3A Criteria for Distribution System Analysis and Support

This appendix provides the design criteria for the U.S. EPR distribution system analysis and supports. As noted in Section 3.7.3, this appendix describes criteria for design of supports for:

- Piping.
- Heating, ventilation, and air conditioning (HVAC) ducts.
- Cable trays.

3A.1 Piping and Supports

Information on piping, instrumentation, and supports is provided in AREVA NP Topical Report ANP-10264NP, "U.S. EPR Piping Analysis and Pipe Support Design," (Reference 1).

3A.2 Heating, Ventilation, and Air Conditioning Ducts and Supports

HVAC ductwork and its associated support structures are designed to withstand the loadings and load combinations presented in Section 3A.2.2 and Section 3A.2.3, based on the Codes and Standards provided in Section 3A.2.1. A typical HVAC duct system includes structural components (e.g., sheet metal ducts, duct stiffeners, duct supports) and inline components (e.g., heaters and dampers).

Safety-related, Seismic Category I HVAC ductwork, supports, and restraints meet the stress allowables provided in paragraph SA-4220 of ASME AG-1 (Reference 2). Seismic Category II HVAC ductwork, supports, and restraints are analyzed to make sure that a failure would not adversely impact safety-related equipment or components. Seismic Category II requirements are satisfied by conservatively analyzing the Seismic Category II HVAC ductwork, supports, and restraints to the same criteria as Seismic Category I.

Non-Seismic HVAC ductwork meets Sheet Metal and Air Conditioning Contractors National Association (SMACNA) standards (Reference 5). Non-Seismic HVAC ductwork support and restraint systems meet the analysis requirements of the American Institute of Steel Construction (AISC) Manual (Reference 3).

3A.2.1 Codes and Standards

HVAC ductwork, ductwork supports, and ductwork restraints conform to the following codes and standards:

- ASME AG-1-2003, Code on Nuclear Air and Gas Treatment, with 2004 Addenda (Reference 2).
- AISC Manual of Steel Construction, Ninth Edition (Reference 3).

- American Iron and Steel Institute (AISI), North American Specification for the Design of Cold-Formed Steel Structural Members, 2001 Edition with 2003 Errata (Reference 4).

- SMACNA, HVAC Duct Construction Standards, Metal and Flexible, Third Edition, 2005 (Reference 5).

- American Welding Society (AWS) D1.1/D1.1M: 2004, Structural Welding Code-Steel, with errata through June 2005 (Reference 6).

- AWS D1.3-98, Structural Welding Code – Sheet Steel (Reference 7).

3A.2.2 HVAC Ductwork

3A.2.2.1 HVAC Ductwork Loads

The structural loads for the HVAC ductwork are listed below:

- Additional Dynamic Loads (ADL)—loads resulting from system excitations due to structural motion caused by safety relief valve actuation and other hydrodynamic loads due to the design basis accident (DBA), small pipe break accident (SBA), and intermediate pipe break accident (IBA).

- Constraint of Free End Displacement Loads (T)—loads caused by constraint of free end displacement that results from thermal or other movements.

- Dead Weight (DW)—weight of the equipment or ductwork including supports, stiffeners, insulation, any contained fluids, and internally and externally mounted components.

- Design Pressure Differential (DPD)—dynamic pressure loads resulting from a DBA, IBA, or SBA.

- Design Wind Loads (W)—loads due to design hurricane, design tornado, or other abnormal meteorological conditions. See Section 3.3 for a discussion of design wind loads.

- External Loads (EL)—applied loads caused by attached piping, accessories, or other equipment.

- Fluid Momentum Loads (FML)—momentum and pressure forces because of fluid flow, as clarified in SA-4211 of ASME AG-1.

- Live Loads (L)—loads occurring during construction and maintenance and may also include loads due to snow, ice and ponded water. Live loads will not be less than a 250 lb construction or maintenance midspan man load over a 10 square inch area.

- Normal Operating Pressure Differential (NOPD)—maximum positive or negative differential pressure that may occur during normal plant operation including start-up and test conditions; this includes pressures resulting from normal airflow, and

valve or damper closure.

- Seismic Loads (SL)—Loads that are the result of the safe shutdown earthquake (SSE).

3A.2.2.2 HVAC Ductwork Load Combinations

Table 3A-1 lists the HVAC ductwork loading combinations for the design of HVAC ductwork.

3A.2.3 HVAC Duct Supports and Restraints

3A.2.3.1 HVAC Support and Restraint Loads

Loads ADL, DPD, DW, EL, FML, L, NOPD, SL, T, and W (see Section 3A.2.2.1) apply to HVAC ductwork supports and restraints.

3A.2.3.2 HVAC Support and Restraint Load Combinations

Table 3A-2 lists the HVAC support and restraint loading combinations for the design of HVAC supports and restraints.

3A.2.4 Design and Analysis

3A.2.4.1 Allowable Stress Criteria

Ductwork stresses are based on Reference 4. Ductwork support stresses are based on AISC "Specification for the Structural Steel Buildings - Allowable Stress Design and Plastic Design," contained in Reference 3.

The basic general membrane design stress for Service Level A condition does not exceed 0.6 F_y and is reduced as appropriate to account for lateral-torsional buckling of bending members and effective lengths of compression members. The combined membrane and bending stress for Service Level A does not exceed 1.5 x 0.6 F_y. The basic general membrane stress for Service Level C condition does not exceed 1.2 x 0.6 F_y and is reduced as necessary to account for lateral-torsional buckling of bending members and effective lengths of compression members. The combined membrane and bending stress for Service Level C does not exceed 0.9 F_y.

3A.2.4.2 Deflection Limits

The allowable deflections for the load combinations described above are provided in Table 3A-3. Deflection criteria conform to Section SA-4230 of Reference 2.

3A.2.4.3 Damping

The damping values for the design of HVAC duct systems are discussed in Section 3.7.1.2 and are contained in Table 3.7.1-1.

3A.2.4.4 Seismic Analysis

The methods for seismic analysis are provided in Section 3.7. Seismic loads are determined by a dynamic analysis or by the equivalent static load method. Seismic excitation occurs in three directions (two horizontal and one vertical). Stresses resulting from the excitations are combined using the square root of the sum of the squares (SRSS) method.

3A.2.5 Other Criteria

3A.2.5.1 Vibration Isolation

The vibration isolation equipment restraints resist the loads generated by any service condition.

3A.2.5.2 Relative Movement

Clearances are provided that allow for relative movement between equipment, ductwork, and supports.

3A.2.5.3 Tolerances

Fabrication tolerances comply with Subarticle SA-6400, of Reference 2.

3A.2.5.4 Attachments

Attachments withstand the load combinations listed in Section 3A.2.2.2. The allowable types of welded joints are designed in accordance with the applicable requirements of AWS Structural Welding Code-Steel and Sheet Steel, D1.1 and D1.3 (References 6 and 7). Local stresses induced in the ductwork by integral attachments, as defined in Paragraph AA-4243 of Reference 2, are analyzed. The material selected for items used as part of an assembly for supporting or guiding the ductwork is compatible for welding. Consideration is given to the mechanical connection and local stresses induced in the ductwork by nonintegral attachments, as defined in Paragraph AA-4243 of Reference 2. The design of bolts for structural supports meets the requirements of Subarticle AA-4360 of Reference 2.

3A.3 Cable Tray, Conduit, and Supports

The following criteria apply to Seismic Category I and II cable trays, conduits, and the associated supports and restraints.

3A.3.1 Codes and Standards

Cable tray, conduit, and cable tray supports and restraints conform to the following codes and standards:

- ANSI/AISC-N690-1994, AISC “Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities,” with Supplement 2 (10/06/2004), (Reference 8).

- American Iron and Steel Institute (AISI), North American Specification for the Design of Cold-Formed Steel Structural Members, 2001 Edition with 2003 Errata (Reference 4).

- AISC Manual of Steel Construction, Ninth Edition, (Reference 3).

3A.3.2 Loads

The following loads are considered for the design of cable trays, conduits, and their supporting structures.

- Dead Load (D)—weight of cable trays or conduits, supports, cable inside of the raceways, tray covers, and other permanently attached components and fittings.

- Live Loads (L)—loads occurring during construction and maintenance. Live loads will not be less than a 250 lb load applied to a tray span in a manner providing worst case stresses in the tray and/or maximizing support loads. This load is not combined with seismic loads and is not applicable for conduits.

- Seismic (S)—See Section 3A.2.2.1.

- Thermal (T)—Loads resulting from thermal expansion or contraction. These loads are avoided by placing expansion/contraction joints along raceway runs.

3A.3.3 Load Combinations

Table 3A-4 lists the raceway and support loading combinations for the design of cable trays, conduits and supports.

3A.3.4 Allowable Stress Criteria

The basic stress allowables for carbon steel cold formed sections are in accordance with the AISI cold-formed structural design specification (Reference 4). The basic stress allowables for support structural steel, welds, and bolts are in accordance with Reference 8.

3A.3.5 Damping

The damping values for the design of cable tray and conduit systems are discussed in Section 3.7.1.2 and are contained in Table 3.7.1-1.

3A.3.6 Seismic Analysis

The methods for seismic analysis are the same as described in Section 3A.2.4.4.

3A.4 References

1. AREVA NP Topical Report, ANP-10264(NP), “U.S. EPR Piping Analysis and Support Design,” September 2006, (Enclosure to letter, Ronnie L. Gardner (AREVA NP Inc.) to Document Control Desk (NRC), “Request for Review and

Approval of ANP-10264(NP) Revision 0, U.S. EPR Piping Analysis and Pipe Support Design," NRC:06:040, September 29, 2006).

2. ASME AG-1-2003, Code on Nuclear Air and Gas Treatment, with 2004 Addenda.

3. AISC Manual of Steel Construction, Ninth Edition.

4. American Iron and Steel Institute (AISI), North American Specification for the Design of Cold-Formed Steel Structural Members, 2001 Edition with 2003 Errata.

5. SMACNA, HVAC Duct Construction Standards, Metal and Flexible, Third Edition, 2005.

6. American Welding Society (AWS) D1.1/D1.1M: 2004, Structural Welding Code-Steel, with errata through June 2005.

7. AWS D1.3-98, Structural Welding Code – Sheet Steel.

8. ANSI/AISC-N690-1994, AISC “Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities,” with Supplement 2 (10/06/2004).

Table 3A-1—HVAC Ductwork Load Combinations

Service Level	Category	Load Combination (see Section 3A.2.2.1)	Stress Criteria
A	Normal Condition	DW+NOPD+FML+EL+L+T+W	See 3A.2.4
B	Not Required		
C	Emergency Condition	DW+NOPD+FML+EL+SL+ADL+W	See 3A.2.4
D	Not required unless DPD is applicable		

Table 3A-2—HVAC Support and Restraint Load Combinations

Service Level	Category	Load Combination (see Section 3A.2.2.1)	Stress Criteria
A	Normal Condition	DW+NOPD+EL+L+T	See 3A.2.4
B	Not Required		
C	Emergency Condition	DW+NOPD+EL+SL+ADL	See 3A.2.4
D	Not required unless DPD is applicable		

Table 3A-3—Deflection Limits[1,2]

Service Level	Deflection Limit
A[3]	$d_{all} \leq 0.6\ d_{max}$
B[3]	$d_{all} \leq 0.6\ d_{max}$
C[4]	$d_{all} \leq 0.9\ d_{max}$
D[4]	$d_{all} \leq 0.9\ d_{max}$

Notes:

1. If particular equipment design criteria require more restrictive limits on deflections, those requirements will be stated in the applicable equipment section of Reference 2.

2. Deflections are limited to prevent transmission of excessive load to other components such as filter frames, coils, bearings, and access doors.

3. Deflections are limited to values that prevent buckling in primary load carrying elements.

4. Deflections are limited to values as described in AA-4323 of Reference 2.

Table 3A-4—Load Combinations for Cable Trays, Conduits and Supports

Service Level	Category	Load Combination	Stress Limit[1]
A	Normal Condition	D+L	$1.0 \times S_a$
C	Emergency Condition	D+S	$1.6 \times S_a$ ($<0.9 F_y$)

Notes:

1. S_a= The basic allowable stress.