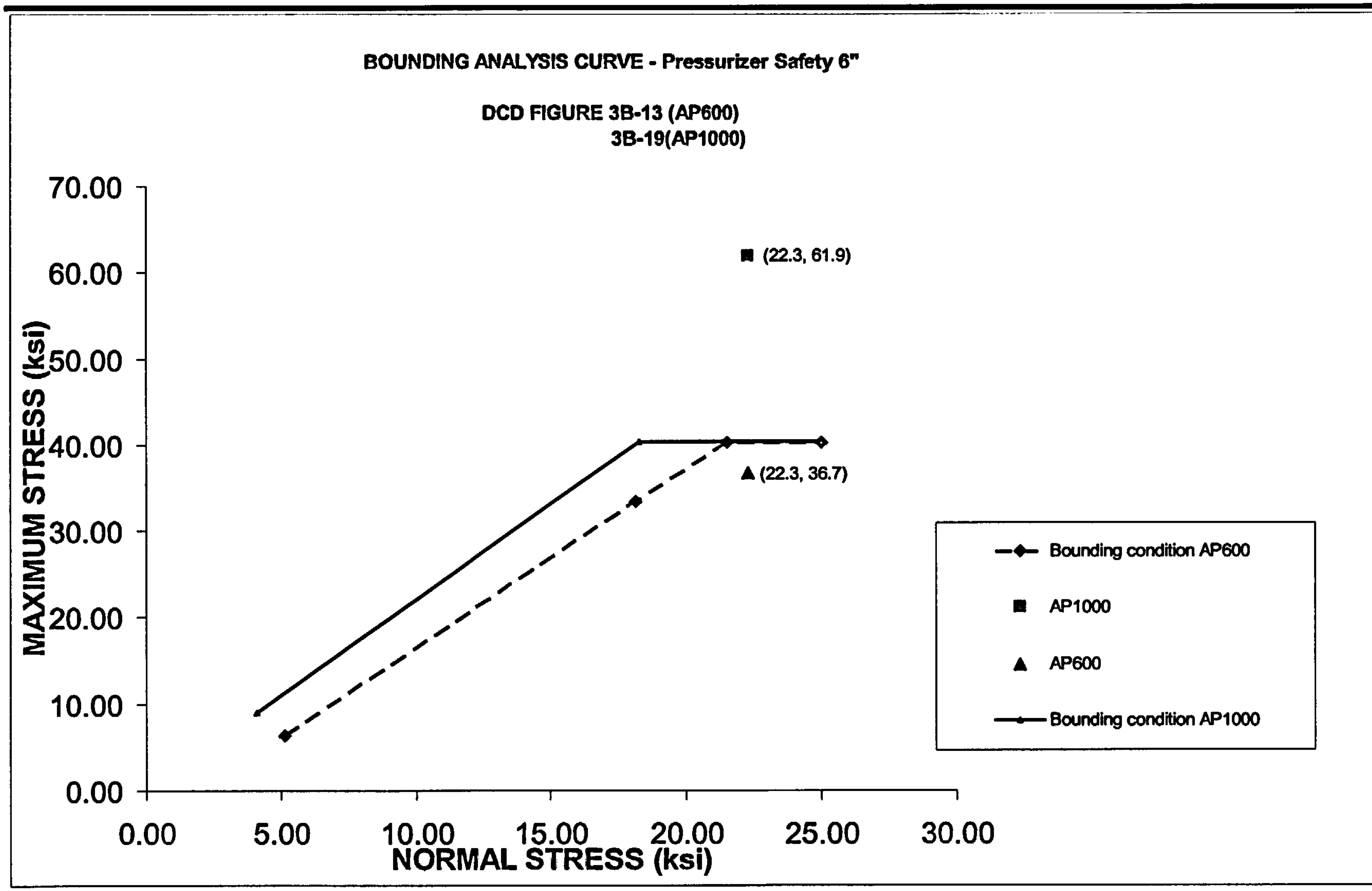


Figure 21 - Bounding Analysis Curve – Pressurizer Safety – 6"

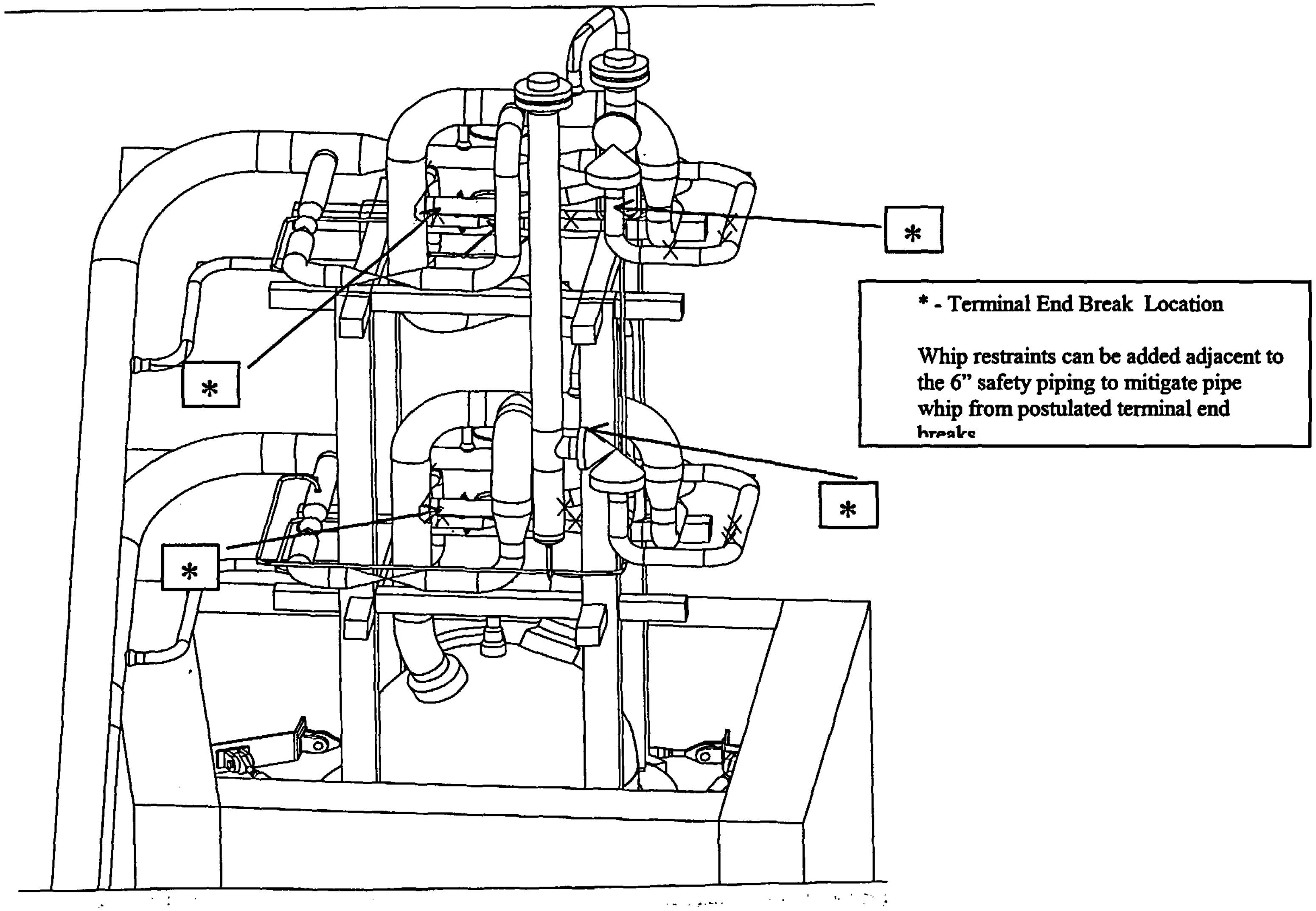
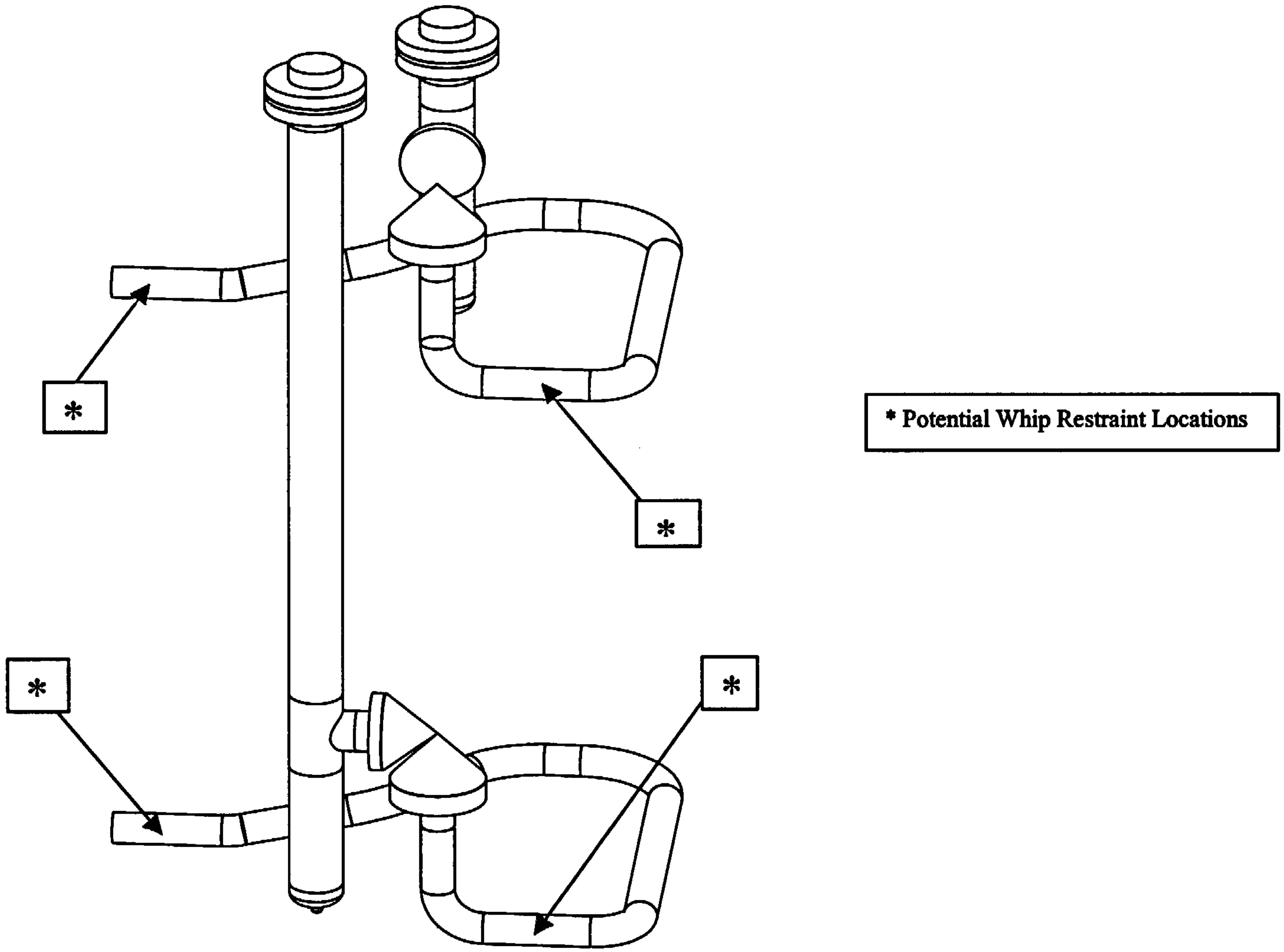


Figure 22 - Pressurizer Safety Valve Inlet Pipe Break Protection (Sheet 1 of 2)



-Figure 22 - Pressurizer Safety Valve Inlet Pipe Break Protection (Sheet 2 of 2)

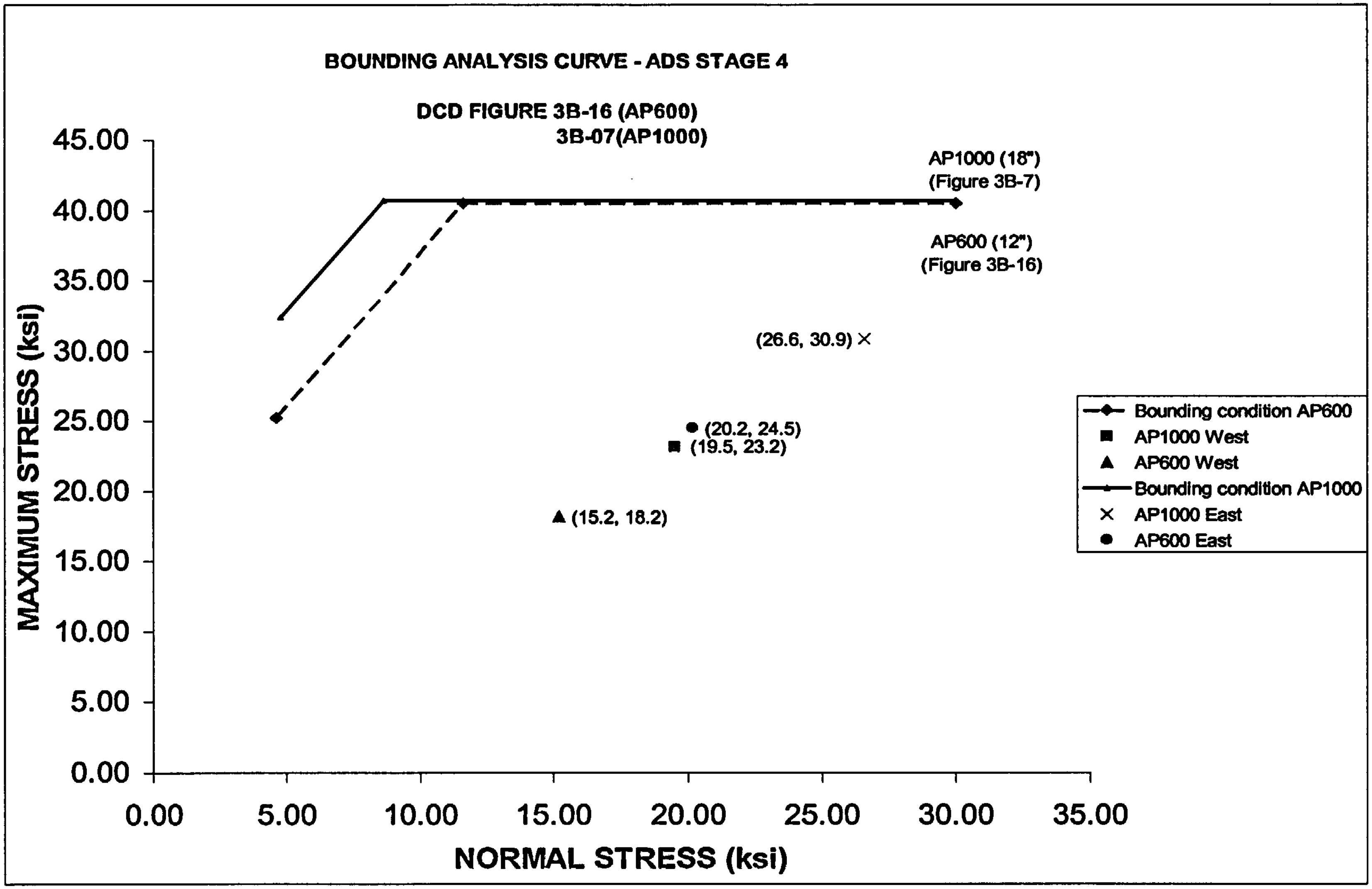


Figure 23 - Bounding Analysis Curve – ADS Stage 4 – 18"

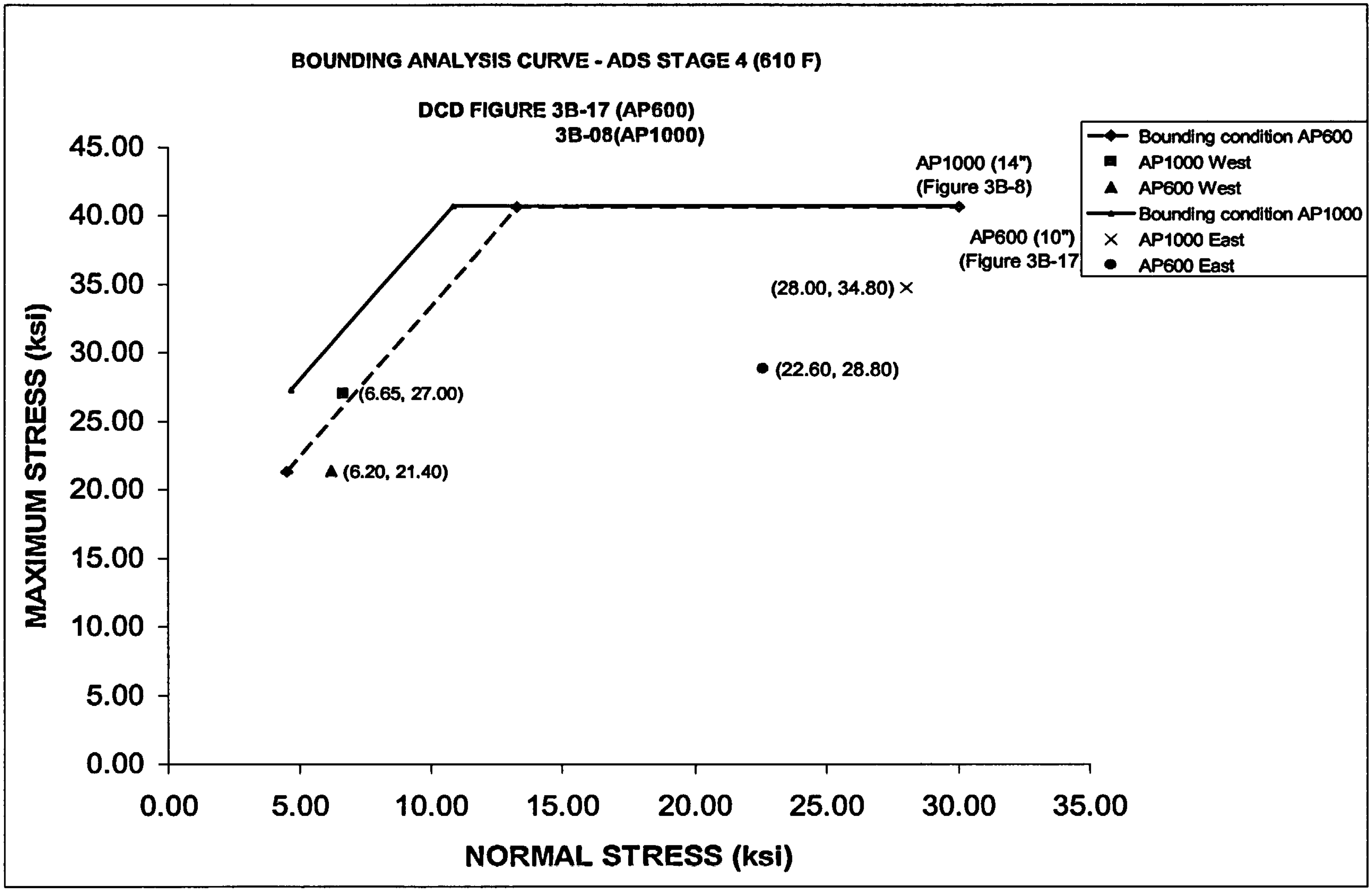


Figure 24 - Bounding Analysis Curve – ADS Stage 4 – 14" (610 °F)

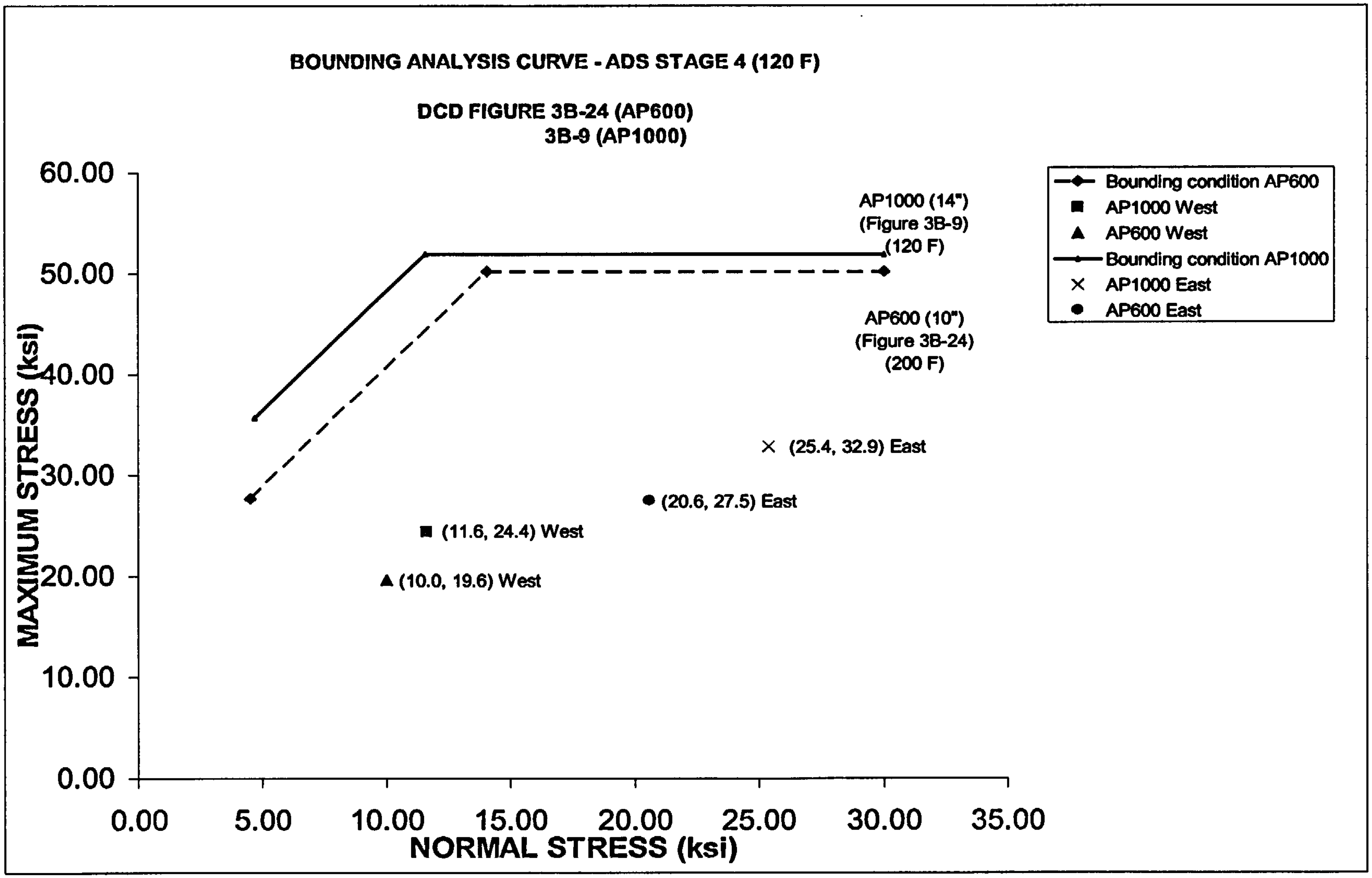


Figure 25 - Bounding Analysis Curve – ADS Stage 4 – 14" (120 °F)

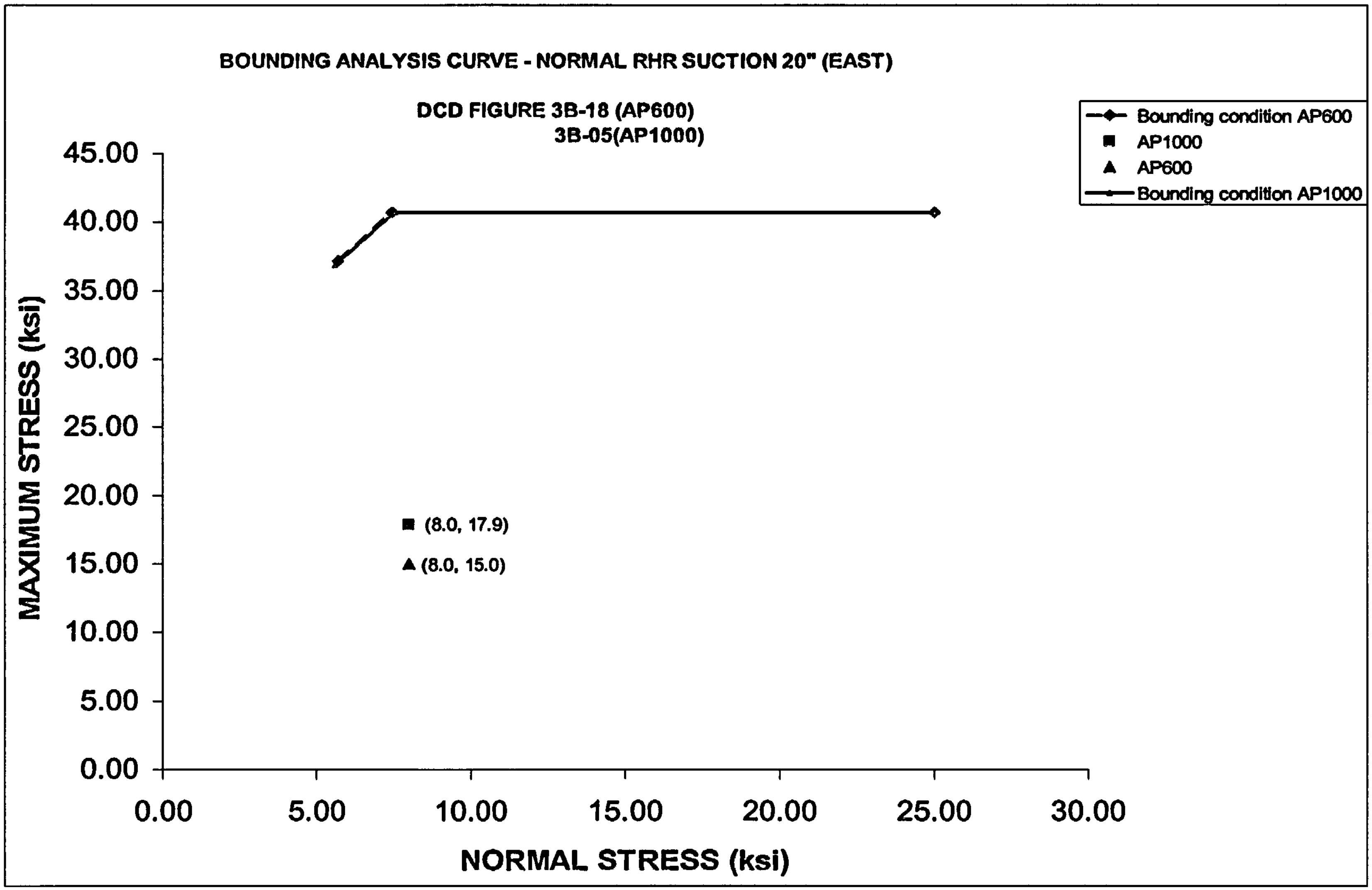


Figure 26 - Bounding Analysis Curve – Normal RHR Suction – 20”

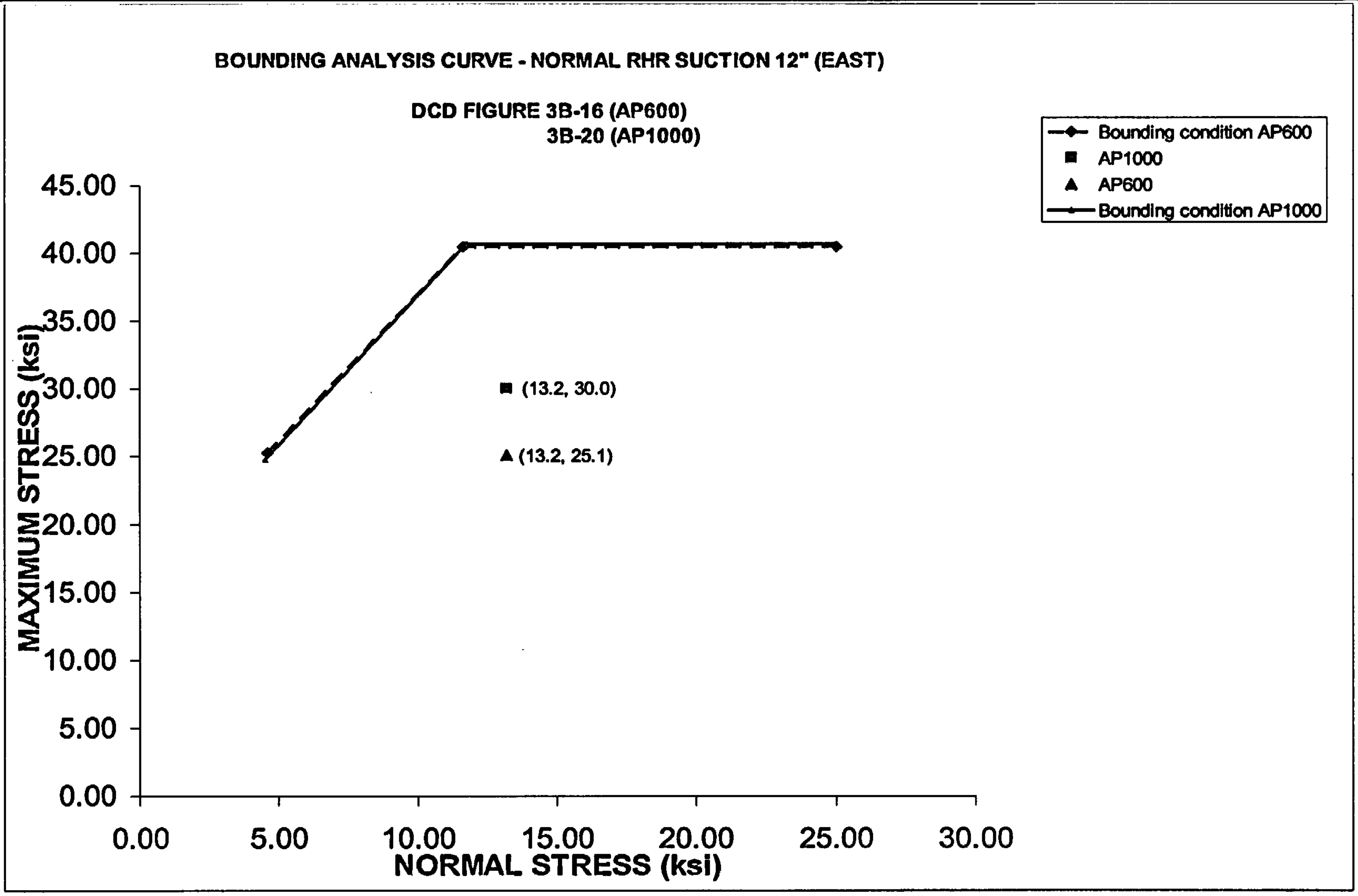


Figure 27 - Bounding Analysis Curve – Normal RHR Suction – 12"

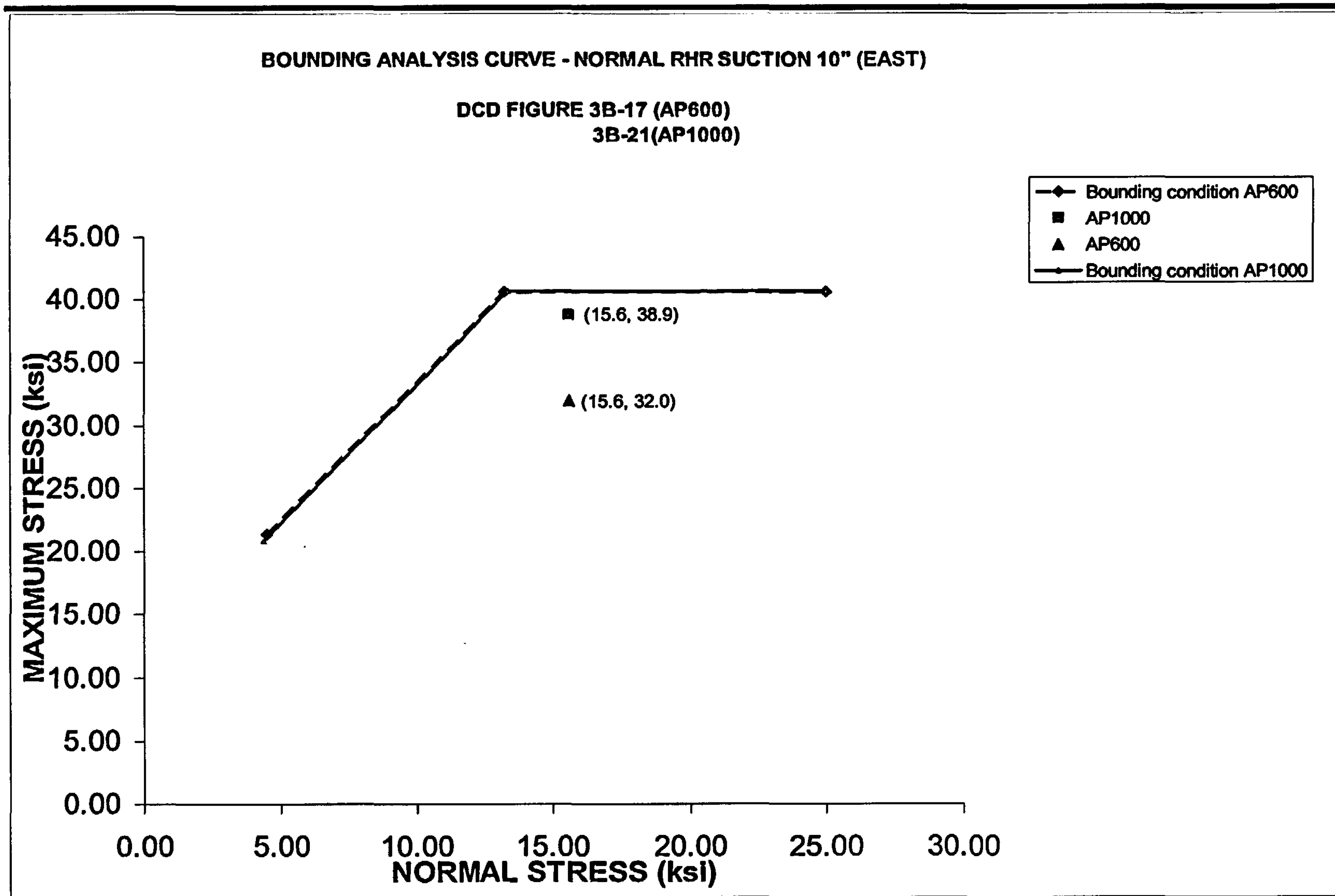


Figure 28 - Bounding Analysis Curve – Normal RHR Suction – 10"

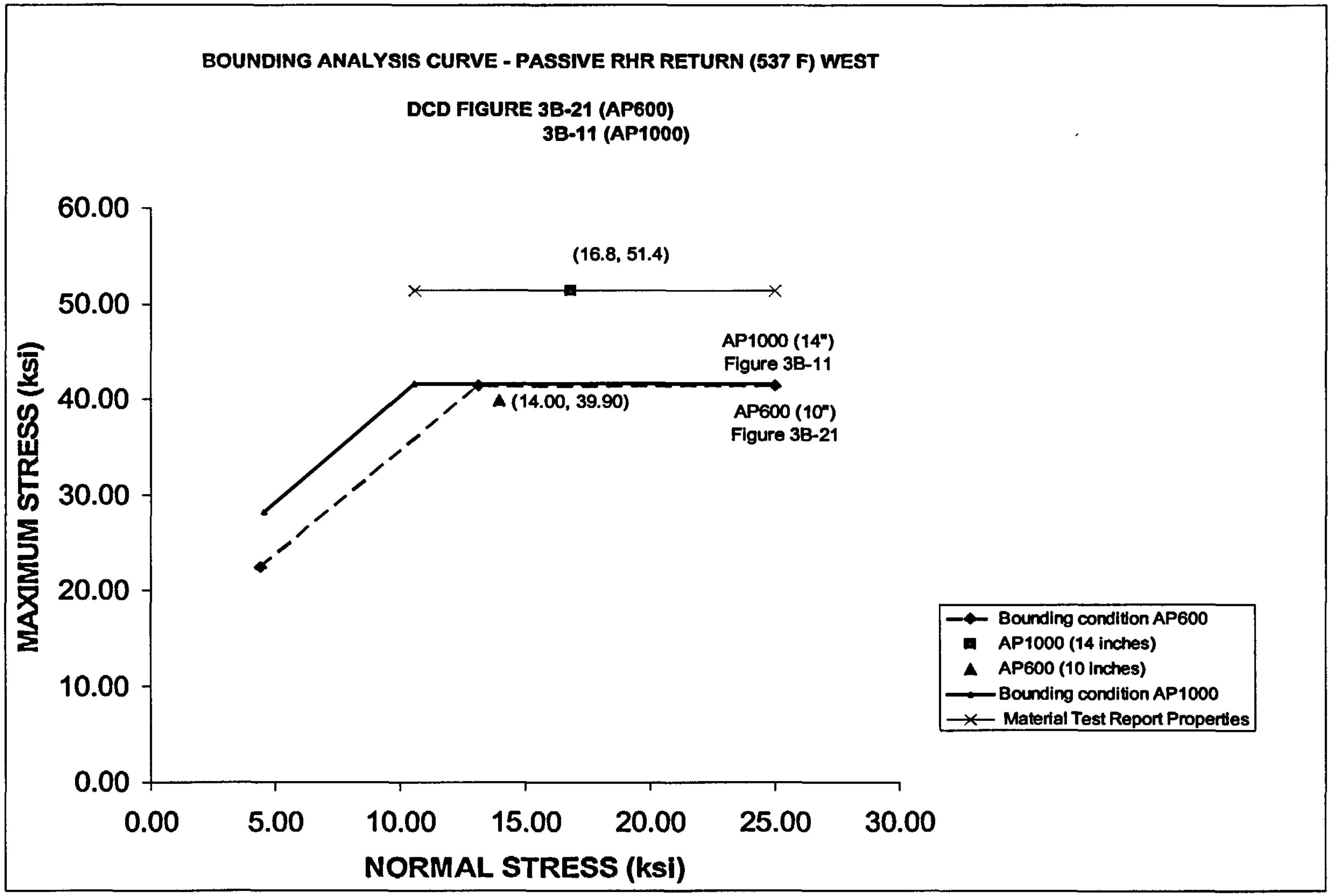


Figure 29 - Bounding Analysis Curve – Passive RHR Return – 14"

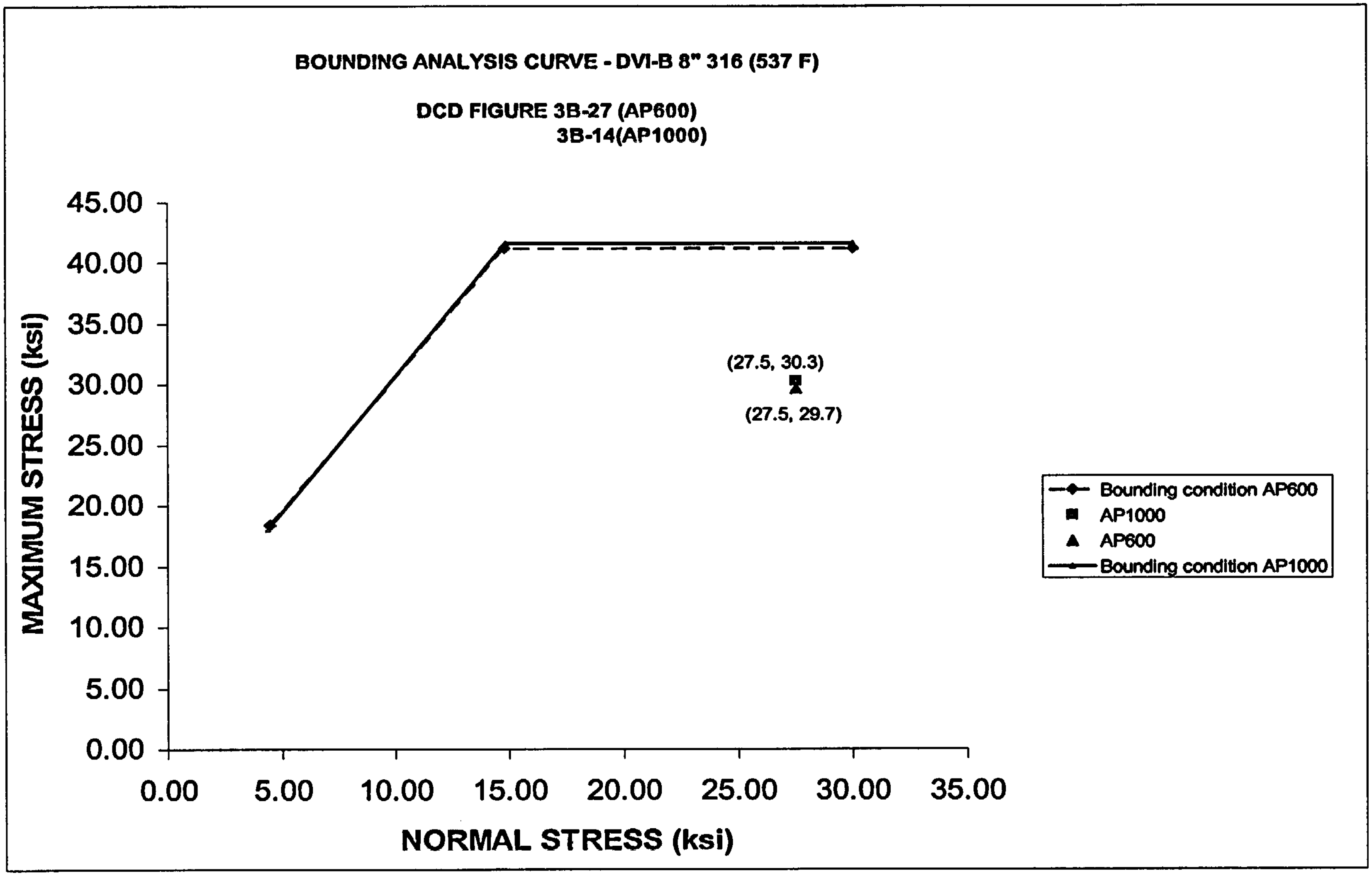


Figure 30 - Bounding Analysis Curve – DVI-B – 8" (316 SS, 537 °F)

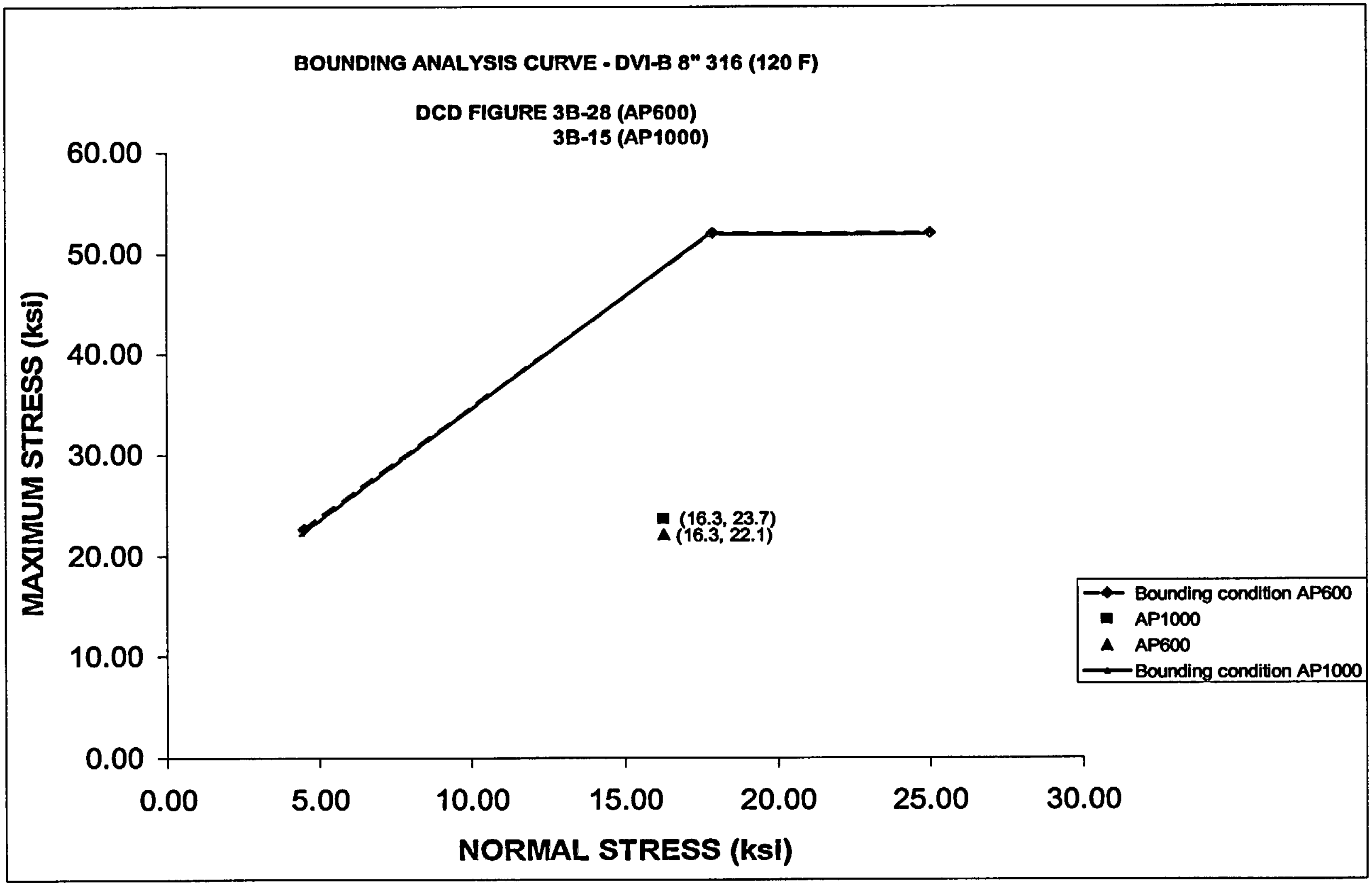


Figure 31 - Bounding Analysis Curve – DVI-B – 8" (316 SS, 120 °F)

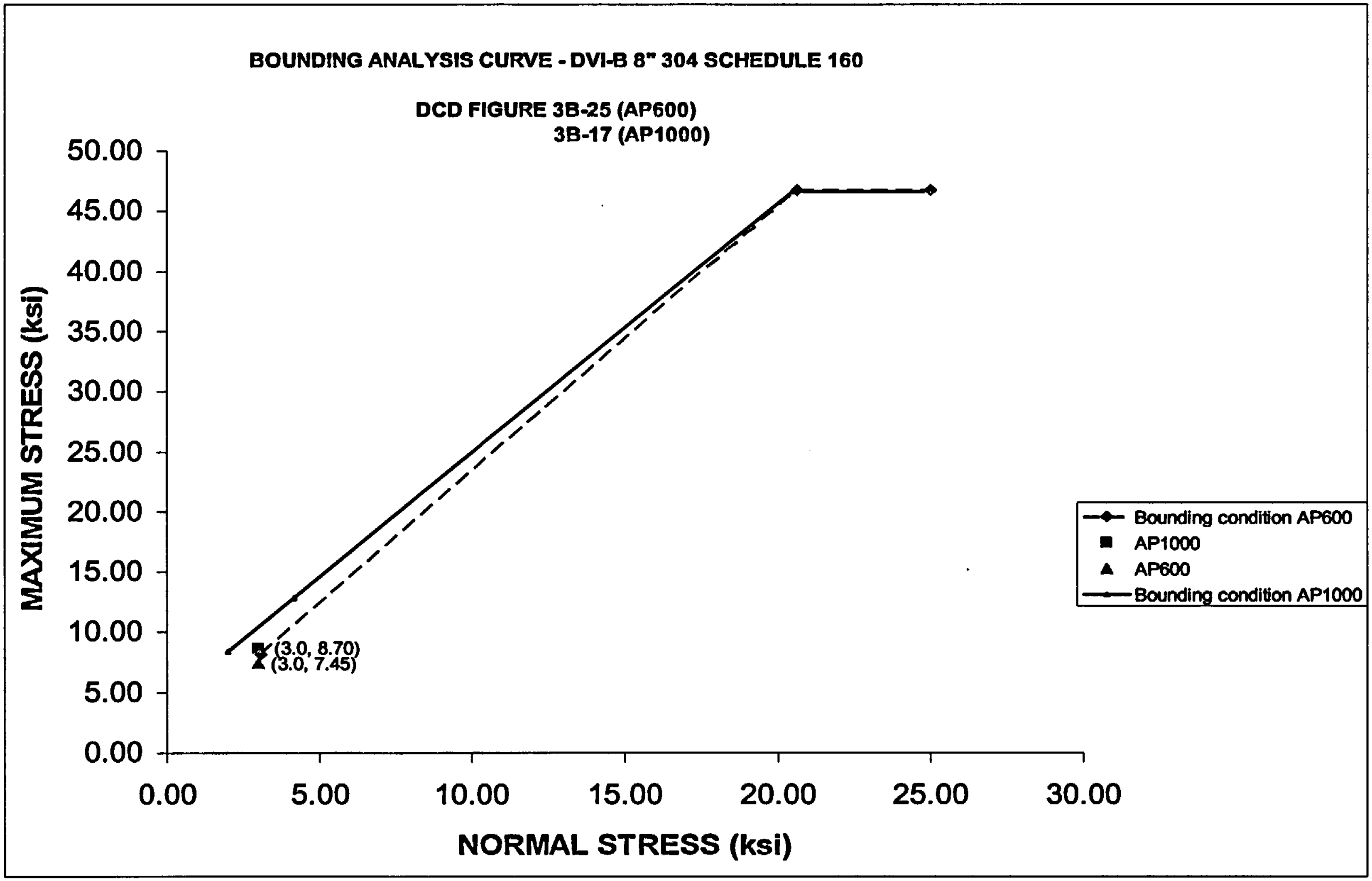


Figure 32 - Bounding Analysis Curve – DVI-B – 8" (304 SS)

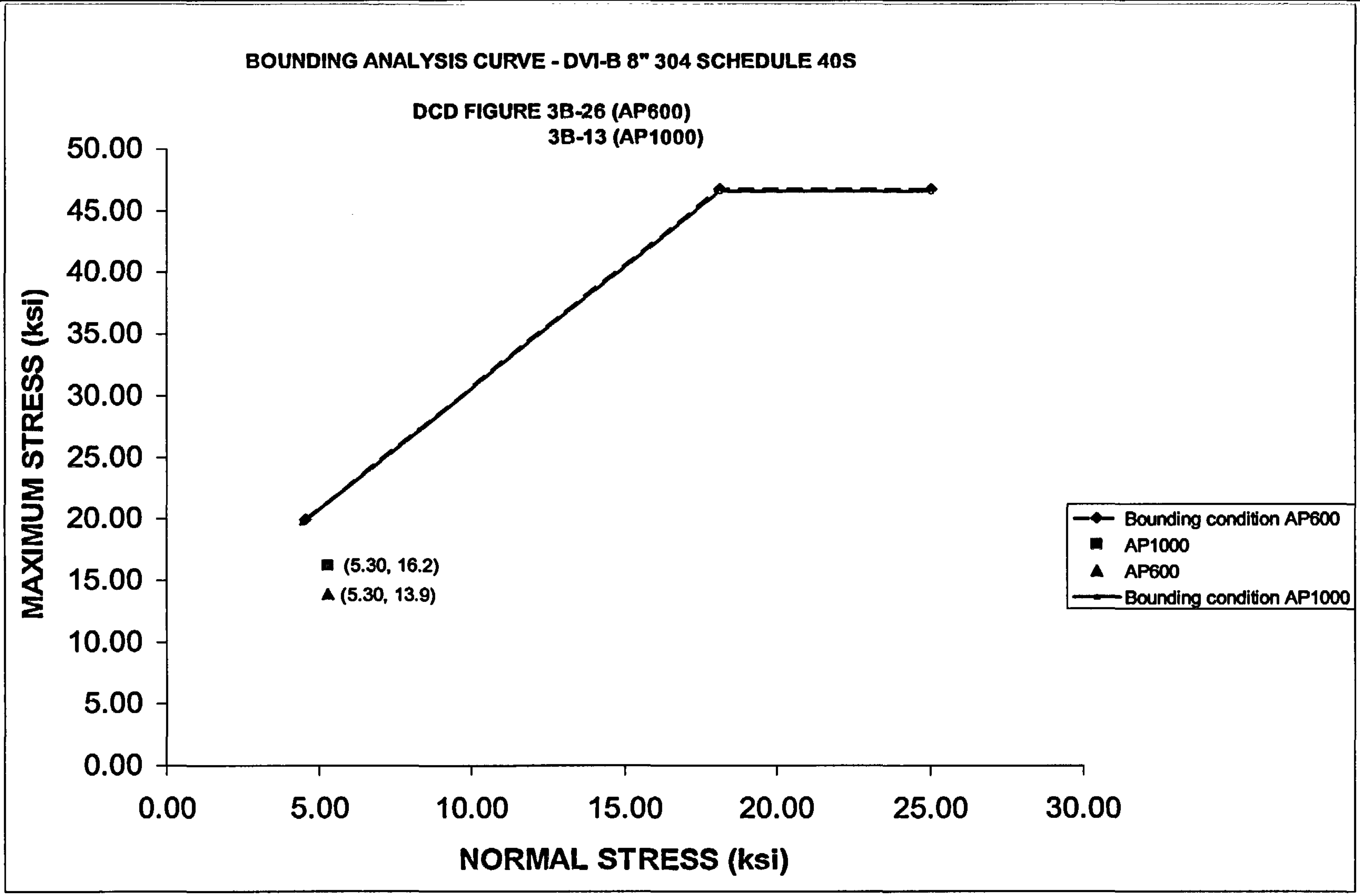


Figure 33 - Bounding Analysis Curve – DVI-B – 8" (Sch 40S)

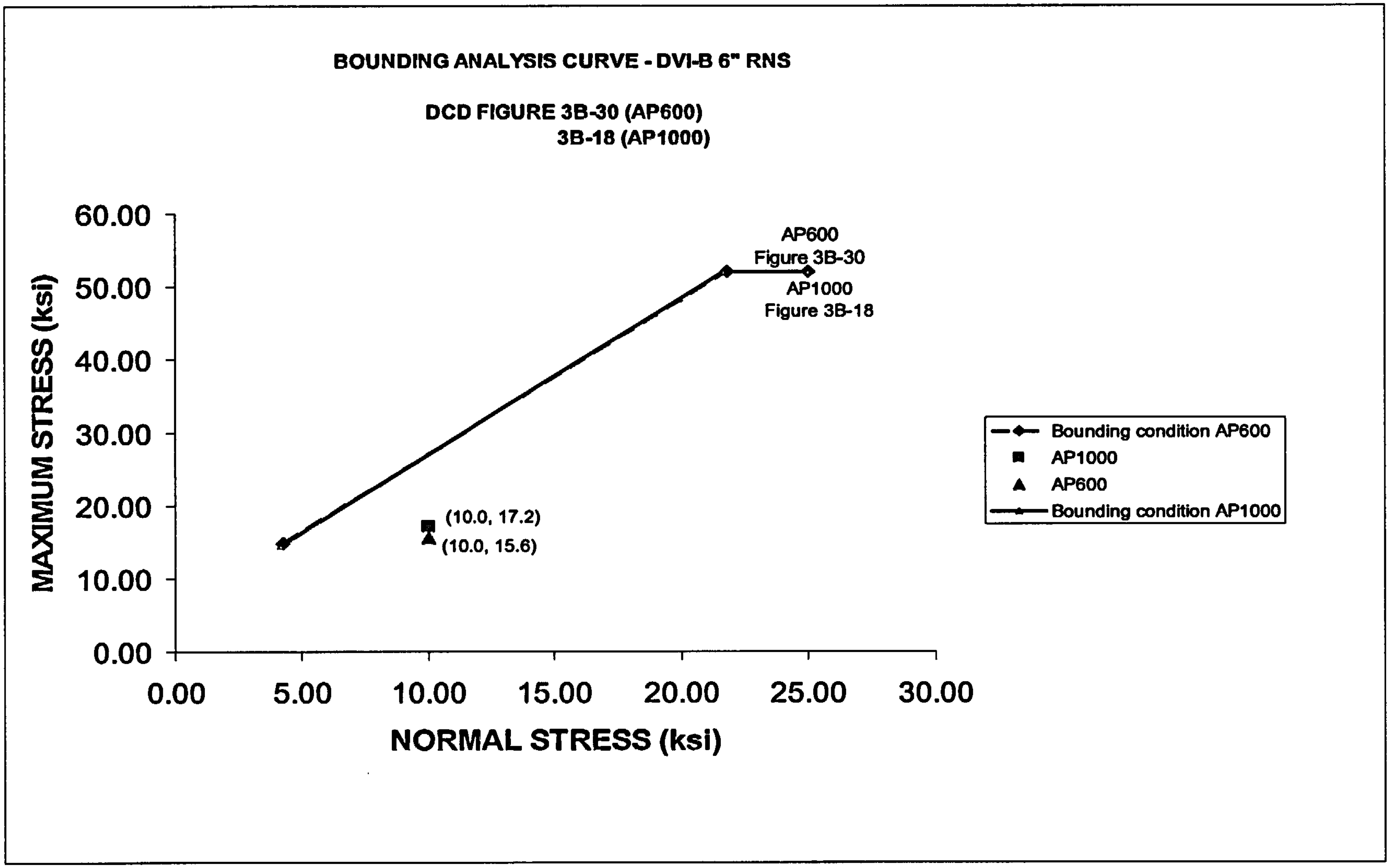


Figure 34 - Bounding Analysis Curve – DVI-B – 6" RNS

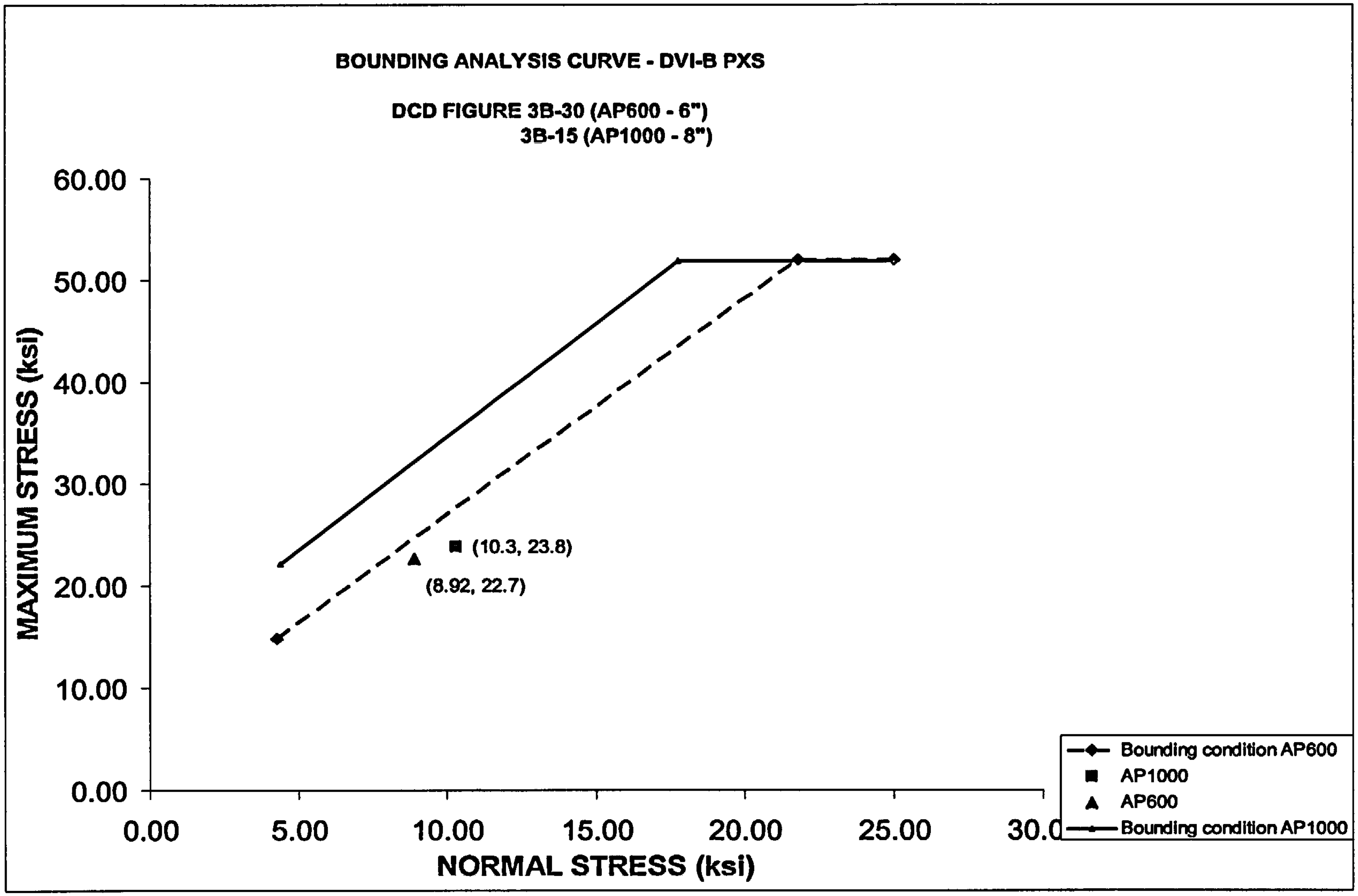


Figure 35 - Bounding Analysis Curve – DVI-B – 8" PXS

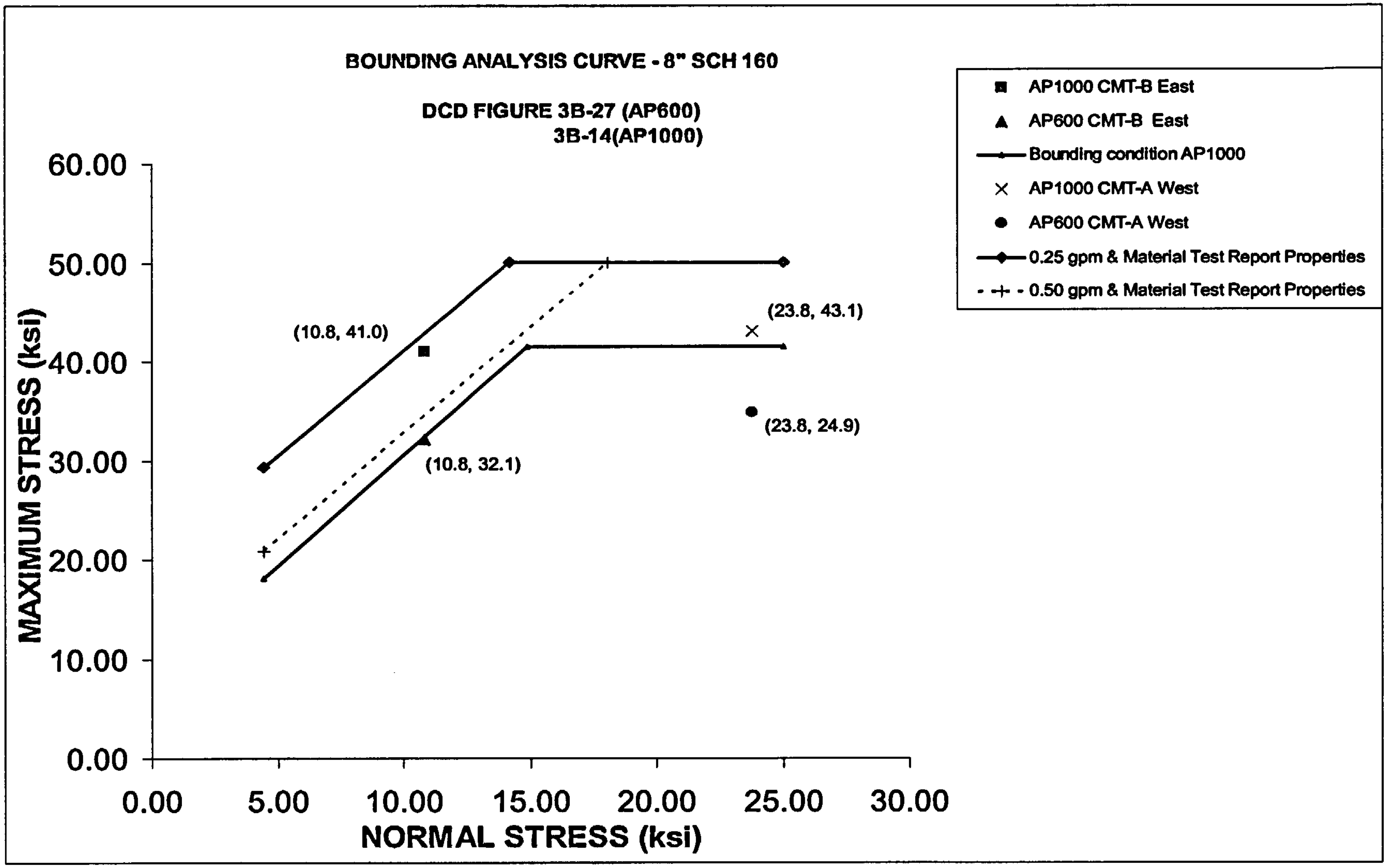


Figure 36 - Bounding Analysis Curve – CMT - 8"

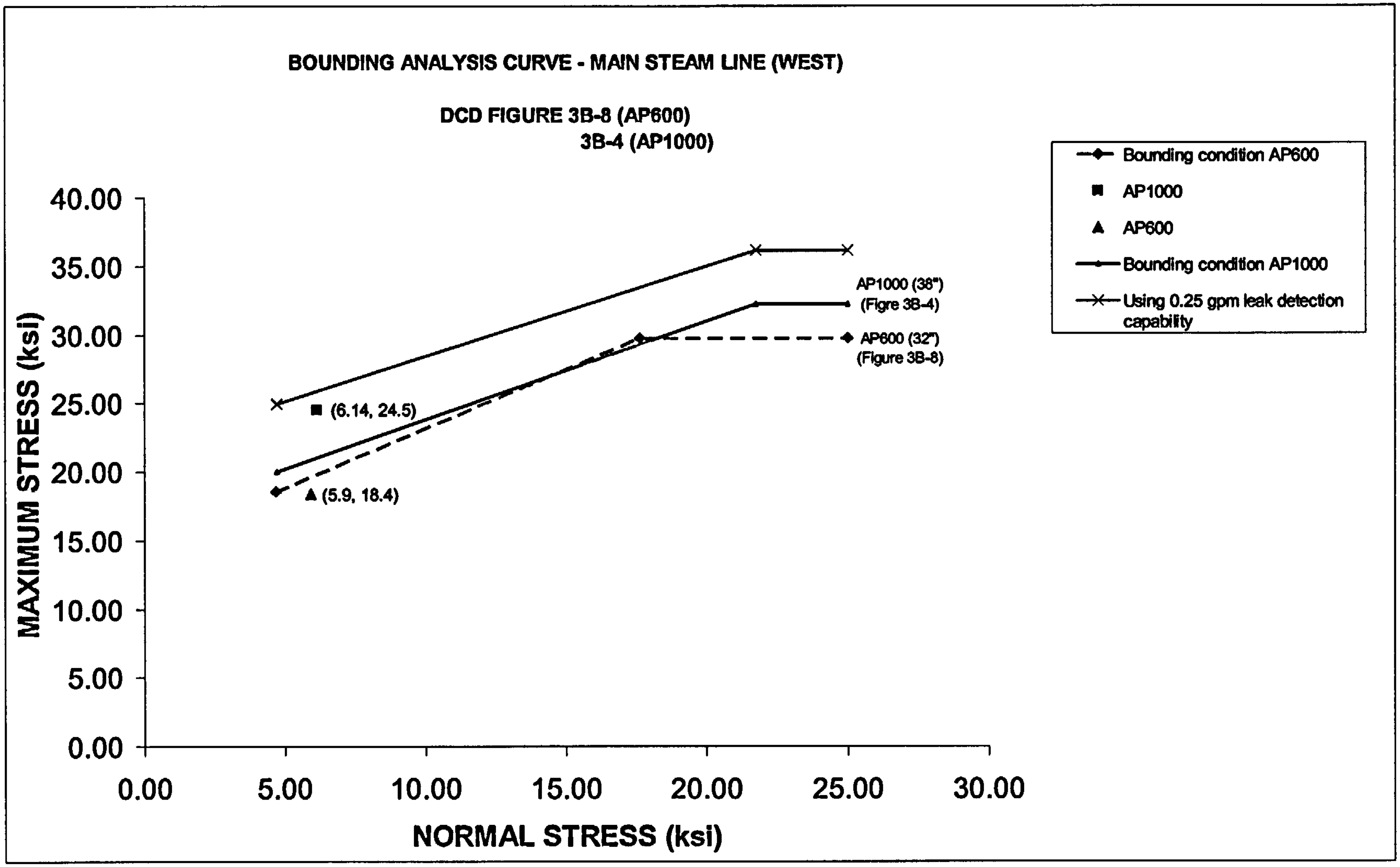


Figure 37 - Bounding Analysis Curve – Main Steam – West – 38"

APPENDIX A

Summary of Sample Certified Material Test Reports Review			
	Room temperature CMTRs properties		
Plant	Material	Yield Strength (psi)	Ultimate Strength (psi)
Plant A	A376/TP316	46800	93800
Aux. lines	A376/TP316	48000	86400
	A376/TP316	45600	87900
	A376/TP316	41300	83200
	A376/TP316	38600	82600
	A376/TP316	44900	84000
Plant B	A376/TP316	59100	84900
Aux. lines	A376/TP316	52100	87400
	A376/TP316	51900	85400
	A376/TP316	48400	84900
	A376/TP316	59100	84900
	A376/TP316	47400	81100
	A376/TP316	47400	81100
	A376/TP316	59100	84900
	A376/TP316	48400	84900
	A376/TP316	48400	84900
	A376/TP316	59100	84900
	A376/TP316	45200	87600
	A376/TP316	51900	85400
	A376/TP316	59100	84900
	A376/TP316	59100	84900
	A376/TP316	59100	84900
	A376/TP316	45200	87600
	A376/TP316	48400	84900
	A376/TP316	47400	81100
	A376/TP316	45200	87600
	A376/TP316	51900	85400
	A376/TP316	47400	81100
	A376/TP316	47400	81100
	A376/TP316	47400	81100
	A376/TP316	59100	84900
	A376/TP316	59100	84900
	A376/TP316	51900	85400
	A376/TP316	52100	87400

Summary of Sample Certified Material Test Reports Review			
	Room temperature CMTRs properties		
Plant	Material	Yield Strength (psi)	Ultimate Strength (psi)
	A376/TP316	47400	81100
	A376/TP316	59100	84900
	A376/TP316	47400	81100
	A376/TP316	51900	85400
	A376/TP316	59100	84900
	A376/TP316	59100	84900
	A376/TP316	48400	84900
	A376/TP316	52100	87400
	A376/TP316	59100	84900
	A376/TP316	47400	81100
	A376/TP316	39200	84200
	A376/TP316	42200	84900
	A376/TP316	39200	84200
	A376/TP316	52100	87400
	A376/TP316	52100	87400
	A376/TP316	52100	87400
	A376/TP316	45200	87600
	A376/TP316	52100	87400
	A376/TP316	51900	85400
	A376/TP316	48400	84900
Plant C	A376/TP316	43300	85600
Aux. lines	A376/TP316	42700	88200
	A376/TP316	38100	82600
	A376/TP316	43300	85600
	A376/TP316	42700	88200
	A376/TP316	38100	82600
	A376/TP316	40100	83000
	A376/TP316	38100	82600
	A376/TP316	43300	87800
	A376/TP316	44100	88600
	A376/TP316	40100	83000
	A376/TP316	40500	84600
	A376/TP316	44500	81400
	A376/TP316	50250	87400
	A376/TP316	42400	84900
	A376/TP316	42100	89000
	A376/TP316	39700	86200
	A376/TP316	44500	81400

Summary of Sample Certified Material Test Reports Review			
	Room temperature CMTRs properties		
Plant	Material	Yield Strength (psi)	Ultimate Strength (psi)
	A376/TP316	44500	81400
Plant D	A376/TP316	42700	88200
Aux. lines	A376/TP316	38100	82600
	A376/TP316	42700	88200
	A376/TP316	38100	82600
	A376/TP316	42700	88200
	A376/TP316	46700	92600
	A376/TP316	42700	88200
	A376/TP316	42050	82500
	A376/TP316	44600	85100
	A376/TP316	49100	81200
	A376/TP316	41150	80900
	A376/TP316	49100	81200
	A376/TP316	41150	80900
	A376/TP316	42100	82900
	A376/TP316	51400	91050
	A376/TP316	42050	82500
	A376/TP316	41150	80900
	A376/TP316	49100	81200
	A376/TP316	40100	83000
	A376/TP316	40100	83000
	A376/TP316	40100	83000
	A376/TP316	41100	98400
	A376/TP316	39300	84200
	A376/TP316	41150	80900
	A376/TP316	45150	86600
	A376/TP316	41050	79600
	A376/TP316	41150	80900
	A376/TP316	41050	79600
	A376/TP316	41650	78550
	A376/TP316	41050	79600
Plant E	A376/TP316	38800	84500
Aux. lines	A376/TP316	45600	87900
	A376/TP316	41300	83200
	A376/TP316	41900	87400
Plant F	A376/TP316	41400	87100

Summary of Sample Certified Material Test Reports Review			
	Room temperature CMTRs properties		
Plant	Material	Yield Strength (psi)	Ultimate Strength (psi)
Aux. lines	A376/TP316	42400	86100
	A376/TP316	40900	86100
	A376/TP316	38900	79400
	A376/TP316	39300	82600
	A376/TP316	42500	83800
	A376/TP316	42200	86100
	A376/TP316	42200	86100
	A376/TP316	44900	84200
	A376/TP316	41200	81600
	A376/TP316	41700	85800
	A376/TP316	42900	84600
	A376/TP316	39700	83400
	A376/TP316	40200	85100
	A376/TP316	40200	83000
	A376/TP316	40900	82600
	A376/TP316	40200	84200
	A376/TP316	44500	86300
	A376/TP316	44600	84800
	A376/TP316	44200	85000
Plant G	A376/TP316	38200	82900
Aux. lines	A376/TP316	38200	82900
	A376/TP316	38200	82900
	A376/TP316	38200	82900
Plant H	A376/TP316	47100	88500
Aux. lines	A376/TP316	47100	88500
	A376/TP316	47100	88500
	A376/TP316	48600	88500
	A376/TP316	47100	88500
	A376/TP316	38400	79900
	A376/TP316	49300	83100
Plant I	A376/TP316	42700	88200
Aux. lines	A376/TP316	42700	88200
	A376/TP316	42700	88200
	A376/TP316	42700	88700
	A376/TP316	43300	85600
	A376/TP316	43300	85600

Summary of Sample Certified Material Test Reports Review			
	Room temperature CMTRs properties		
Plant	Material	Yield Strength (psi)	Ultimate Strength (psi)
	A376/TP316	44500	81400
	A376/TP316	44500	81400
	A376/TP316	44500	81400
	A376/TP316	43900	89800
	A376/TP316	44500	81400
	A376/TP316	44500	81400
	A376/TP316	44500	81400
	A376/TP316	44500	81400
	A376/TP316	43900	89800
	A376/TP316	44500	81400
	A376/TP316	38100	82600
	A376/TP316	43900	89800
	A376/TP316	44100	88600
	A376/TP316	43300	87800
	A376/TP316	43900	89800
	A376/TP316	43300	87800
	A376/TP316	44500	81400
	A376/TP316	44500	81400
	A376/TP316	40500	84600
	A376/TP316	43800	89800
	A376/TP316	44500	81400
	A376/TP316	44500	81400
	A376/TP316	44500	81400
	A376/TP316	44500	81400
	A376/TP316	44500	81400
Total 169 Heats	Average	45228.70	84704.73
Average Flow stress=	(45228.70+84704.73)/2=	64967 psi	
ASME Code Flow stress=	(30000+75000)/2=	52500 psi	
Ratio of flow stresses=	64967/52500=	1.237	

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 3.7.1.5-1 (Revision 1)

Original RAI Number(s): 241.001

Summary of Issue:

In Section 2.0, "Site Characteristics," and DCD Tier 2 Table 2-1, the applicant specified that the COL applicant will use the following design site-parameters to confirm the adequacy of the AP1000 seismic design for a specific site:

- The site-specific ground motion response spectra, defined at the foundation level, are bounded by the proposed design response spectra (the modified RG 1.60 ground response spectra) anchored to 0.3g as shown in DCD Tier 2 Figures 3.7.1-1 and 3.7.1-2.
- No potential for fault displacement is expected at the site.
- No liquefaction is expected at the site.
- The average allowable static bearing capacity is greater or equal to 402 kPa (8,400 psf) over the foot print of the NI at its excavation depth. The allowable bearing capacity under static plus dynamic loads exceeds 4,070 kPa (85,000 psf).
- The minimum shear wave velocity of the rock foundation is equal to or greater than 8,000 ft/sec.

Based on its review experience of other advanced reactors such as ABWR, System 80$^+$ and AP600, the staff concludes that the above design site-parameters are reasonable and acceptable bounding limits for the COL applicant to use in confirming the adequacy of the AP1000 seismic design, except for the definition for the average allowable static bearing capacity for the hard rock site.

The staff requested the applicant to clarify whether this term refers to allowable strength or allowable displacement of the foundation. In its response to RAI 241.001, the applicant stated that the design will be acceptable for a hard rock site that has an allowable bearing capacity of 450 kips per square foot. The staff's review experience indicates that this is an extremely high value of "allow bearing capacity," that is difficult for the COL applicant to substantiate. Also, the response still did not clarify whether this definition refers to strength or displacement considerations. In addition, the review of the Civil/Structural Criteria document performed by the staff during the November 12 through 15, 2002, audit indicated that hard crystalline bedrock should have an allowable bearing capacity of four (4) kips per square foot. The definition of allowable bearing capacity for the hard rock site must also account for the influence of bedding direction, level of cracking and other discontinuities in the rock material which can serve to limit bearing capacity. These discrepancies need to be clarified by the applicant. The staff identified this as Open Item 3.7.1.5-1.

In a telephone call on August 22, 2003, NRC requested additional clarification of the "allowable" bearing pressure.

Westinghouse Response (Revision 1):

Additional information was provided in RAI 241.001 Response Revision 1 transmitted by Westinghouse letter DCP/NRC1557, dated March 26, 2003.

Additional clarification of the "allowable" bearing pressure has been provided in the response revision 1 to DSER Open Item 2.5.4.2.

Design Control Document (DCD) Revision:

None

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 3.7.2.16-1 (Revision 1)

Original RAI Number(s): None

Summary of Issue:

The seismic design basis earthquake for the AP1000 structures, systems, and components are essentially defined at the plant grade level in the free field by an SSE with the peak acceleration of 0.3g and the ground response spectra shown in DCD Tier 2 Figures 3.7.1-1 and 3.7.1-2. The seismic design of the NI features (structures including basemat, systems, and components) is predicated on the limitation of constructing the AP1000 at hard rock sites with shear wave velocity equal to 2438 m/sec (8,000 fps) or higher. If these design bases are not satisfied (i.e., the site condition is not within the range of site conditions specified in the DCD) or if the seismic analysis responses used for the design do not envelop the results obtained from a potential plant's site conditions other than the hard rock sites, the basis established for the design certification will no longer apply. The applicant should commit in the DCD (similar to the AP600 DCD) that the COL applicants should perform an analysis and an evaluation using the design basis earthquake ground motion and plant-specific site conditions to confirm the design adequacy of the AP1000 design. This is COL Action Item 3.7.2.16-1 and Open Item 3.7.2.16-1.

In the telephone call on August 22, 2003, the NRC noted that additional guidance should also be provided for the evaluation of the nuclear island basemat.

Westinghouse Response (Revision 1):

The DCD is being revised similar to the AP600 DCD so that the COL applicants may perform an analysis and an evaluation using the site specific earthquake ground motion and site conditions to confirm the design adequacy of the AP1000 design.

Additional guidance has been provided for the evaluation nuclear island basemat as shown in the Response Revision 1 to DSER Open Item 2.5.4-2.

Design Control Document (DCD) Revision:

The following will be incorporated in the next revision of the DCD **(this was included in Revision 7).**

2.5.2.3 Sites With Geoscience Parameters Outside the Certified Design

If the site specific spectra at foundation level exceed the response spectra in Figures 3.7.1-1 and 3.7.1-2 at any frequency, or if soil conditions are outside the range evaluated for AP1000 design certification, a site specific evaluation can be performed. This evaluation will consist of a site-specific dynamic analysis and generation of in-structure response spectra to be compared with the floor response spectra of the certified design at 5 percent damping. The site design response spectra at the

foundation level in the free-field given in Figures 3.7.1-1 and 3.7.1-2 were used to develop the floor response spectra. The site is acceptable for construction of the AP1000 if the floor response spectra from the site-specific evaluation do not exceed the AP1000 spectra for each of the locations identified below.

- Reactor vessel support — Figure 3.7.2-17, Sheets 1-3
- Containment operating floor — Figure 3.7.2-17, Sheets 4-6
- Coupled auxiliary and shield building at control room floor — Figure 3.7.2-15, Sheets 1-3
- Coupled auxiliary and shield building at fuel building roof — Figure 3.7.2-15, Sheets 4-6
- Coupled auxiliary and shield building at shield building roof — Figure 3.7.2-15, Sheets 13-15
- Steel containment vessel at polar crane support — Figure 3.7.2-16, Sheets 1-3

Site-specific soil structure interaction analyses must be performed by the Combined License applicant to demonstrate acceptability of sites that have seismic and soil characteristics outside of the site parameters in Table 2-1. These analyses would use the site specific soil conditions (including variation in soil properties in accordance with Standard Review Plan 3.7.2). The three components of the site specific ground motion time history must satisfy the enveloping criteria of Standard Review Plan 3.7.1 for the response spectrum for damping values of 2, 3, 4, 5 and 7 percent and the enveloping criterion for power spectral density function. Floor response spectra determined from the site specific analyses should be compared against the design basis of the AP1000 described above. These evaluations and comparisons will be provided and reviewed as part of the Combined License application.

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 3.8.4.3-1 (Revision 1)

Original RAI Number(s): 220.015

Summary of Issue:

The applicant referenced DCD Tier 2 Figure 3D.5-9 in its response to RAI 220.015; however, it does not appear to have considered the effect of rapid increase in compartment temperature. Based on its review of the selected calculations, the staff could not reach a conclusion that the applicant has adequately addressed the effects of thermal transients on concrete filled steel modules. The analysis approach for the thermal transient inside the IRWST is discussed in Subsection 3.8.3.3 of this report, and has been found to be acceptable. However, for subcompartment locations inside containment (other than the IRWST) and locations outside containment, rapid heat-up of the steel plate of the structural wall modules must be considered in the analysis and design of the structural wall module. The concern is that for a rapid temperature transient, the mismatch in thermal conductivity between the steel faceplate and the concrete could impose significant thermal stresses on the faceplate, studs, and concrete core. This could potentially result in degradation of the faceplate/concrete bond and invalidate the assumption of composite behavior. The applicant needs to evaluate the thermal transients that can occur in the various subcompartments, and demonstrate that no unacceptable degradation would result from differential thermal expansion of the steel and concrete throughout the entire transient. This is Open Item 3.8.4.3-1.

During the telephone call on August 22, 2003, NRC requested confirmation that SS surfaces were also evaluated and requested that the evaluation be described in the DCD.

Westinghouse Response (Revision 1):

The effects of temperature transients resulting from postulated breaks have been evaluated. Temperatures are used from the containment analyses described in DCD Subsection 6.2.1.1.3. These analyses provide both subcompartment atmospheric temperatures and through wall temperatures in the heat sinks based on one dimensional heat flow. The structures are evaluated for the through wall temperature profile at critical times during the transient.

This response evaluates the initial part of accident thermal transients inside containment and demonstrates that the shear studs, and concrete within the Containment Internal Structure (CIS) structural modules retain their structural integrity. The structural modules outside containment are not subject to rapid thermal transients.

Thermal Transient

Structural modules are subjected to a rapid temperature transient in the event of a loss of coolant accident (LOCA) or a main steam line break (MSLB). The steel plate of the structural modules heats up most rapidly in the LOCA event. DCD Figure 6.2.1.1-6 shows the containment temperature response for the double ended cold leg break. Figure 3.8.4.3-1-1

shows the temperature distributions in the surface zone of the 30" thick structural module wall during the initial part (2000 seconds) of this LOCA transient. The relative distance shown on this plot is the ratio of the depth to the full thickness of the wall so the ½" thick plate is a relative distance of 1/60 = 0.0167. These curves show that there are high differential thermal gradients. The initial conditions in this thermal analysis are assumed to be 120 °F. Temperatures as high as 270°F are obtained in the first few minutes. The heat up of the plate would be slower but reach similar magnitudes for initial temperatures of the wall of 50 °F. The faceplate of a structural module may see differential temperatures ranging from 140°F to 220°F (based on an ambient temperature of 50°F). The concrete heats up more slowly and does not see a significant temperature increase during this early part of the transient. This results in relative thermal expansion of the faceplate, causing shear loads in the shear studs and embedded angles of the structural steel trusses that are welded to the faceplate. It also causes cracking of the concrete once the forces in the steel plate exceed the tensile strength of the concrete wall.

Structural Module

The structural modules in the containment internal structures (CIS) are described in the Design Control Document, Section 3.8.3.1. Two materials are used for the faceplates: (1) A36; and (2) Nitronic 33, ASTM A240 Type XM-29 UNS designation S2400. Shear studs on A 36 faceplates are ¾-inch diameter, 6 inches long, spaced at 10 inches each way. Shear studs on Nitronic 33 plates are the same size, spaced 10 inches horizontally and 8 inches vertically. The faceplate thickness is ½ inch.

The thermal growth of the faceplate on the structural modules is primarily uniaxial due to the restraint from the adjacent walls, floors, and ceilings. The configuration of the structural modules is shown in DCD Figure 3.8.3-1. The surface plates of the rooms (see DCD Figures 1.2-6 and 1.2-7) formed by the structural modules are as follows:

- Refueling Cavity – The faceplates are stainless steel. The adjacent walls restrain them horizontally. They are free to grow upwards.
- IRWST – The faceplates are stainless steel. The faceplates are not subject to heat up during the initial stages of the LOCA transient since the IRWST is full of water.
- Steam Generator and Pressurizer Compartments – The faceplates are carbon steel. The adjacent walls restrain them horizontally. They are free to grow upwards.
- Maintenance floor and vertical access – The faceplates are carbon steel. The adjacent walls restrain the approximately 90 degree corners horizontally. Embedded steel box columns assist the shear studs in providing horizontal restraint at the approximately 270 degree corners. The operating or maintenance floors restrain them vertically.
- CVS room – The faceplates are carbon steel. The adjacent walls restrain them horizontally. The maintenance floor restrains them vertically.

- Reactor vessel cavity – The faceplates are stainless steel. The adjacent walls restrain them horizontally. They are free to grow upwards.

The thermal evaluation shows that the fully restrained surface plates yield in compression when the temperature differential between the surface plate and concrete exceeds about 170°F. In regions where the walls are able to expand, the restrained growth of the surface plate loads the shear studs, which load the concrete in tension. This tension is sufficient to crack the concrete thereby reducing the stress in the surface plate and the loads on the shear studs. The maximum loads on the shear connectors occur in edge regions of the plate at locations where the concrete is restrained such that the wall may not crack. This restraint of horizontal growth of the concrete in the structural module wall occurs close to the bottom of the structural module where the thick basemat is slow to heat up and does not crack. It may also occur at locations above and below the floors where there is additional horizontal restraint provided by the floors. This case is evaluated using a uniaxial strip model of the steel plate and studs with the assumption of full restraint for the concrete.

Uniaxial Strip Model

The uniaxial strip plate shown in Figure 3.8.4.3-1-2 represents a single row of shear studs in either the horizontal or vertical direction. A typical wall is considered with a length or height of 30'. Similar uniaxial models were evaluated for the AP600. The AP600 evaluation used a continuum representation of the shear studs to evaluate the interface between the steel plate, studs and concrete. The AP1000 evaluation uses a discrete representation of each shear stud.

The formulation for the AP1000 thermal evaluation is given in Figure 3.8.4.3-1-3. The load in the shear stud is determined from a non-linear shear stud load-deflection curve based on Ollgaard and Slutter 1971 tests (Reference 3.8.4.3-1-1) as shown in Figure 3.8.4.3-1-4. The shear stud can transmit a peak load (24 kips) to the concrete even if there is localized deformation and crushing of the concrete in the vicinity of the shear stud. The test results show continued load capacity at deflections above 0.10 inches. This deflection of 0.1" is chosen as a representative limit for the evaluation. The force in a shear stud (F_i) and its displacement is a function of the axial stiffness of the plate (AE/L_k), the net force in the plate at stud location i, and the movement of the plate caused by the forces in the shear studs below the stud at location i.

The force in the central portion of the plate (F_{PL}) is limited by its yield stress. The maximum load that the shear studs must restrain is that corresponding to yield of the plate. The most critical thermal case is the one associated with a faceplate temperature of 240°F for both the carbon steel and stainless steel plates. Lower faceplate temperatures will not stress the faceplate to yield; higher faceplate temperatures will reduce the yield stress and hence the axial load that the shear studs must resist.

The shear stud load and deflections calculated using the uniaxial model for the carbon steel plate are shown in Figure 3.8.4.3-1-5. Figure 3.8.4.3-1-6 shows the stress in the faceplate when the surface plate is heated to 240°F during the initial part of the thermal transient. The maximum stress reaches yield in the central region of the plate. The maximum deflection in the shear stud (near the edge of the plate) is 0.057" (0.075" for the stainless steel plate) and is less

than the established maximum limit of 0.1". The effective load length of the shear studs on the carbon steel plate that act to restrain the plate is 7 ½'. This is consistent with the design criterion used for the stud spacing that required that the studs over a length of 7.5 feet be capable of developing yield in the plate.

Mechanical loads

Dead and live loads that could occur during the thermal transient are not significant. Loads due to the safe shutdown earthquake are also small. The combination of the safe shutdown earthquake and thermal transient would have an extremely low probability since it is an independent event occurring during the few minutes after the LOCA when the maximum difference in temperature occurs between the steel surface plate and the concrete. Mechanical loads on the studs would not occur in the direction of free growth. They may occur in the direction normal to the free growth. These loads are small relative to those due to the thermal growth in the other direction and the biaxial loading would be acceptable.

Conclusion

The heat up of the surface plates during the initial portion of the LOCA transient results in cracking of the concrete walls except in regions where there is significant external restraint. This cracking reduces the stresses in the surface plates and the loads on the shear studs relative to the cases where there is significant external restraint. The cracking of the concrete does not cause degradation of the structural integrity of the wall.

In regions where there is significant external restraint, the structural module faceplates are restrained so that their thermal growth is uniaxial. This evaluation, using the uniaxial model with no growth of the concrete, demonstrates that the design is acceptable for the AP1000 thermal transients. Portions of the plate away from a free edge will reach yield. There are no shear loads on the studs in this central portion. The shear studs on the portions of the plate near the edge do not exceed the maximum deflection capacity. Loads in the plate and studs will be lower if there is also thermal growth of the concrete or if there is cracking.

References

3.8.4.3-1-1 Ollgaard, Jorgen, Roger Slutter, John Fisher, "Shear Strength of Stud Connectors in Lightweight and Normal-Weight Concrete," AISC Engineering Journal, April 1971.

Design Control Document (DCD) Revision:

In response to the comment on the Revision 0 response to this open item, the following paragraph will be added after the first paragraph of subsection 3.8.3.4.3:

The structural modules are subject to a rapid temperature transient in the event of a loss of coolant accident (LOCA) or a main steam line break (MSLB). The structural modules were evaluated for these rapid temperature transients. The evaluation considered both

carbon and stainless steel faceplates. The steel plate heats up most rapidly in the LOCA event with temperatures up to 270°F in the first few minutes. The faceplate of the structural module will see differential temperatures relative to the concrete ranging from 140°F to 220°F (based on an ambient temperature of 50°F). The concrete heats up more slowly and does not see a significant temperature increase during the early part of the transient. There is relative thermal growth of the faceplate, causing shear loads in the shear studs, and embedded angles of the structural steel trusses that are welded to the faceplate. The heat up of the surface plates during the initial portion of the LOCA transient results in cracking of the concrete walls except in regions where there is significant external restraint. The structural module maintains its integrity throughout the rapid thermal transient.

PRA Revision:

None

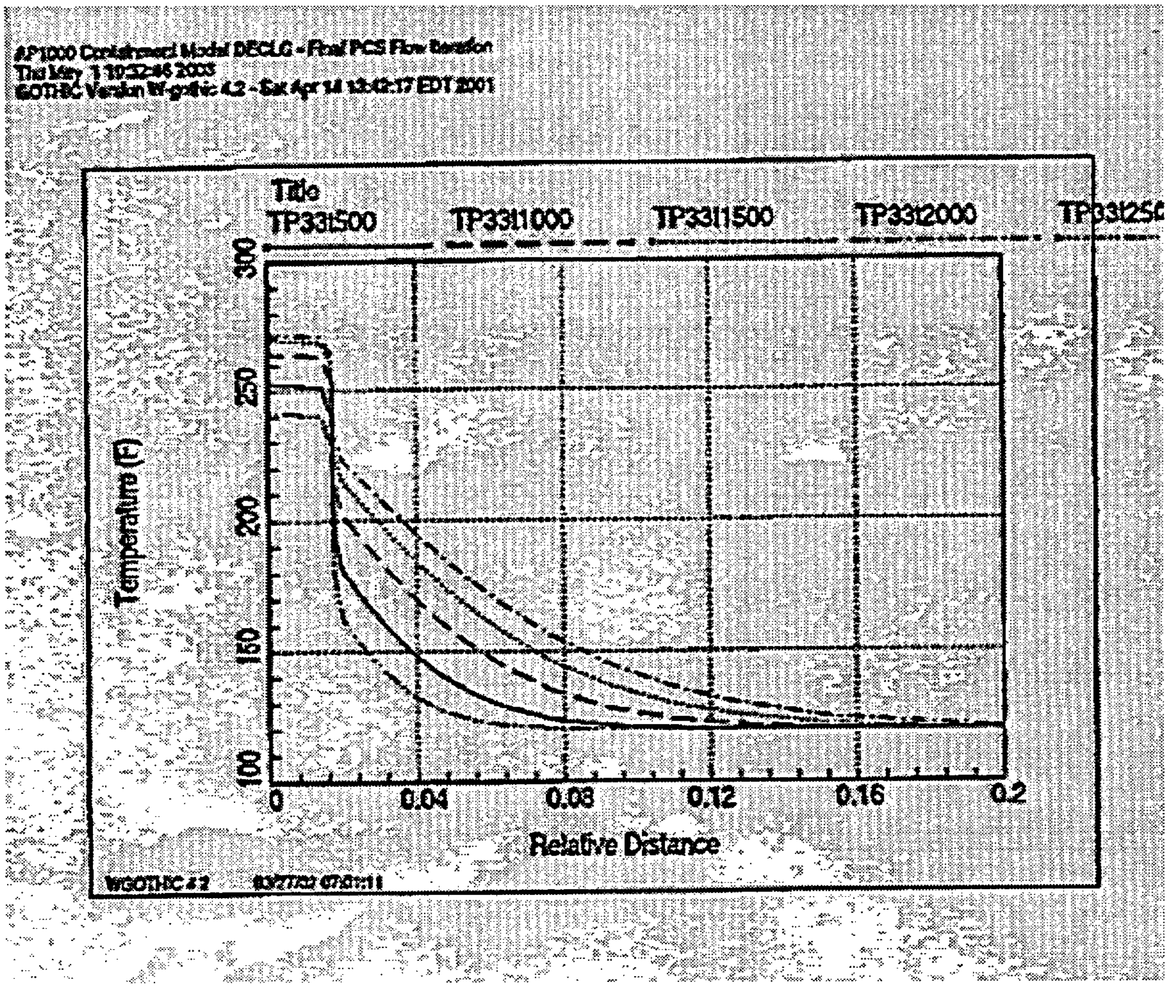


Figure 3.8.4.3-1- 1 – Temperature Profiles in Structural Module Wall During Initial Part of Thermal Transients

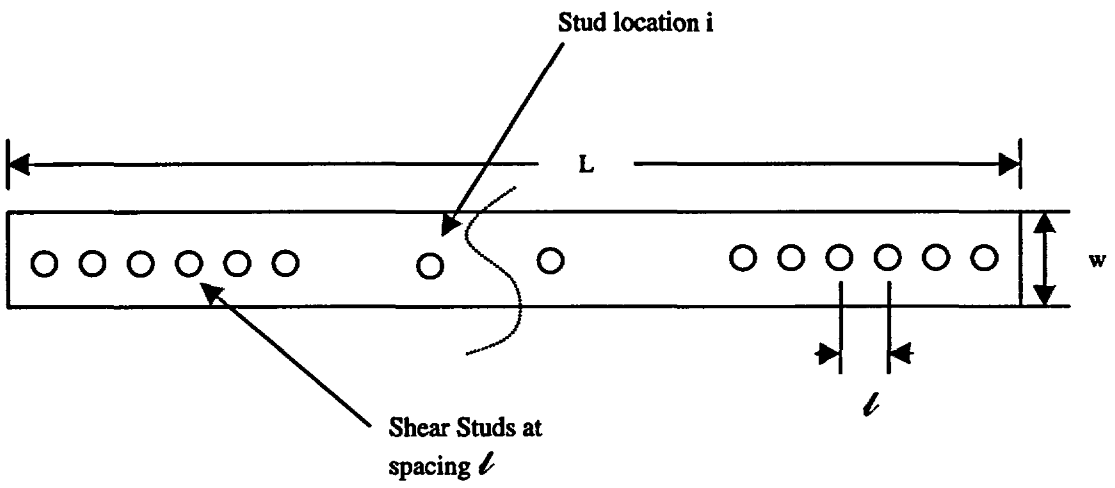
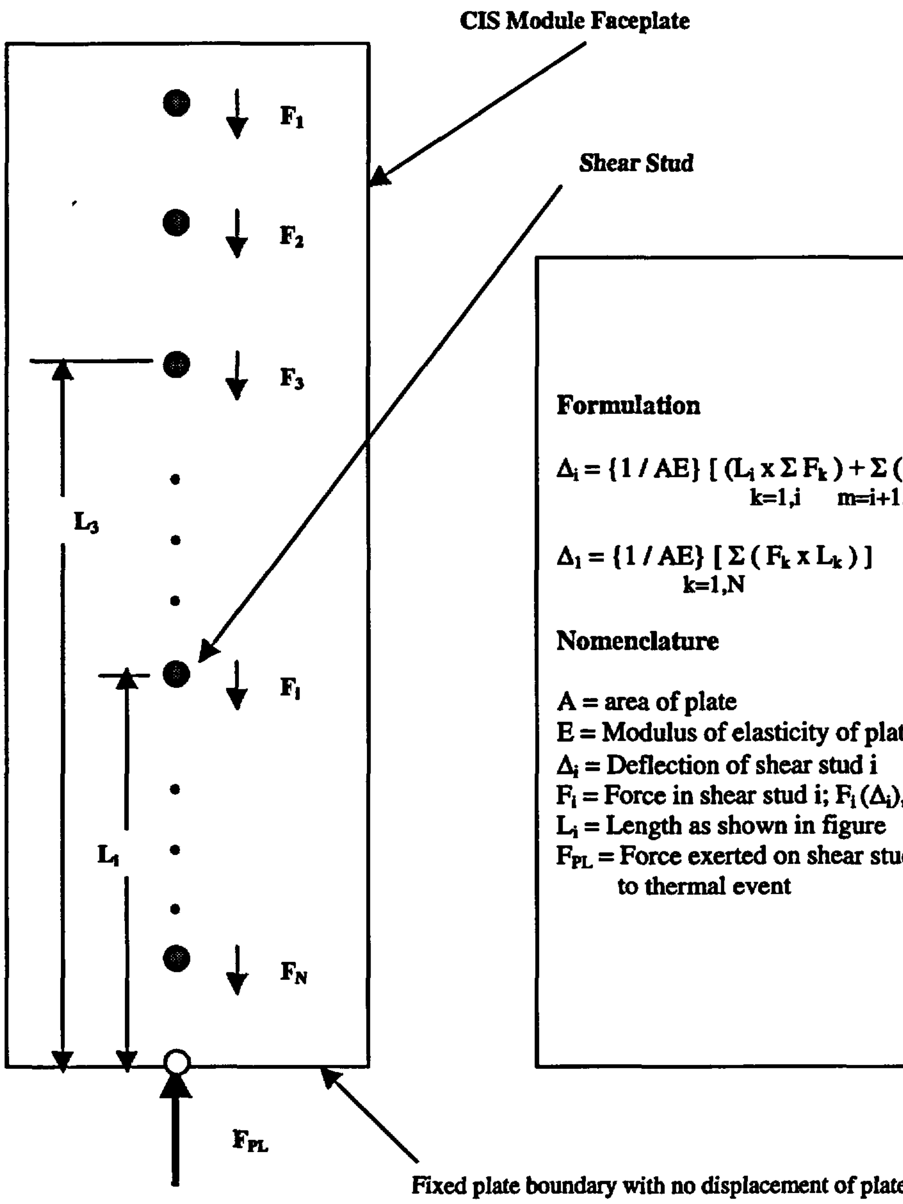


Figure 3.8.4.3-1- 2 – Uniaxial Strip Plate



Formulation

$$\Delta_i = \{1 / AE\} \left[\left(L_i \times \sum_{k=1,i} F_k\right) + \sum_{m=i+1,N} \left(F_m \times L_m \right) \right]$$

$$\Delta_1 = \{1 / AE\} \left[\sum_{k=1,N} \left(F_k \times L_k \right) \right]$$

Nomenclature

A = area of plate
E = Modulus of elasticity of plate
Δ_i = Deflection of shear stud i
F_i = Force in shear stud i; $F_i(\Delta_i)$, see Figure 220.015-4
L_i = Length as shown in figure
F_{PL} = Force exerted on shear studs from plate due to thermal event

F_N is defined so that the plate maximum stress is not exceeded (e.g., plate yield stress)

Figure 3.8.4.3-1- 3 – Thermal Displacement Mathematical Formulations

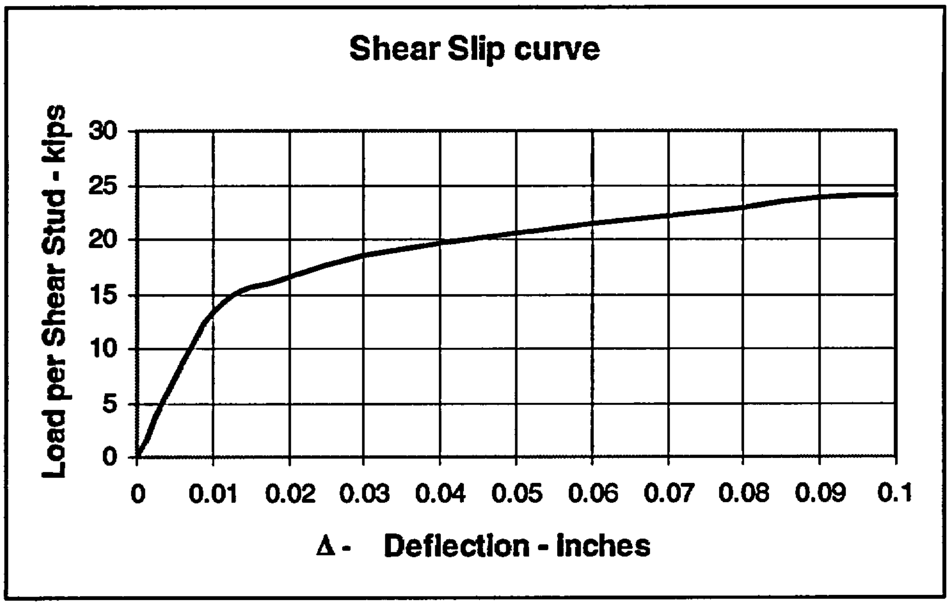


Figure 3.8.4.3-1- 4 – Shear Stud Load Deflection Curve

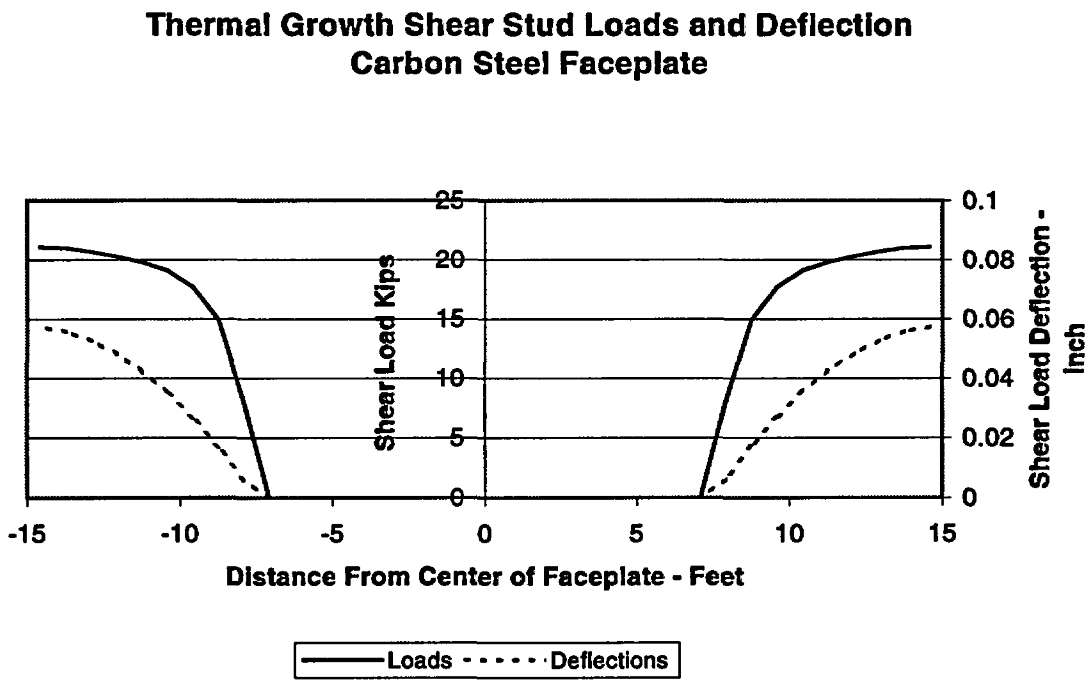


Figure 3.8.4.3-1- 5 – Thermal Growth Shear Stud Loads

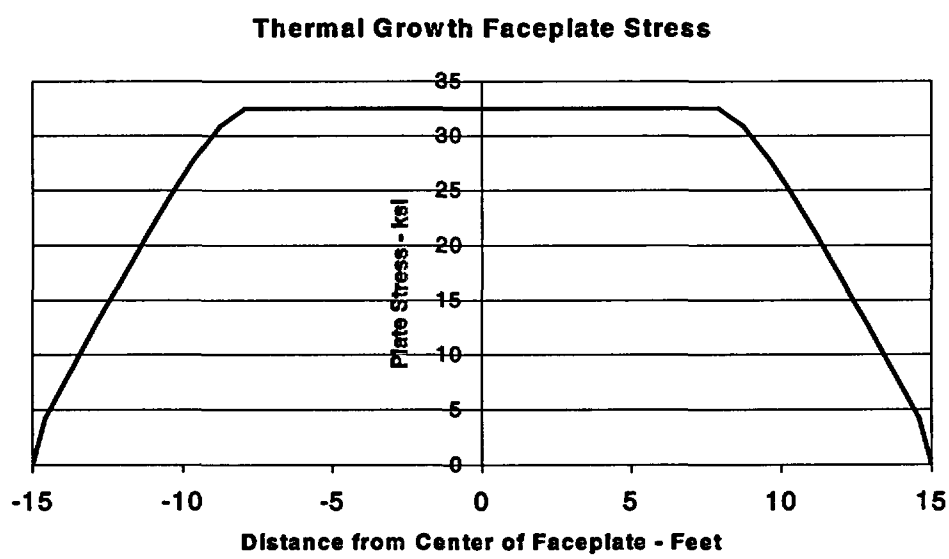


Figure 3.8.4.3-1- 6 – Thermal Growth Faceplate Stress

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: **3.8.4.5-2 (Revision 1)**

Original RAI Number(s): None (April 3, 2003, meeting summary)

Summary of Issue:

During the course of its review of the Wall 7.3 design calculation, the staff noted that the applicant had previously identified and corrected an error in the equation used by INITEC to calculate the required positive reinforcement for a section subjected to both bending moment and axial load. The staff could not conclude during the audit that the corrected equation accurately calculates required positive reinforcement. Therefore, the applicant was requested to submit the derivation of the equation currently used to calculate the required reinforcement. The applicant was also requested to submit a sample verification calculation for the computer algorithm, and verify that the corrected equation has been utilized in all calculations. This is Open Item 3.8.4.5-2.

NRC discussion during telephone call on August 22, 2003

The Revision 0 response only showed development of equation for one case (axial plus bending with both tension and compression steel at yield). Clarify how range of applicability is checked and what other cases are used in the macro or explain how design engineer is told that the case is out of range of applicability.

Westinghouse Response:

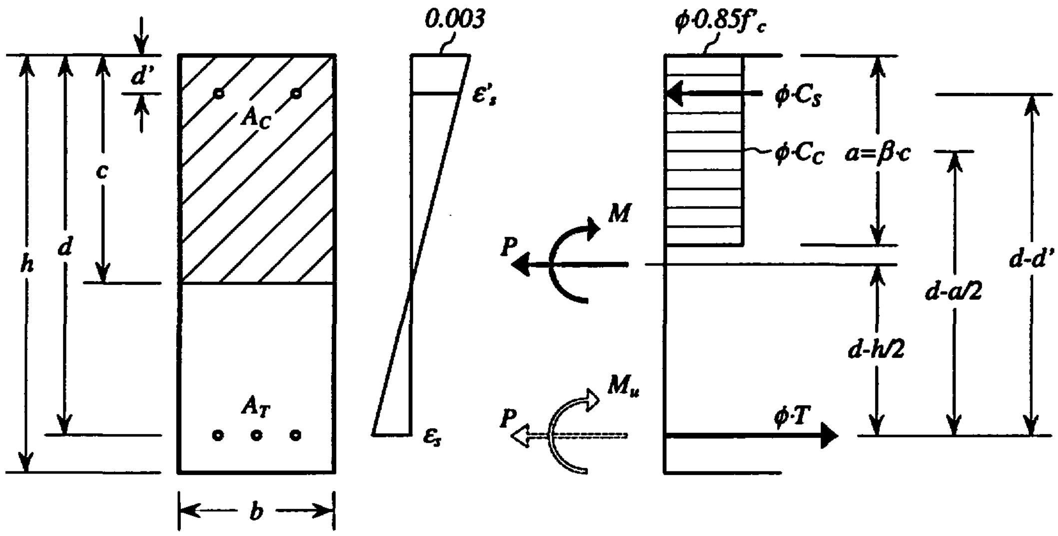
The development of the equation for sizing the required reinforcement for a section subject to bending moment and axial load is shown in this response. This equation is applicable when the strength of the section is controlled by yielding of the tension steel and both tension and compression steel, if any, are at yield. Loads and internal forces are shown in the following figures. The design loads P and M act at the centroid of the section, where:

P = Design Axial Load (P is positive in tension)
M = Design Moment

These loads are then converted to loads P and M_u relative to the plane of tension reinforcement.

The strength reduction factor ϕ is applied to both the steel and concrete strengths to obtain the design strength as shown in the figures.

Compression reinforcement is calculated such that the portion of tension reinforcement not equalized by compression reinforcement ($A_T - A_C$) does not exceed 75% of the A_b that would produce balanced strain conditions.



Transfer design loads P and M to the plane of tension reinforcement as P and M_u:

$$M_u \equiv M - P\left(d - \frac{h}{2}\right) \tag{1}$$

From equilibrium of forces and moments:

$$T = C_C + C_S + \frac{P}{\phi} \tag{2}$$

$$M_u = \phi \cdot C_C \left(d - \frac{a}{2}\right) + \phi \cdot C_S (d - d') \tag{3}$$

Where, the concrete stress block is defined in 10.2.7 of ACI 349 as follows:

$$C_C = b \cdot \beta \cdot c \cdot 0.85 f'_c \tag{4}$$

$$\beta = 0.85 \qquad (\because f'_c \leq 4000 psi) \tag{5}$$

For tension controlled failure with both tension and compression reinforcement strain at or greater than yield:

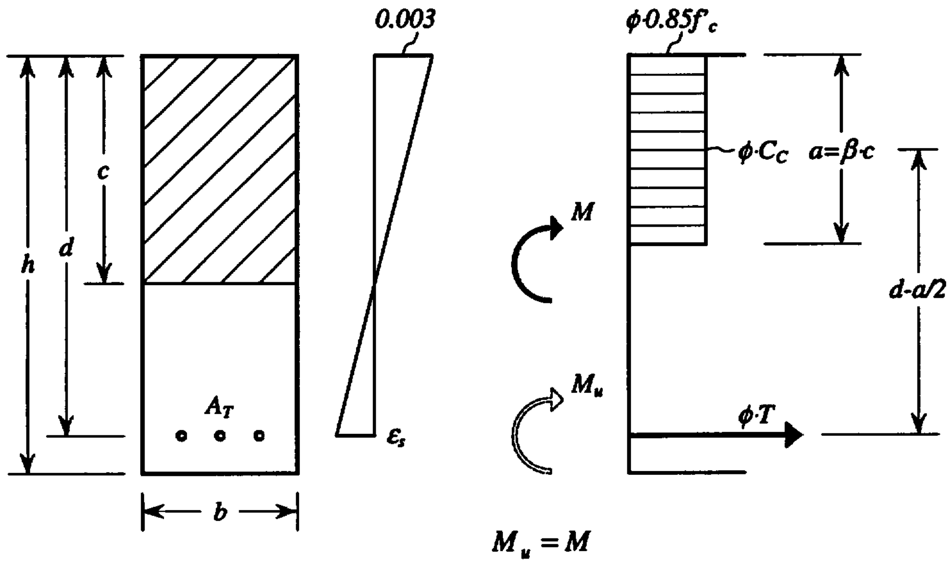
$$T = A_T \cdot f_y \tag{6}$$

$$C_S = A_C \cdot f_y \tag{7}$$

From equations (2), (6) and (7), the required reinforcement is given as follows:

$$A_T = \frac{C_C}{f_y} + A_C + \frac{P}{\phi \cdot f_y} \tag{8}$$

The third term on the right side can be calculated directly. The other terms are calculated to satisfy the limit of 75% of balanced strain conditions as described below:



From equilibrium of forces and moments:

$$T = C_C \tag{9}$$

$$M_u = \phi \cdot C_C\left(d - \frac{a}{2}\right) \tag{10}$$

From equations (4), (6) and (9):

$$A_T = \frac{b \cdot \beta \cdot c \cdot 0.85 f'_c}{f_y} \tag{11}$$

From equation (4):

$$a = \beta \cdot c = \frac{C_C}{b \cdot 0.85 f'_c} \tag{12}$$

From equations (6), (9), (10) and (12):

$$M_u = \phi \cdot C_C \left(d - \frac{C_C}{2 \cdot b \cdot 0.85 f'_c} \right) = \phi \cdot A_T \cdot f_y \left(d - \frac{A_T \cdot f_y}{2 \cdot b \cdot 0.85 f'_c} \right) \qquad (13)$$

In the balanced strain condition, the neutral axis is calculated as follows:

$$\frac{c_b}{d} = \frac{0.003}{0.003 + f_y / E_s} = \frac{87000}{87000 + f_y} \qquad (14)$$

Substituting the above c_b for c in equation (11), the balanced tensile steel A_b is given as follows:

$$A_b = \frac{b \cdot \beta \cdot 0.85 f'_c}{f_y} \cdot \frac{87000}{87000 + f_y} \cdot d \qquad (15)$$

If M_u requires more reinforcement than 75% of A_b, compression reinforcement A_C is needed as 10.3.3 of ACI 349. Define M_{75} corresponding to 75% of balanced conditions as equation (13):

$$M_{75} \equiv \phi \cdot 0.75 A_b \cdot f_y \left(d - \frac{0.75 A_b \cdot f_y}{2 \cdot b \cdot 0.85 f'_c} \right) \qquad (16)$$

The area of required reinforcement is calculated using the moment M_{75} as follows:

1) $M_u \leq M_{75}$ (thus, compression reinforcement A_C is not required)

Solving equation (13) for C_C:

$$\frac{C_C}{f_y} = \frac{0.85 f'_c}{f_y} \left\{ 1 - \sqrt{1 - \frac{2 \cdot M_u}{\phi \cdot b \cdot d^2 \cdot 0.85 f'_c}} \right\} \cdot b \cdot d \qquad (17)$$

2) $M_u > M_{75}$ (thus, compression reinforcement A_C is required)

$$\frac{C_C}{f_y} = 0.75 A_b \qquad (18)$$

$$M_u - M_{75} = \phi \cdot C_S (d - d') \qquad (19)$$

From equation (7) and (19):

$$A_c = \frac{M_u - M_{75}}{\phi \cdot f_y (d - d')} \tag{20}$$

The equation has been verified against the following sample problems in the ACI Design Handbook (ACI 340.1R-91):

ACI Design Handbook		This Equation	Ratio
Flexure Example	A_S (in^2)	A_T (in^2)	A_T / A_S
3	1.11	1.10	0.99
10	17.7	18.0	1.02
17	1.84	1.84	1.00

- Flexure Example 3 – Determination of tension reinforcement area for rectangular beam subject to small axial load; no compression reinforcement
- Flexure Example 10 – Design of rectangular beam subject to simple bending; compression reinforcement found to be required
- Flexure Example 17 – Determination of tension reinforcement area for rectangular beam subject to bending and axial tensile load; top fiber found to be in compression

The corrected equation as developed herein has been used in all AP1000 calculations of reinforcement using the ANSYS post processors and EXCEL macros.

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Westinghouse Response (Revision 1):

The macro is intended for design of reinforcement in walls and slabs where the strength of the section is controlled by yield of the reinforcement in tension. It calculates the required reinforcement for axial plus bending. One case covers reinforcement on one face in tension with the other face in compression. The other case covers both faces of reinforcement in tension. The macro is not intended or used for design of reinforcement in columns where the strength of the section may be controlled by concrete compression. The documentation states the macros "... are not applicable to walls or columns that are in compression across the complete section".

Additional guidance is being provided to the engineer to confirm the design as described below.

Figure 3.8.4.5-2-1 shows a typical interaction diagram defining the strength of a concrete section under combined axial force (P) and bending moment (M). It shows the nominal strength interaction as well as a simplified nominal interaction based on straight lines connecting the following key points:

- Pure Compression (P_o)
- Balanced Strain Condition (P_b, M_b)
- Pure Flexure (M_n)
- Pure Tension (P_t)

The simplified design interaction diagram is also shown. This is obtained by applying the code specified strength reduction factor (ϕ) to the simplified nominal strength diagram.

The nominal axial load strength at balanced strain conditions, P_b, provides a convenient division point between compression and tension failures (Ferguson "Reinforced Concrete Fundamentals"). This strength is based on the reinforcement provided. When the nominal axial compressive forces are less than P_b, the tension reinforcement is at yield and the compression reinforcement is at or close to yield. Hence the results of the macro are accurate for design axial member forces less than P_b. The macro is used for multiple load combinations and the controlling cases for reinforcement demand are those with axial tension (or smallest compression).

Guidance is being provided to the engineer to perform an additional check when the axial compressive forces are greater than ϕP_b. In this additional check the axial load-moment interaction diagram is calculated for the reinforcement that has been selected based on use of the macro. Combinations of design moments with axial forces greater than ϕP_b are reviewed and confirmed to be bounded by the interaction diagram.

The ACI code imposes a maximum reinforcement limit of 0.08 times the gross area of the section for compression members. There is no maximum limit on members subject to combined flexure and low axial load since ductility is assured by limiting the reinforcement to 75% of the balanced reinforcement ratio. Typical quantities of reinforcement in the AP1000 design are well below the 8% maximum permitted by the code for compression members. For example, the

maximum reinforcement ratio in the cylindrical shield wall is less than 5% (10.74 sq.in/ft on each face).

Design Control Document (DCD) Revision:

None

PRA Revision:

None

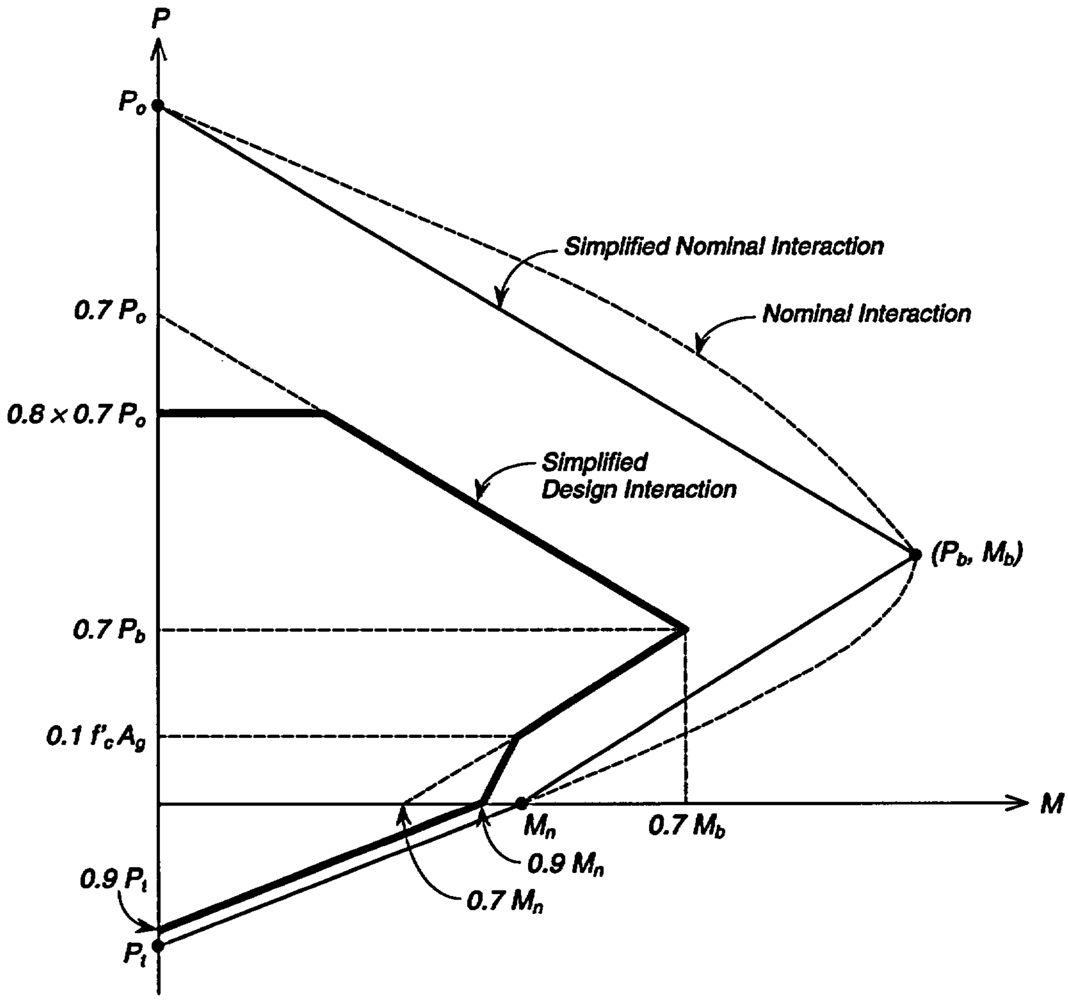


Figure 3.8.4.5-2-1
Axial Load-Moment Interaction Diagram

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 3.8.5.1-1 (Revision 1)

Original RAI Number(s): 230.23

Summary of Issue:

In DCD Tier 2 Section 3.8.5.1, the applicant states that the foundation is built on a mud mat, for ease of construction. The mud mat is lean, nonstructural concrete and rests upon the load-bearing rock. Waterproofing standards are described in DCD Tier 2 Section 3.4.1.1.1. In RAI 230.23, the staff raised a question that the non-structural concrete mud mat cannot withstand the very high toe pressure predicted in the applicant's seismic analysis. This may crush the non structural concrete mud mat and potentially affects the safety of the NI foundation mat under design basis combination of loads. Since the applicant did not provide a response to the RAI, this issue is designated as Open Item 3.8.5.1-1.

In the telephone call on August 22, 2003, the NRC requested inclusion of the functional requirements for the mud mat in the DCD.

Westinghouse Response (Revision 1):

Additional information was provided in the RAI 230.023 Response transmitted by Westinghouse letter DCP/NRC1588, dated May 13, 2003.

The mud mat is a thin layer of lean, nonstructural concrete sandwiched between the rock and the underside of the basemat. Lean concrete in this confined condition will be capable of withstanding the high toe pressures conservatively predicted in the Westinghouse liftoff analysis. The DCD is being revised as shown below so that the Combined License applicant submits information demonstrating that the design of the mudmat will withstand the structural loads.

Design Control Document (DCD) Revision:

Revise last two sentences of subsection 2.5.4.6.3 as follows:

Information will also be provided on the waterproofing system along the vertical face and the mudmat. Information will be provided on the mudmat to demonstrate its ability to resist the structural bearing and shear loads **described in subsection 2.5.4.2. The maximum bearing pressure is 830 psi. The mudmat may be designed as structural plain concrete in accordance with ACI 318-02 (Reference 1). This requires the specified concrete compressive strength to be no less than 2500 psi. The commentary states this requirement is imposed in the code because "lean concrete mixtures may not produce adequately homogeneous material or well formed surfaces". If the Combined License applicant proposes to use a concrete with strength less than 2500 psi, he shall demonstrate that the mix will result in an acceptable homogeneous material.**

Add section 2.6 References

2.6 References

1. American Concrete Institute (ACI), Building Code Requirements for Structural Concrete, ACI-318-02

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 19A.3-3 (Revision 2)

Original RAI Number(s): n/a

Summary of Issue:

EQ-SLOCA: The applicant included a number of elements of seismic fragility in this group. These elements include, simultaneous failure of all small diameter instrument lines, steam generator tube rupture, and large steam line breaks. Steam generator tube rupture event considers up to 5 simultaneous tube ruptures. The EQ-SLOCA grouping appears reasonable. However it is not clear if the applicant considered degradation of steam generator tubes under the full service life of steam generators for developing the seismic fragility. The applicant should explain how service related degradation of steam generator tubes was considered in the development of the HCLPF value of this group. This is Open Item IQA.3-3.

NRC Follow-On Comments:

When considering the steam generator tube rupture event, why were 5 simultaneous tube ruptures considered?
In telephone call on August 22, 2003, NRC requested that the material in the Revision 0 and Revision 1 responses be combined in a single response.~~Put back in response the portion removed In Revision 1.~~

Westinghouse Response (Revision 2):

Five simultaneous tube ruptures were considered consistent with common PRA practices. Further, Westinghouse uses the upper limit of five simultaneous steam generator ruptures consistent with the Commission and staff position as set forth in SECY –93-087 under 19.II.R.1, Multiple Steam Generator Tube Ruptures:

> **"The Commission approves the staff's position to require that analysis of multiple steam generator tube ruptures (STGRs) involving two to five steam generator tubes be included in the application for design certification for the passive PWRs. The Commission understands that, as discussed in the Commission meeting on this SECY [?] paper, since the steam generator multi-tube rupture event is beyond the design basis requirements for PWRs, realistic or best-estimate analytical assumptions may be used to assess plant response."**

Degradation of steam generator tubes under the full service life of steam generators was not considered in the development of the steam generator seismic HCLPF values. The HCLPF value for the steam generators is dominated by the failure of the SG supports with a conservatively estimated HCLPF of 0.54g. In the AP1000 PRA SMA, the failure of steam generators is already identified as one of the contributors to SLOCA initiating event plant HCLPF.

The HCLPF value for the AP1000 SG tubes, whether potential degradation during their operational life is considered or not, will not be significant enough to lower the existing steam generator HCLPF value. Degradation of steam generator tubes for the AP1000 plant will not be significant since new design features are incorporated into the AP1000 steam generator that reduces degradation, such as:

- **Reduced wear due to tighter manufacturing tolerances and through the selection of materials.**
- **Use of stainless steel tube support plates that eliminate denting and high cycle fatigue associated with carbon steel tube support plates.**
- **Use of thermally treated alloy 690 tube materials using better manufacturing methods**

Also, the tubes are inspected throughout the steam generator service life following the EPRI guidelines.

Thus, even if it were possible to estimate the SG tube HCLPF with operational degradation considerations included, the HCLPF value would be expected to be higher than that of the SG supports, which already dominate the SG HCLPF.

Design Control Document (DCD) Revision:

None

PRA Revision:

None