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Subject: Additional Information Related to ESBWR Suppression Pool Bypass Leakage Test Acceptance Criteria

Enclosure 1 contains additional information prepared by GE Hitachi Nuclear Energy (GEH) as requested by the NRC during teleconferences related to NRC RAI 6.2-145 originally transmitted via the Reference 1 letter, and supplemented by NRC requests for clarification in References 2 and 3. GEH previously responded to this RAI and subsequent supplements in References 4 through 6, respectively. The attached information provides further justification for the proposed ESBWR suppression pool bypass leakage test acceptance criteria, including discussions related to the unique design features of the ESBWR containment, the unique design features and prototype testing of the drywell-to-wetwell vacuum breakers, and suppression pool bypass leakage testing experience from the existing BWR fleet to further substantiate the ESBWR design.

If you have any questions or require additional information, please contact me.

Sincerely,

Lee F. Dougherty for

Richard E. Kingston
Vice President, ESBWR Licensing

References:

1. MFN 07-054, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 85 Related to ESBWR Design Certification Application*, January 19, 2007
2. E-Mail from Shawn Williams, U.S. Nuclear Regulatory Commission, to George Wadkins, GE Hitachi Nuclear Energy, dated June 13, 2007 (ADAMS Accession Number ML071640395)
3. MFN 08-493, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, *Request for Additional Information Letter No. 197 Related to ESBWR Design Certification Application*, May 22,2008
4. MFN 07-310, Letter from James C. Kinsey to the U.S. Nuclear Regulatory Commission Document Control Desk, *Response to Portion of NRC Request for Additional Information Letter No. 85 - Containment Systems and Emergency Core Cooling Systems - RAI Numbers 6.2-144, 6.2-145, 6.2-146, 6.2-147, and 6.3-66*, June 7, 2007
5. MFN 08-359, Letter from James C. Kinsey to the U.S. Nuclear Regulatory Commission Document Control Desk, *Response to Portion of NRC Request for Additional Information Letter No. 85 Related to ESBWR Design Certification Application - Containment Systems RAI Number 6.2-145 S01*, April 18, 2008
6. MFN 08-612, Letter from James C. Kinsey to the U.S. Nuclear Regulatory Commission Document Control Desk, *Response to Portion of NRC Request for Additional Information Letter No. 197 Related to ESBWR Design Certification Application - Containment Systems - RAI Numbers 6.2-145 S02, 14.2-63 S02, and 14.3-229 S01*, August 6, 2008

Enclosure:

1. MFN 09-113 - ESBWR Suppression Pool Bypass Leakage Test Acceptance Criteria

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Enclosure 1

MFN 09-113

ESBWR Suppression Pool Bypass Leakage Test Acceptance Criteria

Discussion

NUREG-0800 (Standard Review Plan) Section 6.2.1.1.C, "Pressure Suppression Type BWR Containments," Appendix A requires pre-operational and periodic suppression pool bypass leakage tests. NUREG 0800 also recommends bypass testing acceptance criteria for existing BWR Mark I, Mark II, and Mark III pressure suppression containments. The capabilities for steam bypass for Mark I, II, and III containment designs are as follows: the Mark I design is of the order of 18.6 cm^2, the capability of the Mark II containment is approximately 46.5 cm^2, and the Mark III design has a capability of $A/\sqrt{K}$ = 929 cm^2. The Standard Review Plan (SRP) Section 6.2.1.1.C, Appendix A, recommends that Mark II and Mark III acceptance criteria for suppression pool bypass leakage tests shall be a measured bypass leakage which is less than 10% of the capability of the containment for Mark II and III containments with Mark I leakage from a hole not greater than 2.54 cm in diameter.

General Electric established the 10% of containment capability criterion during licensing of the initial pressure suppression containments in the early 1970s for BWRs with active Emergency Core Cooling Systems (ECCS). The 10% of containment capability criterion was intended to leave sufficient margin for increases in bypass leakage between outages. This was due in part to the limited amount of actual field-testing experience and data, and the large number of penetrations through the diaphragm floor of the Mark II containment. This criterion allows a 90% margin for additional bypass leakage between outages. Current operator experience indicates that there is little increase in bypass leakage for Mark II containments even over intervals as long as 10 to 15 years, and that the actual measured bypass leakage is a small fraction of the design capability. Therefore, the 90% margin to containment capability is overly conservative.

The proposed acceptance criteria for the suppression pool bypass leakage test for ESBWR is less than or equal to 50% of the design basis suppression pool bypass leakage area of 2.0 cm^2 conducted at the same testing frequency as the integrated leak rate testing (ILRT). This still allows a 50% margin to the design basis suppression pool bypass leakage area. This will also provide adequate margin to account for increases between tests, and will ensure the test acceptance criteria is measurable within current technology at a 95% confidence level to account for measurement errors. Furthermore, it ensures that undue regulatory burden is not imposed on plant owners.

For ESBWR, if a suppression pool bypass leakage acceptance criteria of 0.2 cm^2 (10% of 2 cm^2) is used, the plant owners would be required to perform suppression pool bypass leakage tests that are at or near the limit of current technology to accurately measure bypass leakage area at the 95% confidence level. Acceptance criteria of 0.2 cm^2 will leave the utility with little or no margin for unforeseen problems that may arise during bypass testing. To ensure that this low acceptance criterion is met would require increased test time to assure that the error margin of the test is less than the acceptance criteria. This would result in additional radiation exposure, increased time to perform the test, and increased maintenance on the vacuum breakers (the most probable source of suppression pool bypass leakage) in order to achieve a 90% margin to design basis bypass leakage, with the possibility that the increased maintenance could degrade the reliability of the vacuum breaker over time. The plant owner would be faced with increased plant outage time to conduct the additional maintenance on the vacuum breaker to pass an unnecessarily overly conservative suppression pool bypass leakage test acceptance criteria. The increased maintenance would result in increased outage resources for maintenance planning, contingencies, and parts, and would lead to increased radiation dose to plant workers conducting the maintenance. An excessively restrictive suppression pool bypass leakage test acceptance criteria would also increase the costs to plant owners resulting from replacement power costs and increased personnel costs. Thus, the overall burdens associated with an overly conservative test criterion would result in a high implementation cost with no commensurate safety benefit.

GEH considers the 50% acceptance criteria of containment bypass leakage capability adequate for ESBWR for the following reasons:

- The ESBWR has been uniquely designed to minimize the potential suppression pool bypass leakage paths. The ESBWR is designed with a reinforced, lined concrete pressure suppression containment structure. This structure encloses the reactor pressure vessel (RPV), including related systems and components, and incorporates an internal steel liner that provides a leak-tight containment boundary. Similar to the existing BWR Mark II containments, the ESBWR is divided into a drywell and wetwell region by a diaphragm floor with an interconnecting vent system. However, there are significant differences that make the ESBWR unique.
    - The diaphragm floor is a composite structure consisting of a plate steel drywell liner with full penetration welds, a concrete slab, and a wetwell stainless steel liner with full penetration welds. Preservice and inservice inspections of the weld integrity of the liner welds and penetration welds through the diaphragm floor will be conducted to ensure leak tightness.
    - The ESBWR design has minimized the number of penetrations across the diaphragm floor to minimize bypass leakage paths. Existing BWR Mark II containments have over one hundred penetrations through the diaphragm floor with varying outside diameters of 24 inch and 28 inch. The ESBWR containment has only thirteen penetrations through the diaphragm floor with outside diameters of 24 inch (3), 10 inch (6), and 1 inch (4). ESBWR Main Steam Safety Relief Valve (SRV) discharge lines are routed through the containment vent walls and are seal welded at the vent wall penetrations. Bypass leakage across the diaphragm floor penetration welds and plate welds is highly improbable, and the only credible source of ESBWR bypass leakage is from the 3 vacuum breaker pathways.
    - Table 1 compares ESBWR Diaphragm floor penetrations with previous BWR containment designs. ABWR and Mark II containments have 26 and 102 penetrations, respectively, while the ESBWR has only 13 penetrations.

    This unique ESBWR diaphragm floor design gives assurance that the suppression pool bypass leakage test acceptance criteria of less than 50% of the design basis suppression pool bypass leakage area measured at the 95%

confidence level can be met over the 60 year life of the plant and there is sufficient operating margin to give plant owners some flexibility to account for unforeseen testing problems.

- As stated above, the vacuum breakers are the only credible source of bypass leakage. The vacuum breakers will be tested on a 24 month frequency to measure any degradation of suppression pool bypass leakage between refueling outages when the suppression pool bypass test is not conducted. This will provide assurance that bypass leakage does not substantially increase between refueling outages.

  The acceptance criteria for the individual local leakage rate test of the vacuum breakers and vacuum breaker isolation valves is less than or equal to 15% of the design basis bypass leakage area. The acceptance criteria for the total leakage rates of all the vacuum breaker/vacuum breaker isolation valve pairs on a maximum pathway basis is less than or equal to 35% of the design basis bypass leakage area. Total leakage rate is determined by summing the maximum pathway leakage for each vacuum breaker/vacuum breaker isolation valve pair. This provides a 65% margin to the design basis bypass capability.

  The vacuum breakers were developed under SBWR program, and a prototype vacuum breaker was built and qualified per the guidance in IEEE 323. Testing was completed in July 1994 and details were issued to the NRC as part of response to RAI 900.62 issued by letter MFN 155-94 dated December 15, 1994 under Docket STN 52-004. ESBWR uses the identical vacuum breakers, and letter MFN 06-127 transmitted the SBWR vacuum breaker test program report to NRC Staff for review. The program is summarized in Table 2.

  The vacuum breakers are uniquely designed to be leak-tight, and incorporate both a non-metallic seat and a hard seat. The vacuum breaker isolation valve meets the requirements of Class 6 leakage per ANSI FCI-70-2-2003. See Table 3 for valve details.

- The modeling used to determine the containment bypass leakage capability at the ESBWR design pressure is conservative. The mixing of noncondensable gases and mixing in the suppression pool is not modeled. This leads to thermal stratification and higher pressures in the wetwell. Also, not all containment heat sinks are modeled, which leads to less decay heat being removed by containment structures, which in turn results in higher pressures.

  In addition to using a conservative model, the 2 cm^2 containment bypass leakage capability is derived using bounding plant conditions, such as a higher thermal power of 102% of rated. Other bounding plant conditions can be found in ESBWR DCD Tier 2, Table 6.2-8.

  Using nominal analyses further supports the test acceptance criteria of 50%. Substantial margin exist from the bounding conditions used to establish the 2 cm^2 containment bypass leakage capability and nominal conditions.

- The containment ultimate capability bypass leakage is 14 cm^2 while the design pressure bypass leakage is 2 cm^2. This amounts to a margin of about 600%. Figure 1 illustrates bypass leakage margins.
- Test Data for Mark II and III containments indicates that there is no clear indication of bypass leakage increasing over the life of the containments. Test data for various plants is shown in Figures 2 through 10.

Conclusion

The analyses of bypass leakage capability for the ESBWR demonstrate that a 50% test acceptance criterion for suppression pool bypass leakage testing (i.e., 1 cm^2) is acceptable and provides sufficient margin to the design and ultimate containment capability. Even though the NUREG-0800 Standard Review Plan Section 6.2.1.1.c, Appendix A, acceptance criteria for Mark II and Mark III containments is a measured bypass leakage which is less than 10% of the design capability of those containment designs, the unique design features of the ESBWR containment, the existing operating experience of these other containment designs, the bounding and conservative ESBWR containment pressure capability analyses, and the ESBWR ultimate containment pressure capability analyses substantiate the use of the 50% acceptance criterion for the ESBWR.

The ESBWR design is significantly different in that it has been uniquely designed to minimize the potential suppression pool bypass leakage paths. The specific design features that support the robustness of the ESBWR design are the design of the diaphragm floor, which is a composite structure consisting of a plate steel drywell liner with full penetration welds, a concrete slab, and a wetwell stainless steel liner with full penetration welds, and the significantly smaller number of penetrations across the diaphragm floor to minimize bypass leakage paths.

Years of test data for existing BWR Mark II and III containments show no indication of increasing bypass leakage demonstrating that the existing 10% test acceptance criterion for suppression pool bypass leakage testing for the existing BWR containment designs is conservative.

There is significant margin in the specified design suppression pool bypass leakage of 2 cm^2. This margin includes the use of bounding values for most of the controlling variables, and the conservative assumptions used in the containment pressure analyses used to provide additional margin.

Analyses of the ESBWR ultimate pressure containment capability have demonstrated that suppression pool bypass leakage on the order of 14 cm^2 is possible without failure of the containment structure, demonstrating additional margin in the analyses of the design containment pressure capability.

Therefore, the use of a 50% test acceptance criterion for suppression pool bypass leakage testing (i.e., 1 cm^2) is acceptable for the ESBWR and provides sufficient margin to the design and ultimate containment capability based upon 1) the unique design features of the ESBWR, 2) the operating experience of the existing BWR Mark II and III containments that substantiate that the 10% text acceptance criterion for those types of containments is significantly conservative, 3) the use of bounding values and conservative analyses for the ESBWR design suppression pool bypass leakage value, and 4) the additional margin afforded by the ESBWR analyses of the ESBWR ultimate pressure containment capability.

References

1. NUREG-0800, Standard Review Plan 6.2.1.1.C, "Pressure-Suppression Type BWR Containments," Appendix A, Revision 7, March 2007
2. Niagara Mohawk Power Corp., Nine Mile Point Unit 2, Subject Letter: Response to Request for Additional Information Dated June 18, 1996, Regarding a Requested License Amendment to Extend the Interval for Testing Containment Drywell-to-Suppression Bypass Leakage (TAC No. M95083), Dated 7/18/1996, (Accession Number: 9607250280, Microform Addresses: 89162:110-89162:138, Physical File Location: PDR: ADOCK-05000410-P-960718, PDR: ADOCK/05000410/P 960718)
3. Pennsylvania Power & Light Co., Subject Letter: Susquehanna Steam Electric Station Proposed Amendment No. 194 to License NPF-14 and Proposed Amendment No. 152 to License NPF-22: Drywell to Suppression Chamber Bypass Testing, Dated 2/23/1996 (Accession Number: 9602290118, Microform Addresses: 87319:163-87319:188 Physical File Location: PDR: ADOCK-05000387-P-960223, PDR: ADOCK/05000387/P 960223)
4. Energy Northwest, Subject Letter: Columbia Generating Station, Docket No. 50-397; Request for Amendment to Technical Specifications Surveillance Requirements for the Suppression Chamber-to-Drywell Vacuum Breakers and the Drywell-to-Suppression Chamber Bypass Leakage Test, Dated 04/18/2006 (ADAMS Accession Number ML061110163)
5. AmerGen, Clinton Power Station Unit 1, Subject Letter: Request for Amendment to Technical Specification 3.6.5.1, "Drywell" and 5.5.13, "Primary Containment Leakage Rate Testing Program," Dated 11/16/2006 (ADAMS Accession Number ML063210289)
6. Exelon, LaSalle Units 1 and 2, Subject Letter: Supplement to Application for Amendment to Technical Specification Surveillance Requirements for the Suppression Chamber-Drywell Vacuum Breakers and the Drywell-to-Suppression Chamber Bypass Leakage Test, Dated09/10/2001 (ADAMS Accession Number ML012600096)
7. Entergy Operations, Inc., Subject Letter: River Bend Station, Unit 1 – Amendment No. 87 to Facility Operating License No. NPF-47 (TAC No. M92482), Dated 01/29/1996 (ADAMS Accession Number ML021620169)
8. Enclosure 2 - Agenda and Overview of ESBWR Containment Slides, Dated 2008-03-05 (ADAMS Accession Number ML080710286)

Table 1. Comparison of ESBWR Diaphragm Floor Penetrations With Other BWR Containments (from Reference 8)

	Penetration Description	Number Penetrations	Size cm (inches)]	Total Number
ABWR	Vacuum Breaker	8	50.8 (20)	
	SRV Discharge Lines	18	66.0 (26) OD	
				26
Mark II	DW to WW Downcomers	84	61 (24) OD	
	SRV Discharge Line Downcomer	18	71.1 (28) OD	
				102
ESBWR	Vacuum Breaker	3	60.9 (24)	
	PCCS Vent Lines	6	25.4 (10)	
	ICS Vent Lines	4	2.54 (1)	
				13

Table 2. Vacuum Breaker (VB) Test Program Summary (from Reference 8)

VB prototype manufactured and extensively tested and qualified per IEEE 323

VB Test Program:

- Leak Tightness Test – VB as built condition: soft seat tested bubble tight, hard tested with a leakage area equal to 0.00002 cm^2
- Performance Test – Tested in full flow test facility – confirmed lift pressure, flow rate and chatter performance
- Design Basis Accident Leak Tightness – VB was radiation aged, thermally aged and dynamically aged (including seismic) to simulate 60 years of operation. VB was leak tested with steam for 80 hours at Temp and Press enveloping DBA conditions. Periodic spray of cold water simulated thermal shock expected from DW spray. VB had zero steam leakage over duration of test. VB disc was lifted several times during the test with no change in leak tightness. Following the test VB leakage remained zero – bubble tight
- Reliability Testing – Confirm VB could open and close without failure to demonstrate a failure rate of <3E-4/demand. Prior to beginning the test 4 pounds of sand blasting grit were passed through the valve to simulate grit collected during the 60 years of service. Valve was coated with oil to ensure that grit adhered to bearing surfaces. VB was then cycled 3000 times in the test facility without measurable change in lift and reset pressure and flow rate. Following the Reliability test the valve was leak rate tested. As tested VB had leakage area << 0.02 cm^2.

Test Program confirmed VB was rugged, reliable and met leak tightness requirements after being exposed to conditions more severe than design basis service

Table 3. Vacuum Breaker (VB) and VB Isolation Valve Details (from Reference 8)

VB Design - VB is a leak tight valve that has redundant seals (soft seat and hard seat) unlike existing BWR VB's, which are check, valves with no redundancy for sealing.	- High reliability - > 1E-4 failures per demand - Leak Tightness – A/sqrt(k) < 0.02 cm^2/VB at end of 60 year life DBA - Double barrier seal design – non-metallic seat and backup hard seat o Provides protection from debris lodging on either seat and still maintains leak tightness – provides seat single failure protection o Either seal provides leak tightness requirements – VB test program demonstrates leak tightness < 0.02 cm^2
VB Isolation Valve Design - VB Isolation Valve provides is a zero leakage (Class IV) valve, which isolates a leaky VB unlike current BWR VB's, which do not have this capability.	- Manually or automatically close to isolate a leaking vacuum breaker - Fail as-is on loss of air or power - Must meet Class VI leakage requirements - Located between diaphragm floor and vacuum breakers - Metal-to-metal seating (hard seated) - Concentric metal rings with graphite spacers - Zero leakage (Class VI) – bi-directional - "Bubble-tight" after 50,000 cycles

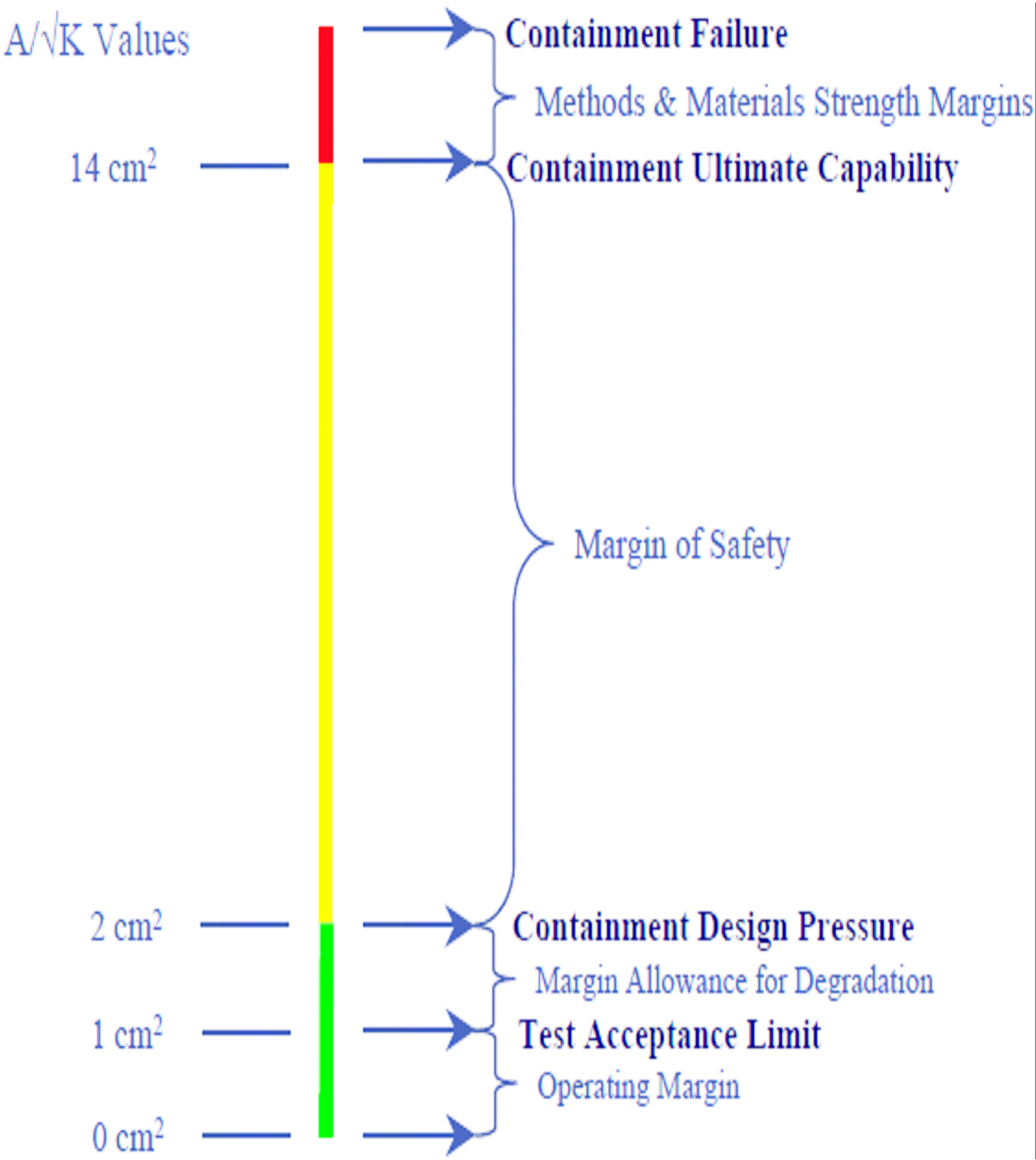

**Figure 1. ESBWR Bypass Leakage
Margin to Containment Ultimate Capability
(from Reference 8)**

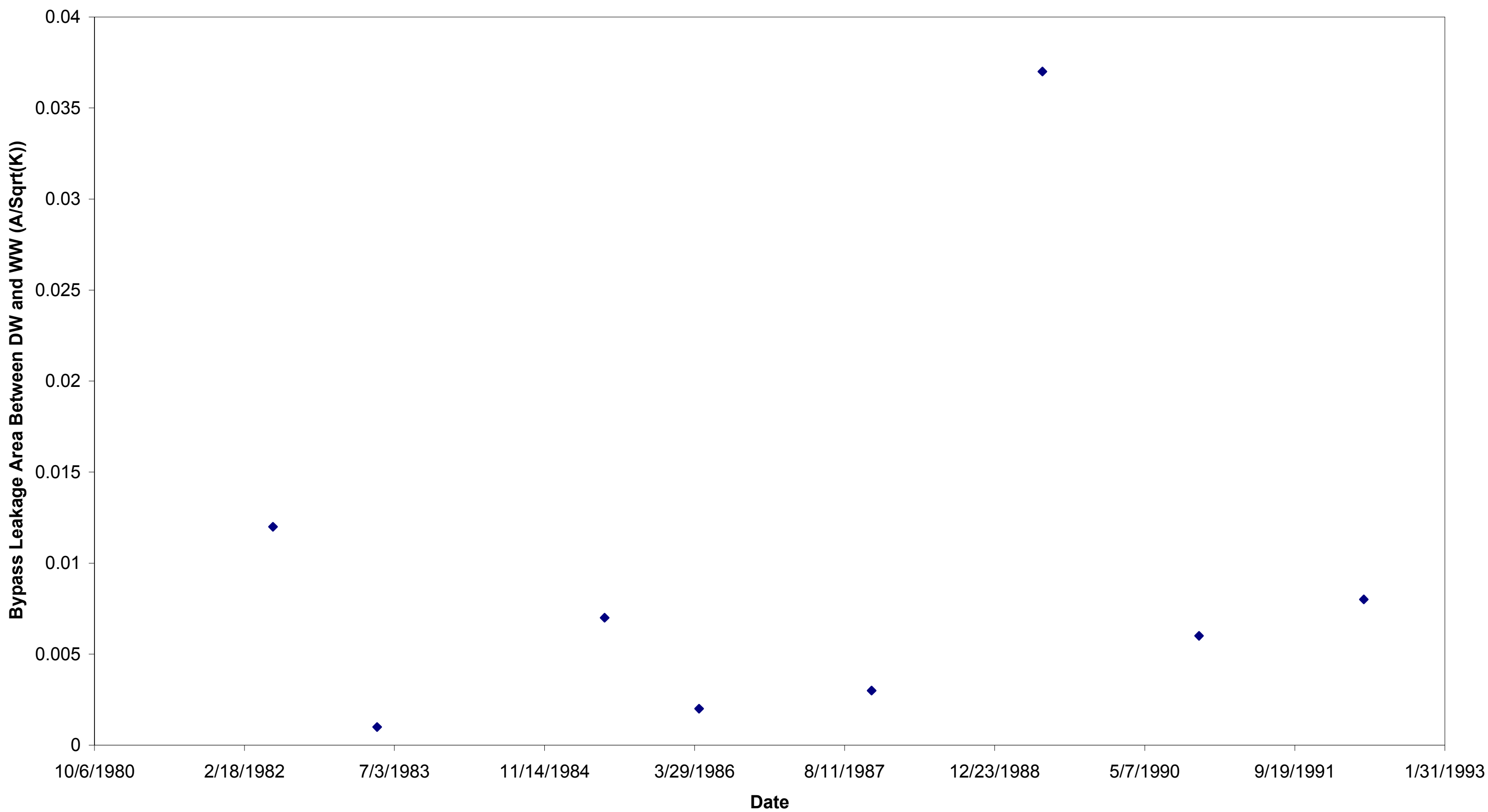

Figure 2. Susquehanna Unit 1
(Data from Reference 3, Table 2)

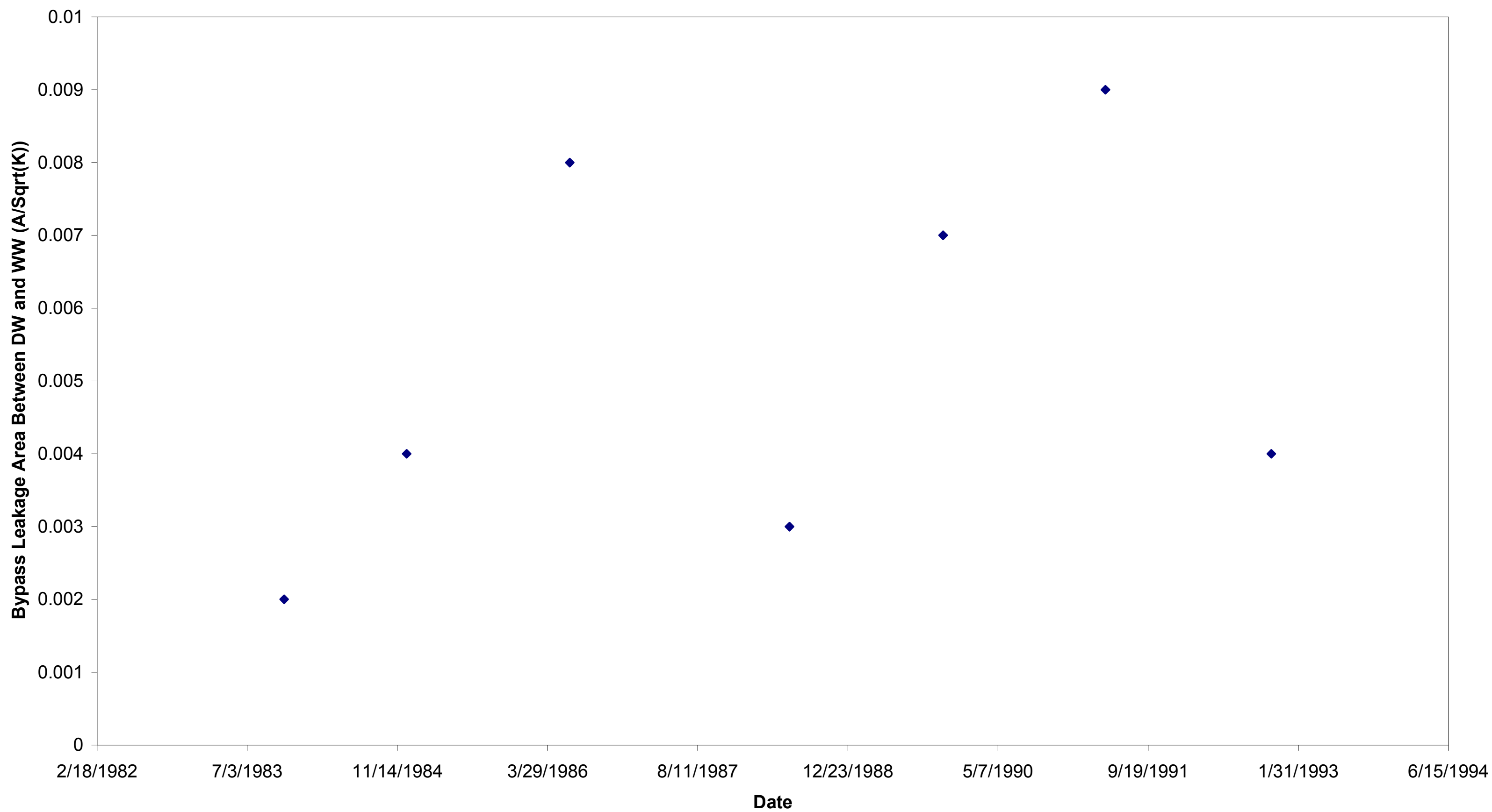

Figure 3. Susquehanna Unit 2
(Data from Reference 3, Table 2)

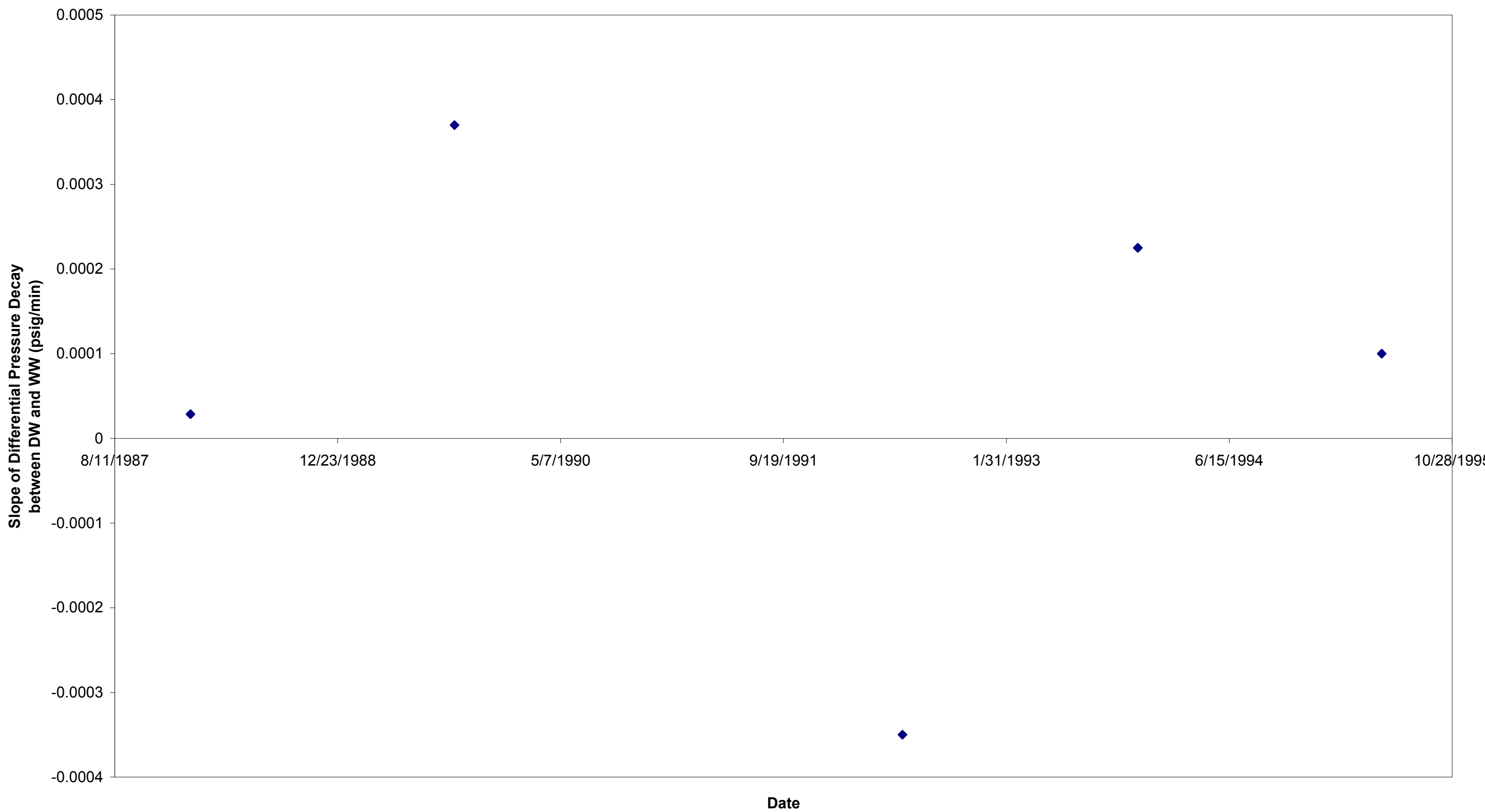

Figure 4. Nine Mile Point Unit 2
(Data from Reference 2, Attachments 1 through 6)

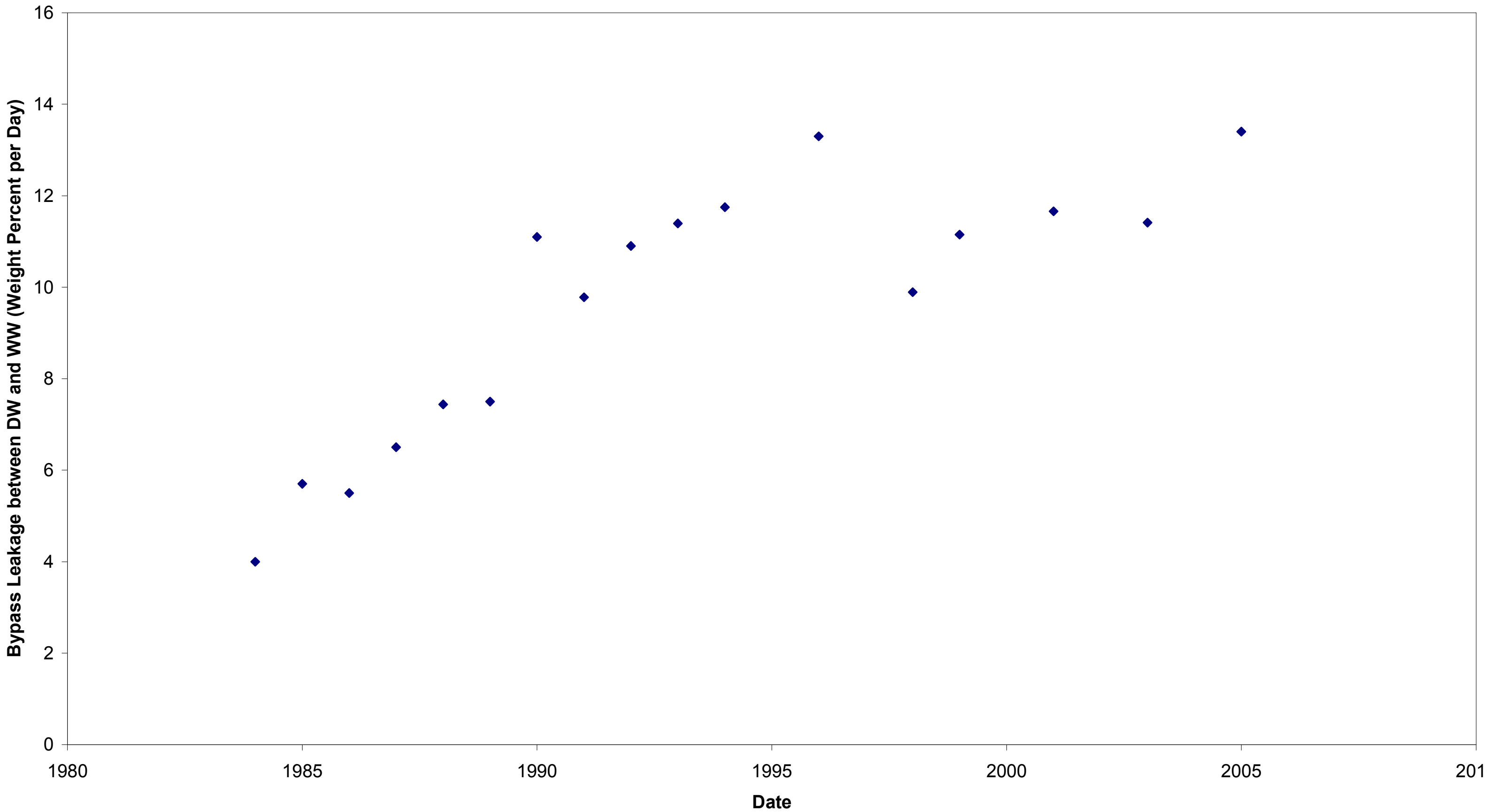

Figure 5. Columbia Generating Station
(Data from Reference 4, Attachment 1, Page 8)

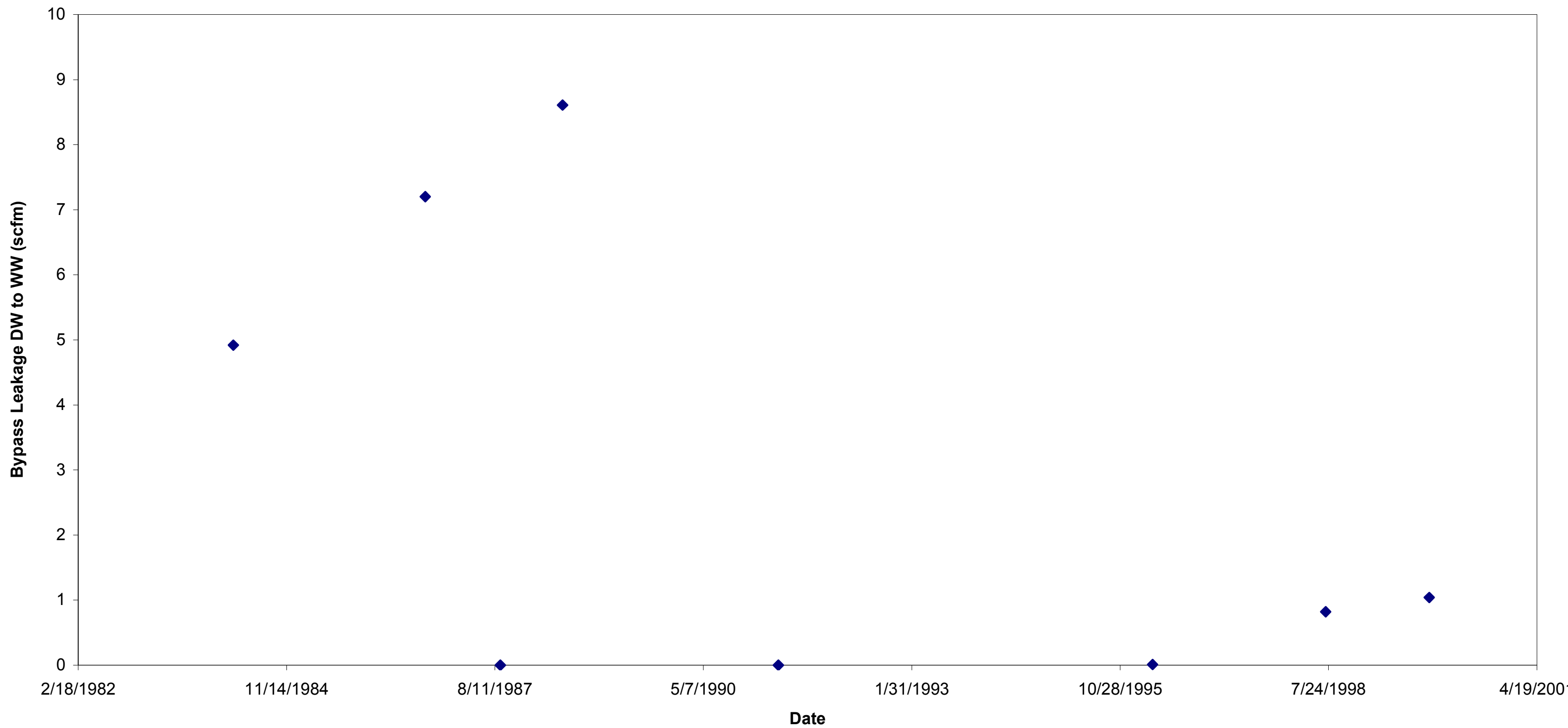

Figure 6. LaSalle County Station, Unit 1
(Data from Reference 6, Table 1)

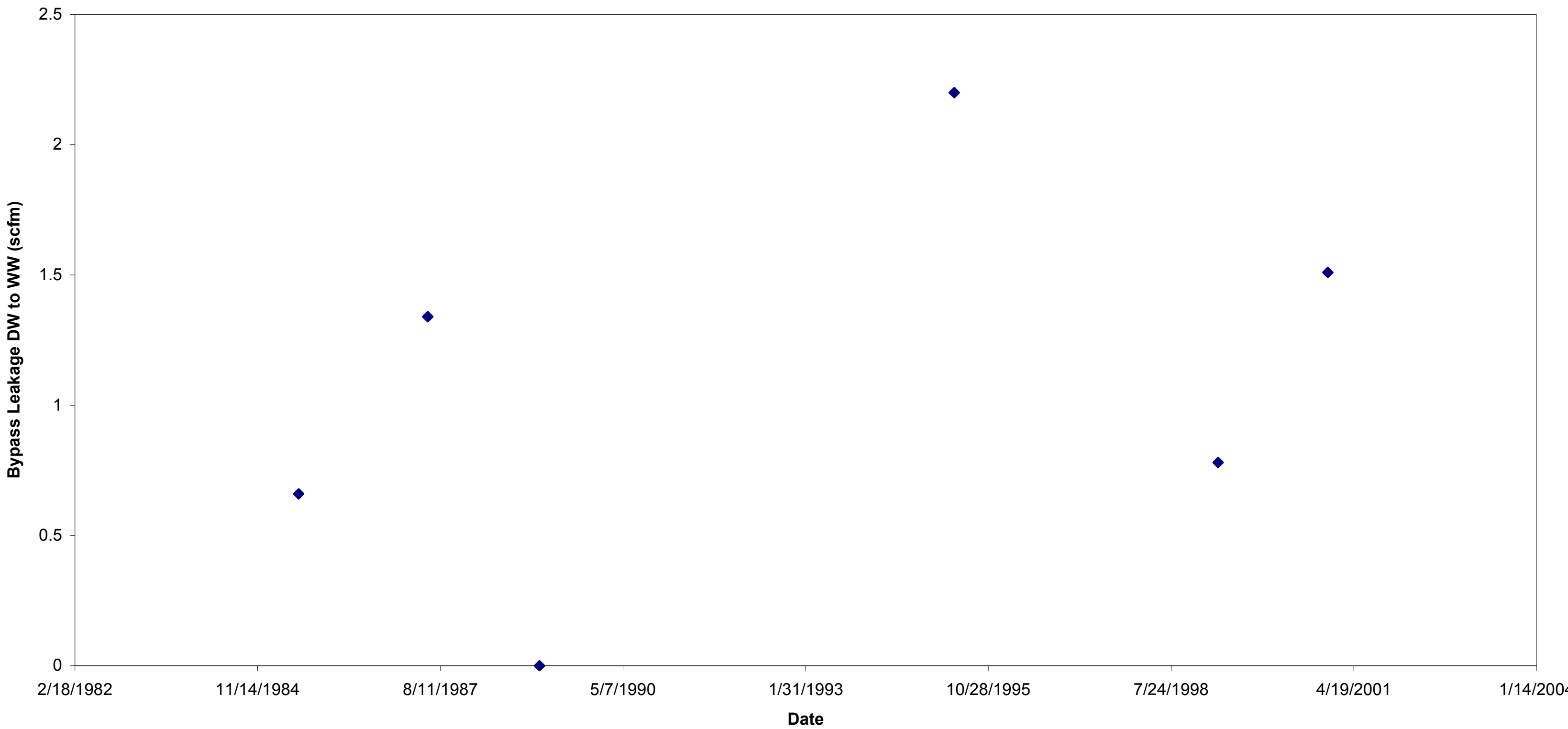

**Figure 7. LaSalle County Station, Unit 2
(Data from Reference 6, Table 4)**

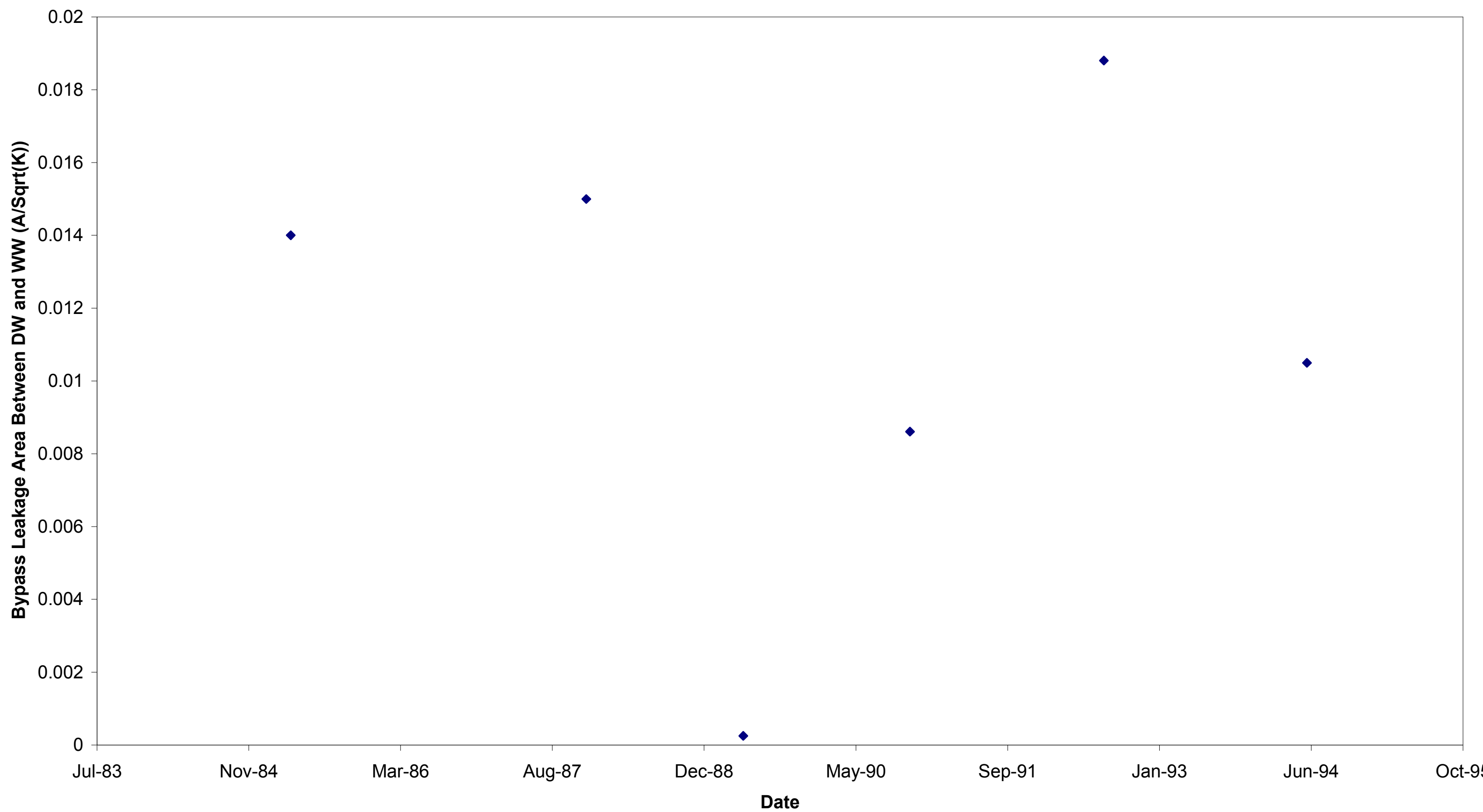

Figure 8. River Bend Station
(Data from Reference 7, Page 8 of Safety Evaluation)

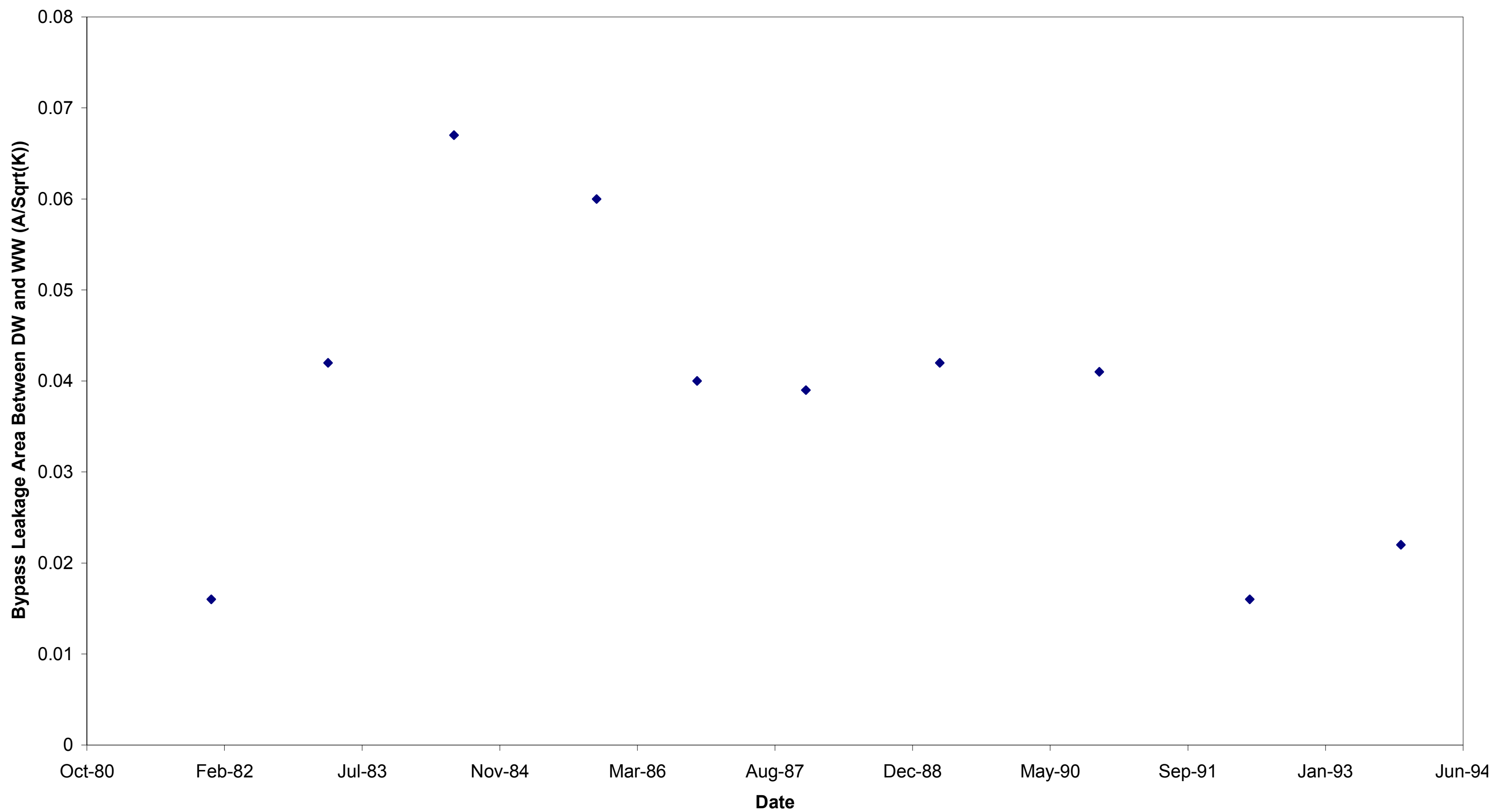

Figure 9. Grand Gulf Nuclear Station
(Data from Reference 7, Page 8 of Safety Evaluation)

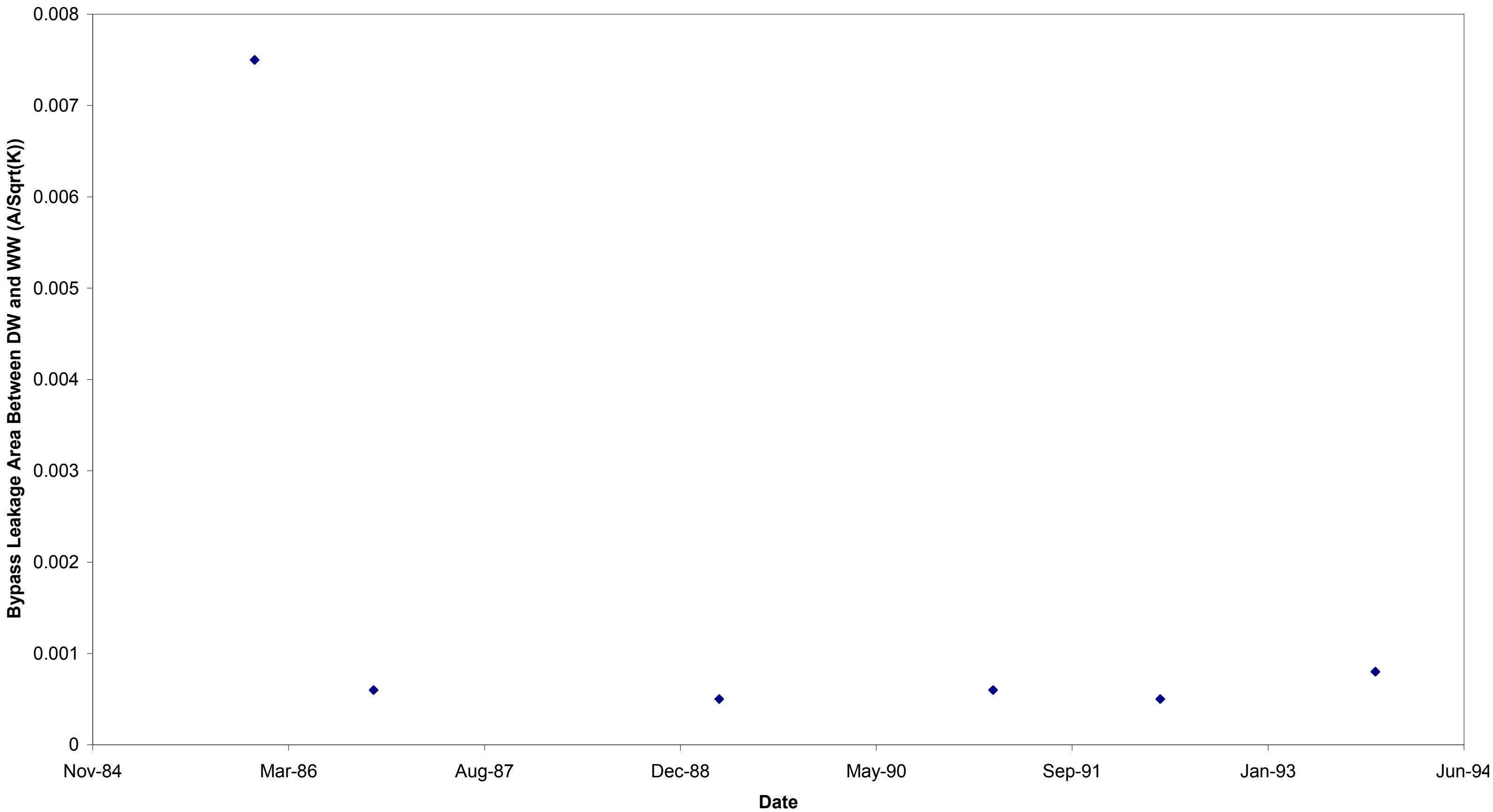

Figure 10. Clinton Power Station, Unit 1
(Data from Reference 5, Table C.2-1)