Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381-2000

AUG 2 2 2001

10 CFR 50.4
10 CFR 50.90

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

Gentlemen:

In the Matter of)
Tennessee Valley Authority)

Docket No.50-390

WATTS BAR NUCLEAR PLANT (WBN) UNIT 1 - TECHNICAL SPECIFICATION (TS) CHANGE NO. WBN-TS-99-014 - STEAM GENERATOR ALTERNATE REPAIR CRITERIA FOR AXIAL OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC) - CLARIFICATION AND ADDITIONAL INFORMATION - (TAC NO. MA8635)

The purpose of this letter is to provide changes, clarifications and additional information to TVA's letters dated April 10, 2000, and September 18, 2000.

Following the issuance of the above letter, TVA and NRC discussed several issues concerning the radiation dose calculation for the Main Steam Line Break (MSLB) in teleconference calls on September 26, 2000, and February 7, 2001. TVA determined from those calls that another revision was necessary to the MSLB dose calculation.

On July 17, 2001, TVA met with NRC to discuss three specific issues. These issues were: 1)revision to the MSLB dose calculation, 2)pressurization rate during tube burst test, and 3)inspection plan for dented tube-support plate intersections.

Enclosure 1 provides information concerning the revision to the MSLB dose calculations. Enclosure 2 provides information concerning the steam generator issues on tube burst testing and

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dented tube support plate inspections. Enclosure 3 provides a copy of the testing results performed specifically for TVA in Westinghouse Report SG-01-07-003, "Pressurization Rate and Foil Strengthening Effects on the Burst Strength of Axially Degraded Steam Generator Tubing," dated July 2001. Enclosure 4 provides a copy of the Electrical Power Research Institute (EPRI) Final Report 1001441, "Effect of Pressurization Rate on Degraded Steam Generator Tubing Burst Pressure," dated April 2001. Both Enclosures 3 and 4 were discussed with NRC in the meeting on July 17, 2001.

TVA has evaluated the changes in the proposed amendment and finds that these changes do not effect the initial proposed No Significant Hazard Consideration provided in the April 10, 2000, request. However, these changes have resulted in a potential TS change for the reduction of reactor coolant system (RCS) activity. The changes to TS 3.4.16, "RCS Specific Activity," which are being evaluated under TVA's Corrective Action Program, are being administratively controlled in accordance with NRC's Administrative Letter 98-10, "Dispositioning of Technical Specifications That Are Insufficient to Assure Plant Safety." TVA expects to submit the request for the TS change in the near future.

There are no new regulatory commitments in this submittal. If you have any questions about this information, please contact me at (423) 365-1824.

Sincerely,

P. D. Pace
Manager, Site Licensing
and Industry Affairs

Enclosures
cc: See page 3

Subscribed and sworn to before me
on this 22nd day of August 2001.

E. Jeannette Long
Notary Public

My Commission Expires May 21, 2005

Enclosures
cc Enclosures:

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ENCLOSURE 1

WATTS BAR NUCLEAR PLANT UNIT 1
PROPOSED TECHNICAL SPECIFICATION CHANGE WBN-TS-99-014
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
RADIOLOGICAL DOSE CALCULATION

ENCLOSURE 1

WATTS BAR NUCLEAR PLANT UNIT 1
PROPOSED TECHNICAL SPECIFICATION CHANGE WBN-TS-99-014
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
RESPONSE TO NRC ISSUE ON DOSE CALCULATIONS

NRC's review of the WBN request for a License Amendment, WBN-TS-99-014, dated April 10, 2000, and the subsequent response to NRC's request for additional information dated September 18, 2001, resulted in additional NRC concerns. TVA recognized from these concerns during subsequent teleconference calls on September 22, 2000, and February 7, 2001, that the computer codes used for the radiological assessment of offsite and control room operator dose calculations needed to be revised. TVA revised the computer codes to incorporate updated analysis techniques and modeling codes. TVA has revised the radiological dose analysis and the control room air intake concentration (χ/Q value) to incorporate NRC's concerns. The changes to the computer codes are discussed in more detail in Attachment 1 to this enclosure. Attachment 2 to this enclosure provides a revision to the summary of the assumptions for the main control room dose (General Design Criteria (GDC) 19) analysis and the 10 CFR 100 offsite dose analysis. Attachment 3 provides the revised dose analysis and Attachment 4 provides the new analysis for the χ/Q values. Attachment 2 and 3 of this enclosure supersede Enclosure 3, Attachment 1 and 2 of TVA's September 18, 2000 letter. These revisions to the dose analysis were discussed with NRC Staff in a meeting on July 17, 2001, at NRC Headquarters.

The following remaining issues were discussed in teleconference calls on September 26, 2000, and February 7, 2001. This documents TVA's response as discussed in the July 17, 2001, meeting with NRC.

Question 1

The iodine source terms appear to be high by a factor of 21. A factor of 0.38 should be used instead of 7.965.

Response

The NRC methodology of calculating the factor was provided to TVA as an example. Using this example and the source terms from UFSAR Table 11.1-7, the NRC methodology gives the 7.965 factor. The example provided had used source terms from the Historical UFSAR Table 11.1-2. TVA and NRC agreed that 7.965 is the correct value at the July 17, 2001, meeting.

ENCLOSURE 1

WATTS BAR NUCLEAR PLANT UNIT 1
PROPOSED TECHNICAL SPECIFICATION CHANGE WBN-TS-99-014
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
RESPONSE TO NRC ISSUE ON DOSE CALCULATIONS

Question 2

Flows of 150,000 lb and 2,509 lb should be considered separately since the 150,000 lb. is secondary side at 0.1 μCI/gm and the 2,509 lb is primary side at higher concentration.

Response

The primary side flow and secondary side flow are now modeled separately. This change reflects steam generator boiling dry.

Question 3

Watts Bar assumed an unfiltered in-leakage into the control room envelop of 51 cfm. What is the basis for that number in the calculation?

Response

The main control room (MCR) steady state unfiltered inleakage is 51 CFM and is established by a calculation. This calculation documents the in-leakage to the control room habitability zone (CRHZ). The basis for this calculation is the following:

1. The calculation assumes the CRHZ is at a positive pressure to adjacent spaces. The control room pressure is verified via periodic surveillance instructions to be at a positive pressure relative to adjacent spaces. This assumption is considered valid.

2. Ducting and the heating, ventilation, and air conditioning (HVAC) components are located within the boundary (with exception of the battery room exhaust duct) and as such leakage, will be out of the CRHZ.

3. With the CRHZ being at a positive pressure, leakage across doors, dampers, walls, floors, ceilings, and penetrations will be out of the CRHZ and not into the CRHZ.

4. The battery room exhaust duct leakage was measured at 1.8 cfm. This measurement was made prior to unit startup and is documented in the calculation.

5. The calculation takes into account egress/ingress through doors and bleed off from pneumatic operations and equipment.

ENCLOSURE 1
ATTACHMENT 1

WATTS BAR NUCLEAR PLANT UNIT 1
PROPOSED TECHNICAL SPECIFICATION CHANGE WBN-TS-99-014
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
DESCRIPTION OF CHANGES TO CALCULATION

ENCLOSURE 1
ATTACHMENT 1

WATTS BAR NUCLEAR PLANT UNIT 1
PROPOSED TECHNICAL SPECIFICATION CHANGE WBN-TS-99-014
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
DESCRIPTION OF CHANGES

The following changes which were discussed with NRC Staff in a meeting on July 17, 2001, at NRC Headquarters, were incorporated in to the radiological dose assessment calculation.

The Main Steam Line Break (MSLB) dose calculation has been updated to incorporate several different methodologies to resolve NRC's concerns. Changes in the computer codes for the dose calculation are discussed below:

A. COROD Revision 5 - TVA's computer program, COROD, calculates the integrated isotopic airborne activity in the control room at the end of specified time periods using the isotopic concentration at the control room intake. The latest analysis version of COROD was modified to calculate the dose to the whole body, skin, and thyroid due to inhalation of Iodine using more realistic Federal Guideline Reports (FGR)-11 and 12 (International Commission of Radiation Protection Publication 30 [ICRP-30]) dose conversion factors. COROD also determines the dose equivalent Iodine 131 by the older dose conversion factors in ICRP-2. In addition, the Total Effective Dose Equivalent (TEDE) is calculated using the FGR-11 and 12 data. The TEDE dose has been determined for information only.

B. FENCDOSE Revision 4 - TVA's computer program, FENCDOSE, is used to calculate the beta, gamma, and inhalation doses to be expected at the Low Population Zone (LPZ) and the Exclusion Area Boundary (EAB). The version of FENCDOSE used for the latest analysis was modified to calculate the dose to the thyroid due to inhalation of Iodine using the more realistic FGR-11 and 12 (ICRP-30) dose conversion factors. FENCDOSE also determines the dose equivalent Iodine 131 by the older dose conversion factors in ICRP-2. In addition, the TEDE is calculated using the FGR-11 and 12 data. The TEDE dose is determined for information only.

The revisions to the above two computer programs are a collection of previously approved codes and methods used to bring the calculation up to date with more recently issued documents. Below is a discussion of those methods for obtaining the results of the calculations.

A. Use of FGR-11, LIMITING VALUES OF RADIONUCLIDE INTAKE AND AIR CONCENTRATION AND DOSE CONVERSION FACTORS FOR INHALATION, SUBMERSION, AND INGESTION. EPA-520/1-88-020. U.S. EPA. Washington, DC 1988 and FGR-12, EXTERNAL EXPOSURE

TO RADIONUCLIDES IN AIR, WATER, AND SOIL. EPA 402-R-93-081 U.S. EPA. Washington, DC 1993 (FGR-12) - FGR-11 and FGR-12 provide the dose conversion factors. FGR-11 and 12 are based on the methodology in ICRP 30 and are considerable advances in the state of knowledge of radionuclide and the effects on humans in the past few decades. NRC adopted ICRP-30 in the revision of Part 20, "*Standards for Protection Against Radiation,*" in 1994.

B. Atmospheric Release Concentrations (ARCON) 96 modeling techniques - ARCON96 methodology is described and recommended by NRC in NUREG/CR-6331, Revision 1 "*Atmospheric Relative Concentration.*" ARCON96 determines the atmospheric dispersion or χ/Q values used to predict the dose to control room personnel from plant releases during normal operation and accident conditions. TVA evaluated the results of using the ARCON96 methodology and the currently used Halitsky Methodology for the accident analysis. The ARCON96 methodology provides more realistic meteorological factors to define atmospheric pathways of radioactive effluents and estimates of changes in concentrations as a result of atmospheric dispersion.

C. Total Effective Dose Equivalent - TEDE values were calculated based on the product of the isotopic concentrations and the concentrations-to-dose conversion factors for the isotopes. TEDE is becoming an increasingly common method of dose measurement. TEDE dose measurements were added to the calculation for information only and are not intended to be the Licensing Basis for WBN.

Other assumptions which are different from those in TVA's September 18, 2000, letter, Enclosure 3, Attachment 1 are as follows:

A. Main Control Room Ventilation System isolation time - The revised value for Main Control Room Ventilation System Isolation (due to high radiation in the Control Building Ventilation intake) was changed from 0 to 20.6 seconds. This includes signal processing time and physical time to isolate the intake.

B. Letdown flowrate revision - In accordance with Westinghouse Nuclear Safety Advisory Letter (NSAL)-00-004, the maximum Iodine production is related to letdown flow rate. It is possible for WBN to utilize both a 45 gpm letdown orifice and a 75 gpm letdown orifice together to obtain 120 gpm. An

additional 4.39 gpm of measurement uncertainty was added to ensure conservatism.

C. RCS Operational leakage - In accordance with Westinghouse letter NSAL-00-004, RCS Operational Leakage must also be considered in the production of Iodine. The WBN Technical Specification limits this value to 11 gpm (10 gpm identified leakage and 1 gpm unidentified leakage).

D. Reduction in RCS Specific Activity - WBN has identified the need to reduce the Technical Specification 3.4.16, RCS Specific Activity, (both steady state and 48 hour spike). In the calculation, the 48-hour value is reduced to 21 μCi/gm and the steady state value is reduced to 0.265 μCi/gm.

E. Primary to secondary leakage - The WBN MSLB dose calculation determined with the steam generator primary to secondary leakage limit of 1 gpm would result in main control room doses and LPZ doses being below the 10 CFR 100 limit and below 10 CFR 50, Appendix A, General Design Criteria (GDC)-19, Control Room, limits.

F. The calculation model was also changed to reflect the steam generator boiling dry to incorporate an NRC comment from the February 7, 2001, teleconference.

As previously stated, COROD, Revision 5 and FENCDOSE, Revision 4 were revised to incorporate more recently issued and more realistic methods. The above methodology changes have been previously approved by NRC for use at other plants. The methodology changes and the above assumptions were discussed in the teleconference calls and the July 17, 2001, meeting. Attachment 2 of this enclosure provide a revised listing of the assumptions for the MSLB dose calculation and Attachment 3 provides the calculation performed by TVA.

ENCLOSURE 1
ATTACHMENT 2

WATTS BAR NUCLEAR PLANT UNIT 1
PROPOSED TECHNICAL SPECIFICATION CHANGE WBN-TS-99-014
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
DOSE CALCULATION SUMMARY

ENCLOSURE 1
ATTACHMENT 2

WATTS BAR NUCLEAR PLANT UNIT 1
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
MAIN STEAM LINE BREAK DOSE CALCULATION SUMMARY

[REVISED ENCLOSURE 3, ATTACHMENT 1 OF SEPTEMBER 18, 2000 LETTER]
It has been previously established in Generic Letter 95-05 that a postulated main steam line break (MSLB) outside of containment but upstream of the main steam isolation valves (MSIVs) represents the most limiting radiological condition relative to the alternate voltage based repair criteria for axial ODSCC.

A calculation has been performed by TVA to determine the permissible steam generator primary-to-secondary leak rate during a steam line break for WBN Unit 1. The calculation determined that 1 gallon per minute (gpm) (at standard temperature and pressure) primary-to-secondary leakage in the faulted steam generator would result in site boundary doses within 10 CFR 100 guidelines and control room doses within the 10 CFR 50, Appendix A, General Design Criteria (GDC) -19 limit. The establishment of the 1 gpm value is controlled by the control room inhalation dose.

The calculation used TVA computer codes STP Revision 6, FENCDOSE Revision 4, and COROD Revision 5. The STP output is used as input to COROD, which determines control room operator dose and FENCDOSE, which is used to determine the 30-day Low Population Zone (LPZ) and the 2-hour Exclusion Area Boundary (EAB) dose.

Two methods of determining the resultant dose for main steam line break were used in accordance with the Standard Review Plan 15.1.5, Appendix A methodology:

1) A pre-accident iodine spike where the iodine level in the reactor coolant spiked upward to the maximum allowable limit of 21 μCi/gm I-131 equivalent (value currently administratively controlled at WBN) just prior to the initiation of the accident.
2) The reactor coolant at the maximum steady state dose equivalent I-131 of 0.265 μCi/gm with an accident initiated iodine spike consisting of a 500 time increase on the rate of iodine release from the fuel.

In both cases, the primary-to-secondary side leak is 150 gallons per day (gpd) in the unfaulted loops, and the secondary side activity is at the WBN Technical Specification LCO 3.7.14 limit of < 0.1 μCi/gm dose equivalent I-131.

Assumptions for the Postulated MSLB accident.

1. RCS Letdown flow of 124.39 gpm is used.
2. RCS Letdown demineralizer efficiency is assumed to be 1.0 for iodines.
3. ANSI/ANS-18.1-1984 spectrum was used and was scaled up to 0.265 or 21 μCi/gm equivalent iodine.

WATTS BAR NUCLEAR PLANT UNIT 1
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
MAIN STEAM LINE BREAK DOSE CALCULATION SUMMARY

4. Two cases were used. In the first, pre-Accident Iodine Spike of 21 μCi/gm dose equivalent I-131 in the RCS was used. In the second case, an accident initiated iodine spike which increases the iodine release rate to a value 500 times greater than the release rate corresponding to the iodine concentration at the equilibrium into the reactor coolant from the fuel rods.
5. Primary side to secondary side leakage of 150 gpd standard temperature and pressure per steam generator in the intact loops.
6. It is assumed that the primary-to-secondary leakage mass release to the environment is 1 gpm standard temperature and pressure from the faulted loop.
7. Steam generator secondary inventory released as steam to the atomosphere:
   1. total from the non-defective steam generators (0 - 2 hr), 480,000 lb
   2. total from the non-defective steam generators (2 - 8 hr), 871,000 lb
   3. total from the faulted steam generator (0 - 30 mins), 150,000 lb and (30 mins - 8 hr), 0 lb
8. Iodine partition coefficients for steaming of steam generator water
   1. non-defective steam generators (initial inventory) and primary-to-secondary leakage, 0.01
   2. faulted steam generator (initial inventory and primary-to-secondary leakage), 1.0
9. Atmospheric dilution factors, χ/Q, are as follows for LPZ (sec/m^3)
   1. 0-2 hr - 1.41E-4
   2. 2-8 hr - 6.68E-5
   3. 8-24 hr - 4.59E-5
   4. 1-4 days - 2.04E-5
   5. 4-30 days - 6.35E-6
10. Atmospheric dilution factor, χ/Q, for 2-hr EAB is 6.07E-4 sec/m^3.
11. Atmospheric dilution factors, χ/Q, (ARCON96) are as follows for the control room (sec/m^3).
    1. 0 - 2 hr 4.03E-3
    2. 2 - 8 hr - 3.35E-3

ENCLOSURE 1
ATTACHMENT 2

WATTS BAR NUCLEAR PLANT UNIT 1
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
MAIN STEAM LINE BREAK DOSE CALCULATION SUMMARY

12. Main Control Room related assumptions
    1. Volume - 257,198 cu ft
    2. Makeup/pressurization flow - 711 cfm
    3. Recirculation flow - 3600 cfm
    4. Unfiltered intake - 51 cfm
    5. Filter efficiency - 95% first pass, 70% second pass, 0% for noble gases
    6. Isolation time, T = 20.6 sec.
    7. Occupancy factors:
        1. 0-24 hr - 100%
        2. 1-4 days - 60%
        3. 4-30 days - 40%

Main Steam Line Break Dose Calculation Results

1 gpm Primary-to-Secondary Leakage (ARCON-96 X/Q)	Control Room Operator (rem)	SRP Guidance for GDC 19 Limits (rem)	30-Day LPZ (rem)	2-Hour EAB (Site boundary) (rem)	SRP Guidance for 10CFR100 Limits (rem)
Accident Initiated Iodine Spike Case (0.265 µCi/gm steady state)					
Gamma:	0.010	5	0.068	0.073	2.5
Beta:	0.076	30	0.0167	0.019	30
Inhalation (ICRP-2):	27.34	30	6.077	5.784	30
Inhalation (ICRP-30):	14.47	30	2.662	2.515	30
TEDE:*	0.504		0.266	0.260	
Pre-Accident Iodine Spike Case (21 µCi/gm max peak)					
Gamma:	0.006	5	0.009	0.028	25
Beta:	0.055	30	0.003	0.009	300
Inhalation (ICRP-2):	22.03	30	1.923	4.952	300
Inhalation (ICRP-30):	12.09	30	1.011	2.527	300
TEDE:*	0.410		0.070	0.185	

* TEDE dose numbers are provided for information only and are not intended to be the Licensing Basis for WBN.

ENCLOSURE 1
ATTACHMENT 3

WATTS BAR NUCLEAR PLANT UNIT 1
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
MAIN STEAM LINE BREAK DOSE CALCULATION

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
B26 931014 409	calculations(nuclear)	T71 010813 801

Calc Title: **Offsite and Control Room Operator Doses Due to a Main Steam Line Break**

CALC ID	TYPE	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISIONAPPLICABILITY
CURRENT	CN	WBN	NTB	WBNAPS3-077	5	6	Entire calc ■ Selected pages ☐
NEW							

ACTION	NEW ☐ REVISION ■	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (D. V. & Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS	SYSTEMS	UNIDS
1/2	NA	NA

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
E-50629A	NA	Essential

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS AFFECTED
Yes ■ No ☐	Yes ■ No ☐	Yes ☐ No ■	Yes ☐ No ■	Yes ☐ No ■	Yes ■ No ☐

PREPARER PHONE NO	PREPARING ORG (BRANCH)	DESIGN VERIFICATION METHOD
751-8122	TVAN Corp Mech Design	Design Review

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Mark C. Berg	8-7-01	Doug Pollock	8/8/01
DESIGN VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
Doug Pollock	8/8/01	Susan M. Brady	8/10/2001

STATEMENT OF PROBLEM/ABSTRACT

This calculation is performed to show that the offsite and control room operator doses do not exceed the 10CFR100 and 10CFR50 App.A GDC 19 dose limits due to a Main Steam Line Break at the Watts Bar Nuclear Plant. The computer code STP determines the activity releases. The STP output is used as input to computer codes FENCDOSE and CORO2 which determine the offsite and control room doses.

There are several cases modeled. Several cases have a pre-accident iodine spike where the iodine level in the reactor coolant is at the 48 hour maximum allowable of 60 or 21 μCi/gm I-131 equivalent. The other cases have the reactor coolant at the maximum steady state I-131 equivalent of 1, 0.265, or 0.177μCi/gm with an accident initiated iodine spike consisting of a 500 increase in the rate of iodine release from the fuel. In both cases, the primary to secondary side leak is 150 gpd in the unfaulted loops, and the secondary side activity is at the Technical Specification limit of 0.1μCi/gm and the primary to secondary side leak in the faulted loop is 10, 5.75, or 2.15 gpm. The Tritium Production Core (TPC) was incorporated. The X/Q values using the Halitsky methodology was used, as well as additional cases using X/Q values as determined by ARCON96. The ARCON96 X/Q values give more limiting results. The following results should ultimately be reflected in the FSAR and Technical Specifications:

In all cases the maximum primary to secondary side leak rate in unfaulted steam generators is 150 gpd/steam generator

using ICRP-2 or ICRP-30:

21 μCi/gm I-131 equivalent 48 hour limit
0.265 μCi/gm I-131 equivalent equilibrium limit
max reactor coolant leak rate: 11gpm (10 ident.,+ 1gpm unident.) prior to accident, 1 gpm in steam gens post accident

See Appendix G for other cases.

Note: these limits are based on a maximum 0.1 uCi/gm I-131 limit in the secondary side and using ARCON96 X/Q values. If the secondary side limit were to be reduced, then the other values will go up. The ARCON96 X/Q values were used to determine the concentrations and leak rates because they bound (produce higher doses than) the current Halitsky X/Q values.

The Tritium Production Core (TPC) does not affect the limits above, because the limiting doses are the thyroid doses. The tritium affects only the beta dose and TEDE. The TPC obviously bounds the non-TPC configuration.

MICROFICHE/EFICHE Yes ■ No ☐ FICHE NUMBER(S) TVA-F-W000220

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TVAN CALCULATION COVERSHEET/CCRIS UPDATE

CALC ID	TYPE	PLANT	BRANCH	NUMBER	REV
	CN	WBN	NTB	WBNAPS3-077	6

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report Yes ■

CATEGORIES

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	CN	WBN	NTB	WBNAPS3-104	
A	P	DN	WBN	NTB	E50629A	
A	P	TS	WBN	MEB	TECH SPEC 3.4.13	
A	P	VD	GEN	MEB	NSAL-00-0004	
A	P	DW	WBN	MEB	1-47W866-4	
A	P	WO	WBN	EEB	WO 94-14264-10	
A	P	DW	WBN	NTB	47E235-46	
A	P	VD	WBN	EEB	WCAP-12096	
A	P	SS	WBN	EEB	WBN NESSD 1-F-62-1	
A	P	IO	GEN	EEB	millers flow eng. handbook	

CCRIS ONLY UPDATES:
Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE

PREPARER PHONE NO.	EDMS ACCESSION NO.

QA Record

ORIGINAL

TVAN CALCULATION COVERSHEET

Title: Offsite and Control Room Operator Doses Due to a Main Steam Line Break		Plant WBN Unit 1/2	Page 1

Preparing Organization: Mechanical Design	Key Nouns (For EDM): MSLB, Offsite, Control Room, STP, COROD, FENCDOSE		
Calculation Identifier: WBNAPS3-077	Each time these calculations are issued, preparer must ensure that the original (R0) RIMS/EDM accession number is filled in.		
	Rev	(for EDM use)	EDM Accession Number
Applicable Design Document(s): NA	R0	Oct 25 1993	B26 931014 409
	R4		B26 000223 411
UNID System(s): NA	R5		T71 000909 802
	R6		

	R0	R4	R5	R6			
					Quality Related?	Yes ■	No ☐
DCN, EDC, NA	NA	50473	50473		Safety related? If yes, mark Quality Related yes	Yes ■	No ☐
Prepared	Marc C. Berg	Marc C. Berg	Marc C. Berg				
Checked	Regis M. Nicoll	Janusz W. Kot	JWKot		These calculations contain unverified assumption(s) that must be verified later?	Yes ☐	No ■
Design Verified	Regis M. Nicoll	Janusz W. Kot	JWKot		These calculations contain special requirements and/or limiting conditions?	Yes ☐	No ■
Approved	Richard J. McMahon	BGBriody	BGBriody		These calculations contain a design output attachment?	Yes ☐	No ■
Approval Date	10/13/93	2/18/2000	9/8/2000		Calculation Classification	Essential	
SAR Affected?	Yes ☐ No ■	Yes ■ No ☐	Yes ■ No ☐	Yes ☐ No ☐	Microfiche generated	Yes ■	No ☐
Revision applicability	Entire calc ■	Entire calc ■ Selected pgs ☐	Entire calc ■ Selected pgs ☐	Entire calc ☐ Selected pgs ☐	Number R5: TVA-F-C000316		

Statement of Problem:
Determine the offsite and control room operator dose due to a Main Steam Line Break (MSLB).

Abstract A Main Steam Line Break at the Watt Bar Nuclear Plant will result in a significant steam release to the environment. This calculation is performed to show that the offsite and control room operator doses do not exceed the 10CFR100 and 10CFR50 App.A GDC 19 dose limits. The computer code STP determines the activity releases. The STP output is used as input to computer codes FENCDOSE and COROD which determine the offsite and control room doses.

There are several cases modeled. The first case has a pre-accident iodine spike where the iodine level in the reactor coolant is at the maximum allowable of 60 μCi/gm I-131 equivalent. The second has the reactor coolant at the maximum steady state I-131 equivalent of 1 μCi/gm with an accident initiated iodine spike consisting of a 500 increase in the rate of iodine release from the fuel. In both cases, the primary to secondary side leak is 150 gpd in the unfaulted loops, and the secondary side activity is at the Technical Specification limit of 0.1μCi/gm and the primary to secondary side leak in the faulted loop is 10 gpm. Additional cases are performed with a maximum leakage, to be determined in this calculation by iteration, so as to not exceed the 10CFR100 or 10CFR50 App.A GDC 19 limits. Finally, the above cases were performed with 10 gpm leak (or maximum leakage with maximum allowable iodine concentration of 60*0.35 = 21 μCi/gm I-131, or with 0.35 μCi/gm I-131 equivalent with 500 factor of spiking.

With the Technical Specification limits of 1 μCi/gm I-131 equivalent steady state (and 60 μCi/gm maximum), the maximum allowable leak so as to not exceed the dose limits was determined to be 15.18 gpm in the faulted line. With the Technical Specification limits of 0.35 μCi/gm I-131 equivalent steady state (and 21 μCi/gm maximum) the maximum allowable leak so as to not exceed the dose limits was determined to be 45.70 gpm in the faulted line.

■ Microfilm and return calculation to Calculation Library: Address:
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☐ Microfilm and destroy.

ORIGINAL

TVAN CALCULATION COVERSHEET

Title: Offsite and Control Room Operator Doses Due to a Main Steam Line Break		Plant WBN Unit 1/2	Page 1

Preparing Organization: Mechanical Design	Key Nouns (For EDM): MSLB, Offsite, Control Room, STP, COROD, FENCDOSE		
Calculation Identifier: WBNAPS3-077	Each time these calculations are issued, preparer must ensure that the original (R0) RIMS/EDM accession number is filled in.		
	Rev	(for EDM use)	EDM Accession Number
Applicable Design Document(s): NA	R0	Oct 25 1993	B26 931014 409
	R4		B26 000223 411
UNID System(s): NA	R5		
	R6		

	R0	R4	R5	R6			
					Quality Related?	Yes ■	No ☐
DCN, EDC, NA	NA	50473			Safety related? If yes, mark Quality Related yes	Yes ■	No ☐
Prepared	Marc C. Berg	Marc C. Berg					
Checked	Regis M. Nicoll	[signature]			These calculations contain unverified assumption(s) that must be verified later?	Yes ☐	No ■
Design Verified	Regis M. Nicoll	[signature]			These calculations contain special requirements and/or limiting conditions?	Yes ☐	No ■
Approved	Richard J. McMahon	[signature]			These calculations contain a design output attachment?	Yes ☐	No ■
Approval Date	10/13/93	2/18/2000			Calculation Classification	Essential	
SAR Affected?	Yes ☐ No ■	Yes ■ No ☐	Yes ☐ No ☐	Yes ☐ No ☐	Microfiche generated	Yes ■	No ☐
Revision applicability	Entire calc ■	Entire calc ■ Selected pgs ☐	Entire calc ☐ Selected pgs ☐	Entire calc ☐ Selected pgs ☐	Number R4: TVA-F-C000296		

Statement of Problem:

Determine the offsite and control room operator dose due to a Main Steam Line Break (MSLB).

Abstract

A Main Steam Line Break at the Watt Bar Nuclear Plant will result in a significant steam release to the environment. The steam will contain radionuclides if a primary to secondary side leak occurs prior to the MSLB event. This calculation is performed to show that the offsite and control room operator doses do not exceed the 10CFR100 and 10CFR50 App.A GDC 19 dose limits. R1 is performed because X/Q values changed. R3 changes the primary to secondary side leak to 150 gpd/steam generator and 10 gpm in the faulted loop.

This calculation used the computer code STP to determine the activity releases. The STP output was used as input to computer codes FENCDOSE and COROD. Computer code FENCDOSE was used to determine the offsite dose. Computer code COROD was used to determine the control room operator dose. This calculation assumed that the reactor had operated with a primary to secondary side leak at the technical specification limit of 150 gpd/steam generator for a duration of 1 year in order to maximize the radionuclide inventory in the secondary side. The primary coolant consisted of expected reactor coolant activity levels (0.12% failed fuel) multiplied by 8 to bring the inventory up to design limits. The base STP model to determine the secondary side activity was taken from WBNAPS3-053. The STP model was modified to add the MSLB steam releases after 1 year of steady state operation with 150 gpd/steam generator primary to secondary side leakage and 10 gpm in the faulted loop. A iodine spike to increase the iodine concentration to 60 uCi/cc prior to the accident is applied. An accident initiated spiking factor of 500 increase in iodine release from the fuel to the reactor coolant was incorporated in the model. The results can be found in the text.

The offsite doses due to a MSLB are significantly less (<10%) than the 10CFR100 limits of 25 rem gamma, 300 rem beta, and 300 rem inhalation. The control room operator doses are also less than the 10CFR50 App.A GDC 19 limits of 5 rem gamma, 30 rem beta, and 30 rem inhalation.

■ Microfilm and return calculation to Calculation Library: Address:
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☐ Microfilm and destroy.

ORIGINAL

TVAN CALCULATION COVERSHEET

Title	Offsite and Control Room Operator Doses Due to a Main Steam Line Break	Plant WBN Unit 1/2	Page 1a

1RH
HCB
12-11-99

Preparing Organization Mechanical Design	Key Nouns (For EDM) MSLB, Offsite, Control Room, STP, COROD, FENCDOSE			
Calculation Identifier WBNAPS3-077	Each time these calculations are issued, preparer must ensure that the original (R0) RIMS/EDM accession number is filled in.			
	Rev	(for EDM use)	EDM Accession Number	
Applicable Design Document(s) NA	R0	Oct 25 1993	B26 931014 409	
	R1	May 15 1995	B26 950501 390	
UNID System(s) NA	R2		B26 950720 359	
	R3		B26 991117 408	

	R0	R1	R2	R3			
					Quality Related?	Yes ■	No ☐
DCN, EDC, NA	NA	NA	NA	~~NA~~ 087 11/16/99 50473	Safety related? If yes, mark Quality Related yes	Yes ■	No ☐
Prepared	Marc C. Berg	Marc C. Berg	Marc C. Berg	Marc C. Berg			
Checked	Regis M. Nicoll	RMNicoll	DGFickey	RMNicoll	These calculations contain unverified assumption(s) that must be verified later?	Yes ☐	No ■
Design Verified	Regis M. Nicoll	RMNicoll	DGFickey	RMNicoll	These calculations contain special requirements and/or limiting conditions?	Yes ☐	No ■
Approved	Richard J. McMahon	FAKoontz, Jr.	PSSmith	[illegible]	These calculations contain a design output attachment?	Yes ☐	No ■
Approval Date	10/13/93	4-27-95	7/20/95	11/17/99	Calculation Classification	Essential	
SAR Affected?	Yes ☐ No ■	Yes ■ No ☐	Yes ■ No ☐	Yes ■ No ☐	Microfiche generated	Yes ☐	No ■
Revision applicability	Entire calc ■	Entire calc ■ Selected pgs ☐	Entire calc ■ Selected pgs ☐	Entire calc ■ Selected pgs ☐	Number		

Statement of Problem:
Determine the offsite and control room operator dose due to a Main Steam Line Break (MSLB).

Abstract

A Main Steam Line Break at the Watt Bar Nuclear Plant will result in a significant steam release to the environment. The steam will contain radionuclides if a primary to secondary side leak occurs prior to the MSLB event. This calculation is performed to show that the offsite and control room operator doses do not exceed the 10CFR100 and 10CFR50 App.A GDC 19 dose limits. R1 is performed because X/Q values changed. R3 adds alternate primary side leak cases of 5 and 10 gpm.

This calculation used the computer code STP to determine the activity releases. The STP output was used as input to computer codes FENCDOSE and COROD. Computer code FENCDOSE was used to determine the offsite dose. Computer code COROD was used to determine the control room operator dose. This calculation assumed that the reactor had operated with a primary to secondary side leak at the technical specification limit of 1 gpm for a duration of 1 year in order to maximize the radionuclide inventory in the secondary side. The primary coolant consisted of expected reactor coolant activity levels (0.12% failed fuel) multiplied by 8 to bring the inventory up to design limits. The base STP model to determined the secondary side activity was taken from WBNAPS3-053. The STP model was modified to add the MSLB steam releases after 1 year of steady state operation with 1 gpm primary to secondary side leakage. The results can be found in the text.

The offsite doses due to a MSLB are significantly less (<<10%) of the 10CFR100 limits of 25 rem gamma, 300 rem beta, and 300 rem inhalation. The control room operator doses are also significantly less than the 10CFR50 App.A GDC 19 limits of 5 rem gamma, 30 rem beta, and 30 rem inhalation.

■ Microfilm and return calculation to Calculation Library: Address: ☐ Microfilm and return calculation to:	☐ Microfilm and destroy.

TVA 10697

CALCULATIONS QA Record

TITLE Offsite and Control Room Operator Doses Due to a Main Steam Line Break			PLANT/UNIT WBN 1/2
PREPARING ORGANIZATION CE/MNE/Analysis	KEY NOUNS (Consult CCRIS LIST) MSLB, Offsite, Control Room, STP, COROD, FENCDOSE		
BRANCH/PROJECT IDENTIFIERS WBNAPS3-077	Each time these calculations are issued, preparers must ensure that the original (R0) RIMS accession number is filled in.		
	Rev	(for RIM'S use)	RIMS accession number
	R0	Oct 25 1993	B26 931014 409
APPLICABLE DESIGN DOCUMENT(S) NA	R1	May 15, 1995	B26 950501 390
	R2	AUG 03 1995 (13)	B26 950720 359
SAR SECTION(S) 15.5 / UNID SYSTEM(S) NA	R3		

Revision 0	R1	R2	R3
ECN No. (or indicate Not Applicable) NA	NA	NA	
Prepared Marc C. Berg	Marc C. Berg	Marc C. Berg	
Checked Regis M. Nicoll	RMNicoll	R. Nicoll	
Reviewed Regis M. Nicoll	RMNicoll	R. Nicoll	
Approved Richard J. McMahon	FAKoontz,Jr	PSSmith	
Date 10/13/93	4-27-95	20 July 95.	
Use form TVA 10534 if more space required. List all pages added by this revision	see rev log	see rev log	
List all pages deleted by this revision	see rev log	see rev log	
List all pages changed by this revision	see rev log	see rev log	

Safety-related? Yes ☑ No ☐

Calculation Revision ☒ Entire Calculation ☐ Selected Pages

Statement of Problem

Determine the offsite and control room operator dose due to a Main Steam Line Break (MSLB).

ORIGINAL

These calculations contain unverified assumption(s) that must be verified later. Yes ☐ No ☑

Calculation contains special requirements or limiting conditions. Yes ☐ No ☑

Abstract

A Main Steam Line Break at the Watt Bar Nuclear Plant will result in a significant steam release to the environment. The steam will contain radionuclides if a primary to secondary side leak occurs prior to the MSLB event. This calculation is performed to show that the offsite and control room operator doses do not exceed the 10CFR100 and 10CFR50 App.A GDC 19 dose limits. R1 is performed because X/Q values changed

This calculation used the computer code STP to determine the activity releases. The STP output was used as input to computer codes FENCDOSE and COROD. Computer code FENCDOSE was used to determine the offsite dose. Computer code COROD was used to determine the control room operator dose. This calculation assumed that the reactor had operated with a primary to secondary side leak at the technical specification limit of 1 gpm for a duration of 1 year in order to maximize the radionuclide inventory in the secondary side. The primary coolant consisted of expected reactor coolant activity levels (0.12% failed fuel) multiplied by 8 to bring the inventory up to design limits. The base STP model to determined the secondary side activity was taken from WBNAPS3-053. The STP model was modified to add the MSLB steam releases after 1 year of steady state operation with 1 gpm primary to secondary side leakage. The results were:

	Control Room Operator [rem]	30-Day LPZ [rem]	2-Hour EAB [rem]
Gamma:	2.854E-5	2.631E-5	9.441E-5
Beta:	3.436E-4	1.866E-5	6.828E-5
Inhalation:	6.817E-4	6.014E-4	2.202E-3

The offsite doses due to a MSLB are significantly less (<<10%) of the 10CFR100 limits of 25 rem gamma, 300 rem beta, and 300 rem inhalation. The control room operator doses are also significantly less than the 10CFR50 App.A GDC 19 limits of 5 rem gamma, 30 rem beta, and 30 rem inhalation.

R2: 13 total pages

☐ Microfilm and store calculations in RIMS Service Center.

☐ Microfilm and return calculations to:

Microfilm and destroy. ☐

Address:

TVAN CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER **WBNAPS3-077**

Title **Offsite and Control Room Operator Doses Due to a Main Steam Line Break**

Revision No.	DESCRIPTION OF REVISION
0	Initial Issue
1	Revision 1 is performed because the X/Q values have changed. R1 pages 6 and 7 are new, and all pages are renumbered. Only changed text have revision bars. pages added: 6, 7 pages changed: all pages deleted: none
2	Revision 2 was performed because of new control room makeup flow (711 cfm). pages added: none pages deleted: none pages changed: 1-7, 9, 13
3	Revision 3 was performed to incorporate larger Technical Specification primary to secondary side leakage as part of the alternate steam generator tube plugging project. Since the final leakage value has not been established, a 5 gpm and a 10 gpm case was performed. All pages were renumbered, however only pages with text changes will have revision bars and will be listed as having been changed: Pages added: none pages deleted: classification forms pages changed: 1-9, 12 R3: 13 total pages
4	Revision 4 was performed to change the iodine partition factor for the faulted steam generator from 100 to 1 to account for steam generator dryout. The steady state preaccident leakage is changed to 150 gpd/steam generator. A preaccident iodine spike of 60 uCi/gm is applied to the reactor coolant. An accident initiated spiking factor of 500 increase in iodine release from the fuel to the reactor coolant was incorporated in the STP model. This revision is part of the corrective action for WBN PER 99-017510-000. Pages added: new coversheet (page 1) Pages deleted: none Pages changed: 1a (old coversheet page 1), 1b (old page 1a), 2-9, 12 R4: 15 total pages
5	Revision 5 is performed to incorporate new iodine production rates, split the iodine spiking model into two separate cases, and also to perform an additional analysis for a maximum Technical Specification limit of 0.35 µCi/gm I-131 equivalent (steady state). The non-steady state maximum limit of 60 µCi/gm I-131 * 0.35 = 21 µCi/gm I-131 is also analyzed. Additionally, the maximum allowable primary to secondary side leakage is determined for all cases. Justification for usage of the ANSI-ANS 18.1-1984 spectrum is also provided. Due to the nature of the revision, all pages were changed, with significant additions (Appendix A, and Attachment 1). Pages added: all pages deleted: all pages changed: all R5: 27 total pages
6	Revision 6 is performed to add the Tritium Production Core (TPC) with a two TPBAR failure, add a 0.265 and 0.177 µCi/gm I-131 equivalent steady state with factor of 500 iodine spike case (and deleted the 0.35 µCi/gm case), add 21 µCi/gm I-131 equivalent 48 hour maximum case, change the noble gas inventories to the maximum allowable based on 100/Ebar, add ARCON96 X/Q values (also use Halitsky X/Q values), and to use the latest versions of COROD (R5) and FENCDOSE (R4) which now determine thyroid doses based on ICRP-2 and ICRP-30 as well as now determines the TEDE. Add a second actual measurement of reactor coolant inventories. Incorporated NISYS and Westinghouse 3rd party review comments. Due to the nature of the changes, all pages were renumbered. Actual text changes are indicated with revision bars. **The results of this calculation affect the FSAR and Technical Specifications.** Pages added: all Pages deleted: all Pates changed: all R6: 60 total pages These changes will be incorporated by the corrective action plan for PER 00-012545-000. JPR 8/10/01

TVAN CALCULATION TABLE OF CONTENTS

Calculation Identifier: **WBNAPS3-077**	Revision: 6	

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TVAN CALCULATION DESIGN VERIFICATION FORM

Calculation Identifier **WBNAPS3-077** Revision 6

Method of design verification used:

1. Design Review ☒
2. Alternate Calculation ☐
3. Qualification Test ☐

Design Verifier David G. Mosby Date 6-28-01

DAVID G. MOSBY (NISYS CORP.)

(770) 518-8680

Comments:

Reviewed inputs and assumptions, methodology, and results for reasonableness and consistency and compliance with requirements. Spot checked several calculational steps and reviewed inputs to selected computer code cases.

Calculation results are accurate and results as expected. Results are conservative and comply with requirements.

After above review, another case was run involving changing the Primary to Secondary Leakage from SG to environment to 1gpm and keeping the flow rate used in the calculation of production of iodine at 10gpm. These both are technical specifications, methodology used prior to this case will lower the technical specification of RCS Leakage but increase the SG leakage. This case shows that current limits are acceptable, Results + inputs were checked and found to be acceptable. Only this case was reviewed by me.

D Jay Pollock 7/20/01

This calculation was reformatted after above reviews to only give the ~~results~~ results for the 10/1 gpm case in the main body, and give rest of previous results in an Appendix. No technical changes were made.

D Jay Pollock 8/8/01

DJP 8/8/01

TVAN COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document **WBNAPS3-077**	Rev. 6	Plant: WBN	

Subject:
Offsite and Control Room Operator Doses Due to a Main Steam Line Break

☐ Electronic storage of the input files for this calculation is not required. Comments:

■ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

The R1 input files are archived on FILEKEEPER under reference I.D.# 263447

The R2 input files are archived on FILEKEEPER under reference I.D.# 263715

The R3 input files are permanently stored in FILEKEEPER file # 302577

The R4 input files are permanently stored in FILEKEEPER file # 302740

The R5 input files are permanently stored in FILEKEEPER file # 303180

The R6 input files are permanently stored in FILEKEEPER file # 303611

☐ Microfiche/eFiche

TVAN COMPUTER OUTPUT
MICROFICHE INFORMATION SHEET

Document	WBNAPS3-077	Rev. 6	Plant: WBN

Subject:
Offsite and Control Room Operator Doses Due to a Main Steam Line Break

Microfiche	Description
R0 TVA-F-G104614	R0 Computer Runs see R5 for listing
R1: TVA-F-C000078	R1 Computer Runs see R5 for listing
R2: TVA-F-C000119	R2 Computer Runs see R5 for listing
R3: TVA-F-C000294	R3: Computer Runs see R5 for listing
R4: TVA-F-C000301	R4: Computer Runs see R5 for listing
R5: TVA-F-C000316	R5: Computer Runs see R5 for listing
R6: TVA-F-W000220	R6: Computer Runs: APS77S6# STP source terms APS77C6# COROD control room dose APS77F6# FENCDOSE offsite dose where #=: A = 60 μCi/gm with 10 gpm primary to secondary side leak, Halitsky X/Q B= 1 μCi/gm with 10 gpm primary to secondary side leak and 500 I spike, Halitsky X/Q C= 21 μCi/gm with 10 gpm primary to secondary side leak, Halitsky X/Q D= 11 μCi/gm with 10 gpm primary to secondary side leak, Halitsky X/Q E= 21 μCi/gm with 5.75 gpm primary to secondary side leak, Halitsky X/Q F= 21 μCi/gm with 10 gpm primary to secondary side leak, 1 gpm SG leak, Halitsky X/Q G= 0.265 μCi/gm with 10 gpm primary to secondary leak, 500 I spike, 1gpm SG leak Halitsky X/Q H= 21 μCi/gm with 2.15 gpm primary to secondary side leak, Halitsky X/Q I= 0.265 μCi/gm with 10 gpm primary to secondary side leak and 500 I spike, Halitsky X/Q J= 0.265 μCi/gm with 5.75 gpm primary to secondary side leak and 500 I spike, Halitsky X/Q K= 0.177 μCi/gm with 10 gpm primary to secondary side leak and 500 I spike, Halitsky X/Q L= 0.177 μCi/gm with 2.15 gpm primary to secondary side leak and 500 I spike, Halitsky X/Q M = 60 μCi/gm with 10 gpm primary to secondary side leak, ARCON96 X/Q N= 1 μCi/gm with 10 gpm primary to secondary side leak and 500 I spike, ARCON96 X/Q O= 21 μCi/gm with 10 gpm primary to secondary side leak, ARCON96 X/Q P= 11 μCi/gm with 10 gpm primary to secondary side leak, ARCON96 X/Q Q= 21 μCi/gm with 5.75 gpm primary to secondary side leak, ARCON96 X/Q R= 21 μCi/gm with 10 gpm primary to secondary side leak, 1 gpm SG leak, Halitsky X/Q S= 0.265 μCi/gm with 10 gpm primary to secondary leak, 500 I spike, 1gpm SG leak Halitsky X/Q T= 21 μCi/gm with 2.15 gpm primary to secondary side leak, ARCON96 X/Q U= 0.265 μCi/gm with 10 gpm primary to secondary side leak and 500 I spike, ARCON96 X/Q V= 0.265 μCi/gm with 5.75 gpm primary to secondary side leak and 500 I spike, ARCON96 X/Q W= 0.177 μCi/gm with 10 gpm primary to secondary side leak and 500 I spike, ARCON96 X/Q X= 0.177 μCi/gm with 2.15 gpm primary to secondary side leak and 500 I spike, ARCON96 X/Q Z= 0.177 μCi/gm with 2.15 gpm primary to secondary side leak and 500 I spike, ARCON96 X/Q, Note: All cases except for "Z" are for the TPC. The "Z" is for the conventional core.

Purpose

The purpose of this calculation is to determine the offsite and control room operator dose due to a Main Steam Line Break (MSLB). The results will be used in FSAR ch.15.5 to show compliance with 10CFR100 and 10CFR50 App.A GDC 19. This calculation also establishes the maximum primary to secondary side leakage and the maximum I-131 equivalent concentrations in the primary and secondary side coolant.

Revision 6 is performed to incorporate the Tritium Production Core (TPC). The previous revision computer runs were redone with tritium (in the reactor coolant due to two TPBAR failure, which is the bounding case for normal and abnormal operation). The control room operator doses were performed with two sets of X/Q values: 1) the original Halitsky methodology X/Q (the current licensing basis of the plant as of June 2001) and 2) the newer ARCON96 X/Q values as found in WBNAPS3-104 (ref.20). The different X/Q methods are performed because the plant may transition from Halitsky to ARCON96 X/Q methodologies in the future. The main calculation has the primary side I-131 concentration at 0.265μCi/gm (with a maximum preaccident spike of 21 μCi/gm I-131) with a maximum of 10 gpm known reactor coolant leakage, plus 1 gpm unknown, with a maximum 1 gpm post accident primary to secondary side leak in the steam generators. Additional cases were performed in Appendix G for the steady state I-131 equivalent limit of 1.0 and 0.177 μCi/gm, and also cases with 60 and 11 μCi/gm I-131 equivalent maximum. These cases were performed to help establish possible future Technical Specification limits. The latest versions of COROD (R5) and FENCDOSE (R4) were used which determines thyroid doses based on ICRP-2, ICRP-30 and also performs the TEDE. Finally, the noble gas concentrations are increased to the maximum allowable based on 100/Ebar calculations.

Introduction

A Main Steam Line Break at the Watts Bar Nuclear Plant will result in a significant steam release to the environment. The steam will contain radionuclides if a primary to secondary side leak occurs prior to the MSLB event. This calculation is performed to show that the offsite and control room operator doses do not exceed the 10CFR100 and 10CFR50 App.A GDC 19 dose limits.

This calculation uses the computer code STP (ref.3) to determine the activity releases. The STP output is used as input to computer codes FENCDOSE and COROD. Computer code FENCDOSE (ref.4) is used to determine the offsite dose. Computer code COROD (ref.5) is used to determine the control room operator dose. The base FENCDOSE and COROD models are taken from WBNTSR-008 (ref.9).

There are several cases modeled. The first case has a pre-accident iodine spike where the iodine level in the reactor coolant is at the maximum allowable of 21 μCi/gm I-131 equivalent (ref.1). The second has the reactor coolant at the maximum steady state I-131 equivalent of 0.265 μCi/gm with an accident initiated iodine spike consisting of a 500 increase in the rate of iodine release from the fuel. In both cases, the primary to secondary side leak is 150 gpd in the unfaulted loops, and the secondary side activity is at the Technical Specification limit of 0.1μCi/gm and the primary to secondary side leak in the faulted loop is 1 gpm which flows directly to the environment to simulate steam generator dryout. To establish the I release rate from the fuel, a preaccident 10 gpm known reactor coolant leak is used with a 1 gpm unknown leak for a total of 11 gpm. Additional cases are performed in Appendix G with a maximum leakage other than 10 gpm (to be determined in this calculation by iteration) so as to not exceed the 10CFR100 or 10CFR50 App.A GDC 19 limits. Finally, other cases were performed in Appendix G with 10 gpm leak (or other maximum leakage, to be determined by trial and error) with maximum allowable iodine concentration of 60μCi/gm I-131, or 11 μCi/gm I-131, or with 1.0, or 0.177 μCi/gm, I-131 equivalent with 500 factor of spiking. These extra cases were performed so as to give additional information for possible future changes in Technical Specifications. In all of the cases in Appendix G, except for two cases in the main text, the steady state reactor coolant leakage (all identified leakage) prior to the accident is the same as the maximum allowable primary to secondary side leakage in the steam generators. The unidentified reactor coolant leakage (1 gpm) is not included in the steam generator leakage. The exception to the above is main text cases where the maximum reactor coolant leakage is 11 gpm (10 gpm identified + 1 gpm unidentified) prior to the accident, and a maximum of 1 gpm in the steam generators post accident. The relative isotopic spectrum is taken from WBNNAL3-003 (Reactor Coolant Activities in Accordance with ANSI/ANS-18.1-1984). Justification of the usage of this spectrum as opposed to the historical design spectrum as found in chapter 11 of the FSAR can be found in Appendix A.

Assumptions

1. The primary side to secondary side leakage is 150 gpd/steam generator, steady state, with 10 gpm (or maximum leak rate determined so as not to exceed the 10CFR100 or 10CFR50 App.A GDC 19 dose limits) on the faulted steam generator starting at the beginning of the accident.

Technical Justification: 150 gpd/steam generator and the 10 gpm (or other value based on this calculation) are for potential future Technical Specification changes. These values are assumed values for this analysis.

2. The maximum letdown of 120 gpm (ref.16) + 4.39 gpm uncertainty for a total of 124.39 gpm is used.

Technical Justification: This will maximize the removal rate of iodines from the primary coolant, and therefore will maximize the production rate of iodine (production = removal at steady state) and is consistent with NSAL-00-004. See Calculation section for the formulas used. Note, this value is used for calculation of iodine production/removal rates. The letdown is assumed to be isolated at the beginning of the accident to maximize the reactor coolant inventories. The uncertainty of 4.39 gpm is determined in Appendix B.

3. The primary to secondary side leak rates and letdown flow rates are based on Standard Temperature and Pressure (STP).

Technical Justification: STP conditions will result in higher densities, therefore higher masses, especially when determining the production rate of iodines.

4. It is assumed that the faulted steam generator dries out at the start of the accident, resulting in an iodine partition factor of 1.0 per ref.10.

Technical Justification: Following an accident, the Main Steam Line will be isolated and the Main and Auxiliary Feedwater will also be isolated. Since the worst case accident occurs with the line associated with a Steam Generator with Technical Specification leakage, that Steam Generator will dry out. In reality, this dry out will not occur until all feedwater has been isolated, and the water boiled off. Assuming dry out conditions at time zero is clearly conservative.

5. In the intact steam generators, the iodine partition factor is assumed to be 100.

Technical Justification: The mass of primary to secondary leakage which occurs to the intact steam generators is small relative to the mass of secondary coolant. Therefore none of this leakage is assumed to flash and the release to the environment is through the steaming process. Reference 10 allows a partition factor of 100 for such cases.

6. A preaccident iodine spike of 21 μCi/gm I-131 equivalent is assumed at the start of the accident. In other cases, an accident initiated iodine spike of 500 increase in the iodine release rate from the fuel is assumed in the accident initiated case with the reactor coolant starting at 0.265 μCi/gm I-131 equivalent.

Technical Justification: SRP 15.1.5 subsection 4a specifies the maximum allowable preaccident spike is required (60 μCi/gm is permissible for 48 hours. This case is performed in Appendix G. The 21 μCi/gm case is performed in the main text which is to support future Tech Spec changes). SRP 15.1.5 subsection 4b specifies that following an accident, the iodine release rate from the fuel to the reactor coolant is increased by a factor of 500. The various cases were performed to provide the leakages and concentrations which would result in acceptable control room and offsite doses.

7. The letdown demineralizer efficiency is assumed to be 1 for iodines.

Technical Justification: This will maximize iodine removal (=production) rate, and therefore result in larger iodine spiking.

8. The control room isolates in 20.6 seconds (ref.9) due to high radiation in the Control Building Ventilation intake (400 cpm, ref.18). This will result in an unfiltered puff into the control room for that 20.6 seconds.

Technical Justification: This is based on 14 seconds closure time of the dampers, plus 6.6 seconds instrument response time.

9. The tritium inventory in the TPC assumes 2 TPBAR failures (98.4 μCi/gm in the reactor coolant, per WBNNAL3-003, ref.2).

Technical Justification: This will maximize the tritium release.

10. The iodine production rate is based on 10 gpm identified primary side leakage (all leaks) plus 1 gpm unidentified leak, for a total of 11 gpm.

Technical Justification: This is per Technical Specification 3.4.13 (ref.21), or a potential modification for the Technical Specification, and maximizes the iodine production rates. This methodology is consistent with NSAL-00-004, ref.22.

11. It is assumed that the secondary side concentrations are at the maximum of 0.1 μCi/gm I-131 equivalent.

Technical Justification: This is the maximum allowed by the Technical Specifications (ref.23) and is conservative.

12. The noble gas inventories are maximized by scaling them up to 100/Ebar.

Technical Justification: This maximizes the noble gas inventories. 100/Ebar is the Technical Specification limit.

13. It is assumed that there are no fuel failures associated with the accident.

Technical Justification: This accident will not uncover the core, therefore the core will not see extreme temperatures which would lead to fuel failure.

Special Requirements/Limiting Conditions

There are no special requirements or limiting conditions in this calculation.

Calculations

The STP models consist of a pre-accident iodine spike (see figure 1) model and an accident initiated iodine spike model (see figure 2). The model(s) consist of the following:

Volumes:

#1: Reactor Coolant: 5.4E5 lb (ref.2) = 2.4494E8 gm

#2: Steam Generator w/Leak: 4.745E7 gm (ref.6, note, this value should be 4.735E7, however this difference will not affect any answers since this component is not used in the models)

#3: Steam Generators w/out Leak: 1.424E8 (ref.6, note this value should be 1.421E8, however this will not significantly affect the results since it is less than 1% off).

#4: Environment: 1 gm (arbitrary) (This volume is made into an accumulator through the "A" card to suppress radioactive decay)

Step Sources:

The following equation is used to set up the initial activities (in Ci) for each component using the initial ANSI/ANS-18.1-1984 source modified for WBN operational parameters (which is in units of μCi/gm):

S = Component Volume [gm] * 1E-6 Ci/μCi * I-131 equivalent conversion factor

To obtain the I-131 equivalent conversion factor, the ANSI/ANS-18.1-1984 spectrum must be converted to I-131 equivalence. See Appendix A for justification for using the ANSI/ANS-18.1-1984 spectrum. From WBNTSR-008, the I-131 equivalence is:

I-131 equivalent = dose conversion factor (D/A) * concentration / I-131 dose conversion factor

	D/A mrads/Ci (ref.9)	μCi/gm coolant ANSI-18.1 (ref.2)	I-131 equivalent μCi/gm	1 μCi/gm I-131 equivalent (validation)
1-131	1.48E+09	4.77E-02	4.77E-02	3.80E-01
1-132	5.35E+07	2.25E-01	8.13E-03	6.48E-02
1-133	4.00E+08	1.49E-01	4.03E-02	3.21E-01
1-134	2.50E+07	3.64E-01	6.15E-03	4.90E-02
1-135	1.24E+08	2.78E-01	2.33E-02	1.86E-01
total		1.06E+00	1.255E-01	1.000E+00
		inverse	7.965E+00	

The above table shows that the I-131 equivalent concentration of the initial RCS ANSI 18.1 source term is 0.1255 uCi/gm, as compared to 1 uCi/gm when the RCS is at the TS allowable concentration. Consequently, to ratio the initial source term up to the TS allowable values, the ANSI 18.1 concentrations must be multiplied by 1/0.1255 or 7.965. Note: this equivalence is based on ICRP-2 iodine dose conversion factors because this is what Chemistry uses. Some of the final dose results are based on ICRP-30. Utilizing the different ICRP conversion factors in this case is appropriate because in the above case, the ICRP-2 establishes the inventories, which is independent of determination of doses due to releases.

For the secondary side concentrations from WBNNAL3-003, the same procedure is performed to determine the I-131 equivalence:

	D/A mrads/Ci	μCi/gm secondary side, water ANSI 18.1	I-131 equivalent μCi/gm
1-131	1.48E+09	1.41E-06	1.41E-06
1-132	5.35E+07	3.37E-06	1.22E-07
1-133	4.00E+08	4.03E-06	1.09E-06
1-134	2.50E+07	2.93E-06	4.95E-08
1-135	1.24E+08	6.19E-06	5.19E-07
total		1.79E-05	3.189E-06
		inverse	3.136E+05

To convert to I-131 equivalence, the secondary side I-131 equivalent conversion factor is (1/3.189E-6) = 3.136E5 gm/μCi (Note: since there is no Technical Specification limit on gross activity for the secondary side like the 100/Ebar for the primary side, this factor is also applied to the secondary side noble gasses in order to retain the proper isotopic ratios).

The isotopes other than iodine in the primary coolant must also be scaled up. In NUREG-0800 R2 Chapter 15.6.3, section III.5 states "The reviewer assumes the primary and secondary coolant activity concentrations allowed by the technical specifications." Reference 3 (of the NUREG-0800) states the following "The specific activity of the reactor coolant shall be limited to: a. Less than or equal to 1 microCurie per gram DOSE EQUIVALENT I-131, and b. Less than or equal to 100/E microCuries per gram of gross activity."

Given the above considerations, the isotopic spectrum found in WBNNAL3-003 was examined. The 100/E values for this particular spectrum are determined in the following Table:

Table 2: Determination of 100/EBAR

Isotope	A(i) Activity [uCi/gm]	E(i) Beta Energy [MeV/dis]	E(i) Gamma Energy [MeV/dis]	E(i) Total	A(i)*E(i)
Kr-85m	1.71E-01	2.5290E-01	1.5862E-01	4.1152E-01	7.04E-02
Kr-85	2.66E-01	2.5060E-01	2.2102E-03	2.5281E-01	6.73E-02
Kr-87	1.61E-01	1.3237E+00	7.9284E-01	2.1165E+00	3.40E-01
Kr-88	3.00E-01	3.7500E-01	1.9629E+00	2.3379E+00	7.01E-01
Xe-131m	6.54E-01	1.4280E-01	2.0058E-02	1.6286E-01	1.06E-01
Xe-133m	7.17E-02	1.8980E-01	4.1559E-02	2.3136E-01	1.66E-02
Xe-133	2.53E+00	1.3540E-01	4.5385E-02	1.8079E-01	4.57E-01
Xe-135m	1.39E-01	9.5000E-02	4.3176E-01	5.2676E-01	7.35E-02
Xe-135	9.04E-01	3.1680E-01	2.4696E-01	5.6376E-01	5.10E-01
Br-84	1.72E-02	1.2842E+00	1.6816E+00	2.9658E+00	5.09E-02
Rb-88	2.04E-01	2.0617E+00	6.8631E-01	2.7480E+00	5.60E-01
Cs-134	7.39E-03	1.5690E-01	1.0361E+00	1.1930E+00	8.82E-03
Cs-136	9.08E-04	1.0140E-01	2.1985E+00	2.2999E+00	2.09E-03
Cs-137	9.79E-03	1.8840E-01	0.0000E+00	1.8840E-01	1.84E-03
Na-24	4.99E-02	5.5460E-01	4.1216E+00	4.6762E+00	2.33E-01
Cr-51	3.26E-03	3.7540E-03	3.2763E-02	3.6517E-02	1.19E-04
Mn-54	1.68E-03	4.1670E-03	8.3592E-01	8.4009E-01	1.41E-03
Fe-55	1.26E-03	4.1920E-03	1.5291E-03	5.7211E-03	7.22E-06
Fe-59	3.16E-04	1.1800E-01	1.1923E+00	1.3103E+00	4.14E-04
Co-58	4.84E-03	2.0490E-01	9.7586E-01	1.1808E+00	5.72E-03
Co-60	5.58E-04	9.6840E-02	2.5043E+00	2.6011E+00	1.45E-03
Zn-65	5.37E-04	6.8940E-03	5.8169E-01	5.8858E-01	3.16E-04
Sr-89	1.47E-04	5.7300E-01	1.3636E-04	5.7314E-01	8.44E-05
Sr-90	1.26E-05	1.9630E-01	0.0000E+00	1.9630E-01	2.48E-06
Sr-91	1.02E-03	6.5050E-01	6.9508E-01	1.3456E+00	1.37E-03
Y-90	1.26E-05	9.3610E-01	0.0000E+00	9.3610E-01	1.18E-05
Y-91m	4.93E-04	0.0000E+00	5.5557E-01	5.5557E-01	2.74E-04
Y-91	5.47E-06	6.0600E-01	3.6147E-03	6.0961E-01	3.34E-06
Y-93	4.46E-03	1.1721E+00	8.9414E-02	1.2615E+00	5.63E-03
Zr-95	4.10E-04	1.1990E-01	7.3474E-01	8.5464E-01	3.51E-04
Nb-95	2.95E-04	4.4970E-02	7.6430E-01	8.0927E-01	2.38E-04
Mo-99	6.75E-03	3.9570E-01	1.6238E-01	5.5808E-01	3.77E-03
Tc-99m	5.01E-03	4.8500E-03	1.4263E-01	1.4748E-01	7.38E-04
Ru-103	7.89E-03	6.7400E-02	4.8394E-01	5.5134E-01	4.35E-03
Ru-106	9.47E-02	1.0100E-02	0.0000E+00	1.0100E-02	9.57E-04

Determination of 100/EBAR - continued

Isotope	A(i) Activity [uCi/gm]	E(i) Beta Energy [MeV/dis]	E(i) Gamma Energy [MeV/dis]	E(i) Total	A(i)*E(i)
Rh-103m	7.89E-03	3.4620E-02	2.2148E-05	3.4642E-02	2.73E-04
Rh-106	9.47E-02	7.0960E-01	2.0348E-01	9.1308E-01	8.65E-02
Te-129m	2.00E-04	1.9150E-01	9.4832E-02	2.8633E-01	5.73E-05
Te-129	2.57E-02	5.2260E-01	5.9948E-02	5.8255E-01	1.50E-02
Te-131m	1.59E-03	2.1240E-01	1.4092E+00	1.6216E+00	2.57E-03
Te-131	8.26E-03	7.5970E-01	4.1616E-01	1.1759E+00	9.71E-03
Te-132	1.79E-03	1.0020E-01	2.0507E-01	3.0527E-01	5.47E-04
Ba-137m	9.79E-03	6.4260E-02	5.9729E-01	6.6155E-01	6.48E-03
Ba-140	1.37E-02	3.1500E-01	1.9522E-01	5.1022E-01	6.98E-03
La-140	2.64E-02	5.4050E-01	2.3074E+00	2.8479E+00	7.52E-02
Ce-141	1.58E-04	1.6930E-01	1.0181E-01	2.7111E-01	4.28E-05
Ce-143	2.96E-03	3.8420E-01	3.4335E-01	7.2755E-01	2.15E-03
Ce-144	4.21E-03	9.1300E-02	3.2865E-02	1.2417E-01	5.23E-04
Pr-143	2.96E-03	3.1430E-01	0.0000E+00	3.1430E-01	9.30E-04
Pr-144	4.21E-03	1.2258E+00	3.1010E-02	1.2568E+00	5.29E-03
Np-239	2.32E-03	1.2380E-01	2.0845E+00	2.2083E+00	5.13E-03
Total	5.82E+00				3.44E+00
				EBAR	5.91E-01
			RCS Specific Activity Limit		169.14

The definition of EBAR or E is as follows: "E shall be the average (weighted in proportion to the concentration of each radionuclide in the reactor coolant at the time of sampling) of the sum of the average beta and gamma energies per disintegration (in MeV) for isotopes, other than iodines, with half lives greater than 15 minutes, making up at least 95% of the total non-iodine activity in the coolant."

The values for E_i in the above table were obtained from reference 9 and the values for A_i are from WBNNAL3-003. The value of E is determined as follows:

$$Ebar = E = (\Sigma A_i E_i) / (\Sigma A_i)$$

The value for E calculated in Table 2 is 0.591 MeV/dis. This results in a non-iodine specific activity limit (100/E) of 169.14 μCi/g. The total specific activity of the expected coolant is 5.82 μCi/g.

Therefore, the values for noble gasses in the design reactor coolant will have to be increased by a factor of 169.14/5.82 = 29.06.

The step sources (Ci-gm/µCi) to initialize the reactor coolant and the secondary side activities are:

All cases:

S=2.4494E8 gm*1E-6 Ci/µCi * 29.06 =7.118E3 (noble gasses)

S=2.4494E8 gm*1E-6 Ci/µCi = 2.4494E2 (tritium)

Pre-accident iodine spike case (initial concentration = 21 µCi/gm):

S=2.4494E8 gm*1E-6 Ci/µCi * 7.965[µCi/gm I-131]$^{-1}$ *21µCi/gm I-131 = 4.097E4 (iodines)

Accident initiated iodine spike case (initial concentration = 0.265 µCi/gm):

S=2.4494E8 gm*1E-6 Ci/µCi * 7.965 [µCi/gm I-131]$^{-1}$*0.265 µCi/gm I-131= 5.170E2

Secondary side, all cases, steam generator w/ leak, release to environment. (concentration = 0.1µCi/gm) which is due to dryout (from reference 8, the steam released for a 1 gpm primary to secondary leak case from the defective steam generator is 150,000 lb):

S = 150,000 lb *453.59 g/lb * 1E-6 Ci/µCi * 3.136E5 [µCi/gm I-131]$^{-1}$* 0.1µCi/gm I-131 = 2.1337E6

S = 150,000 lb *453.59 g/lb * 1E-6 Ci/µCi = 6.8039E1 (tritium)

Secondary side, all cases, steam generators without leak (initial concentration = 0.1 µCi/gm):

S = 1.424E8 gm * 1E-6 Ci/µCi * 3.136E5 [µCi/gm I-131]$^{-1}$* 0.1µCi/gm I-131 = 4.466E6

S = 1.424E8 gm*1E-6 Ci/µCi = 1.424E2 (tritium)

Continuous Sources:

For the accident initiated iodine spike case, the iodine spike is 500 times the iodine release rate from the fuel. At steady state, the iodine release (production) rate is equal to the removal rate. The iodine removal is due to a) radioactive decay, b) removal by the letdown system, and c) removal through reactor coolant leakage. These terms are expressed as:

$P = \Sigma$removal rates = decay + letdown + leakage

or $P = \lambda + f_L\varepsilon/V + p_s/V$

where P = production rate [hr^{-1}]

λ = decay constant for the isotope in question [hr^{-1}] = $\ln(2)/T_{1/2}$

f_L = letdown flow rate = 120 gpm + 4.39 gpm = 124.39 gpm

ε = letdown demineralizer efficiency = 1 (assumed so as to maximize removal/production rate)

V = volume of primary coolant = 5.4E5 lb

p_s = removal rate of iodine from the primary side due to preaccident primary side leakage = 11 gpm (10 gpm identified + 1 gpm unidentified)

$T_{1/2}$ = halflife taken from ref.15

Note: all the above flow rates are converted to mass flow rates at STP:

Production Rates for a Reactor Coolant Leak of 11 gpm (10 gpm identified + 1 gpm unidentified)

	Half Life	λ [1/hr]	$f_L\varepsilon/V$ [1/hr]	p_s/V [1/hr]	prod rate P [1/hr]
I-131	8.04 d	3.59E-03	1.15E-01	1.02E-02	0.1291
I-132	2.28 h	3.04E-01	1.15E-01	1.02E-02	0.4296
I-133	20.9 h	3.32E-02	1.15E-01	1.02E-02	0.1587
I-134	52.6 m	7.91E-01	1.15E-01	1.02E-02	0.9162
I-135	6.61 h	1.05E-01	1.15E-01	1.02E-02	0.2304

The accident initiated iodine spike of 500 times the increase in the iodine release (production) rate from the fuel is modeled as a continuous source:

C = Volume * 1E-6 Ci/μCi * Prod. Rate * 500 * 1 μCi/gm I-131 equiv. conversion factor*I-131 equiv.

where Volume = 2.4494E8 gm

Prod Rate = see table above

1 μCi/gm I-131 equivalent conversion factor = 7.965 (value determined above, this is to get the ANSI/ANS-18.1-1984 source into 1 μCi/gm I-131 equivalent

I-131 equiv. = 0.265 μCi/gm I-131

Continuous Source [gm-Ci/μCi-hr] for Accident Initiated Iodine Spike:

Reactor Coolant Leak of 11 gpm (10 gpm identified + 1 gpm unidentified)

case:	0.265 μCi/gm I-131
I-131	3.338E+04
I-132	1.110E+05
I-133	4.103E+04
I-134	2.368E+05
I-135	5.956E+04

Flow Rates:

The following flow rates/leakage rates for each component are (determined by trial and error with the ultimate goal being to find the flow/leak which would lead to the offsite/control room doses reaching the regulatory limits):

Flow from Reactor Coolant #1 to Environment #4 all classes (10 gpm case):

F = 10 gpm * 60 min/hr * 3785.48 cc/gal * 1g/cc = 2.271E6 g/hr

Flow from Reactor Coolant #1 to Environment #4 all classes (1 gpm case, note that this case is for 1 gpm leak in the steam generators, however the production rate of iodines is based on 11 gpm=10gpm identified +1gpm unidentified):

F = 1 gpm * 60 min/hr * 3785.48 cc/gal * 1g/cc = 2.271E5 g/hr

Flow from Reactor Coolant #1 to Steam Generator w/ no Leak #3 all classes:

F = 3 steam generators * 150 gpd * 3785.48 cc/gal / 24 hr/day * 1g/cc = 7.098E4 g/hr

From reference 8, the steam released for a 1 gpm primary to secondary leak case from the defective steam generator is 150,000 lb (0-30 min), and 1000 lb (30 min - 8 hr), and from the non-defective steam generators (= "steam generators without leak" in this model) is 480,000 lb (0-2 hr), and 871,000 lb (2-8 hr). The accident releases end at eight hours. From reference 11 and 12, the steam released for a 10 gpm primary to secondary leak case is an additional 2509 lb (at STP) in the 0-30 min time period, and a total of 42290 lb (at STP) from 30 min to 8 hr. To take into account uncovery of the faulted steam generator, there is no iodine partitioning in the release to the environment (iodine partition coefficient = 1). The mass release representing 10 gpm primary to secondary side leak is a flow directly to the environment. This is reflected in the flows listed above. For other leak rates, the flow cards will correctly take into account the mass released.

The reactor coolant release to the unfaulted steam generator is small relative to the secondary side mass, therefore partitioning is allowed per the SRP. The iodine partition coefficient due to steaming for the unfaulted steam generators to the environment is 100. These mass releases translate into the following flows:

Flow from Steam Generators w/out Leak #3 to Environment #4:

F = (480,000 lb)(453.59 g/lb)/(2 hr) = 1.0886E8 g/hr (0-2 hr, noble gasses, tritium)

F = (480,000 lb)(453.59 g/lb)/(100*2 hr) = 1.0886E6 g/hr (0-2 hr, iodines)

F = (871,000 lb)(453.59 g/lb)/(6 hr) = 6.5846E7 g/hr (2-8 hr) (noble gasses, tritium)

F = (871,000 lb)(453.59 g/lb)/(100*6 hr) = 6.5846E5 g/hr (2-8 hr) (iodines)

The STP output is used as input to COROD (which determines control room operator dose) and FENCDOSE (which determines 30-day and 2-hour LPZ offsite dose).

Some pertinent information from the COROD and FENCDOSE models used (but not changed) in this analysis are (from ref.9):

30-day LPZ Offsite X/Q values [sec/cum]: 1.41E-4 0-2hr, 6.68E-5 2-8 hr, 4.59E-5 8-24 hr, 2.04E-5 1-4 day, 6.35E-6 4-30 day

2-hr EAB X/Q values: 6.07E-4

Control Room X/Q (Halitsky method): 4.07E-3 0-2 hr, 2.47E-3 2-8 hr, 1.68E-3 8-24 hr, 1.18E-3 1-4 day, 8.89E-4 4-30 day (note: the 8+ hr X/Q values take into account control room vent switching, however it is not important what values are used since there are no 8+ hr releases.)

Control Room X/Q (ARCON96 method): 4.03E-3 0-2 hr, 3.35E-3 2-8 hr, 2.27E-4 8-24 hr, 1.81E-4 1-4 day, 1.45E-4 4-30 day

Control Room volume: 257198 cuft

Control Room makeup/pressurization flow: 711 cfm (3200 cfm prior to isolation, ref.24)

Control Room total flow: 3600 cfm

Control Room unfiltered intake: 51 cfm

Control Room filter efficiency: 95% first pass, 70% second pass, 0% for tritium, 0% all elements prior to isolation

Control Room occupancy factors: 100% 0-24 hr, 60% 1-4 days, 40% 4-30 days

ICRP-2 and ICRP-30 dose conversion factors (internal to the codes)

Figure 1: STP Model

Pre-accident Iodine Spike

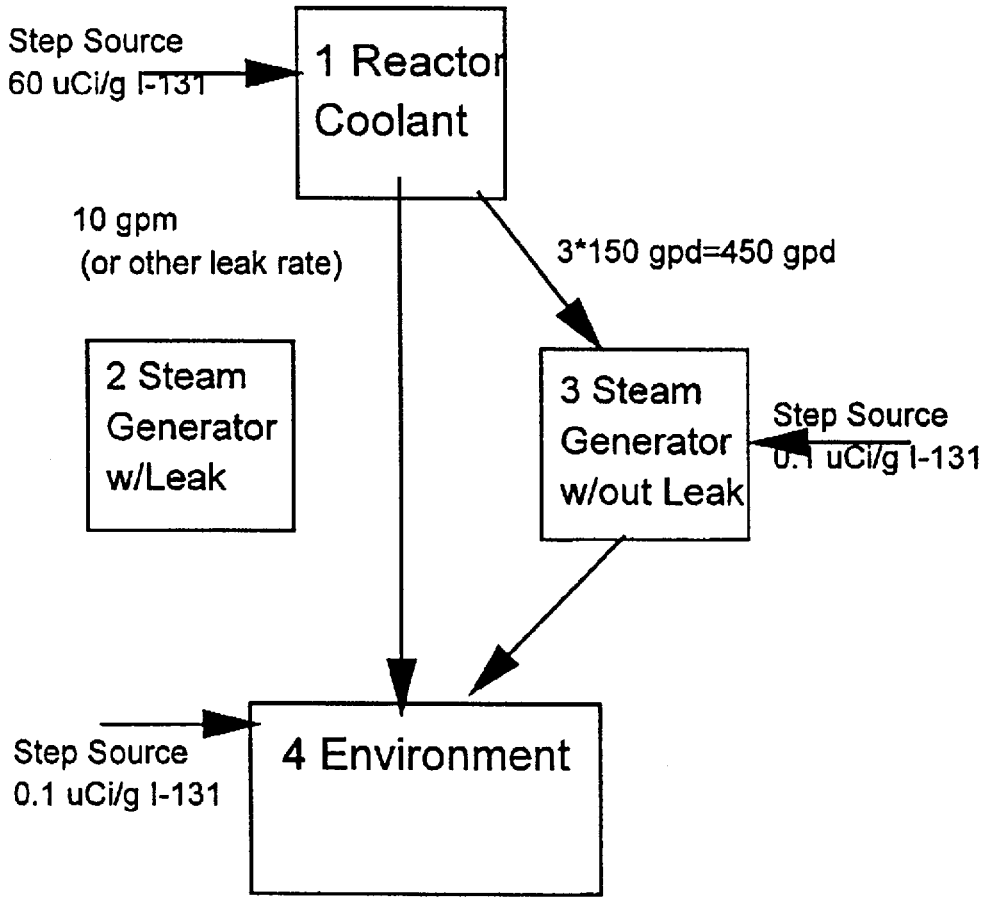
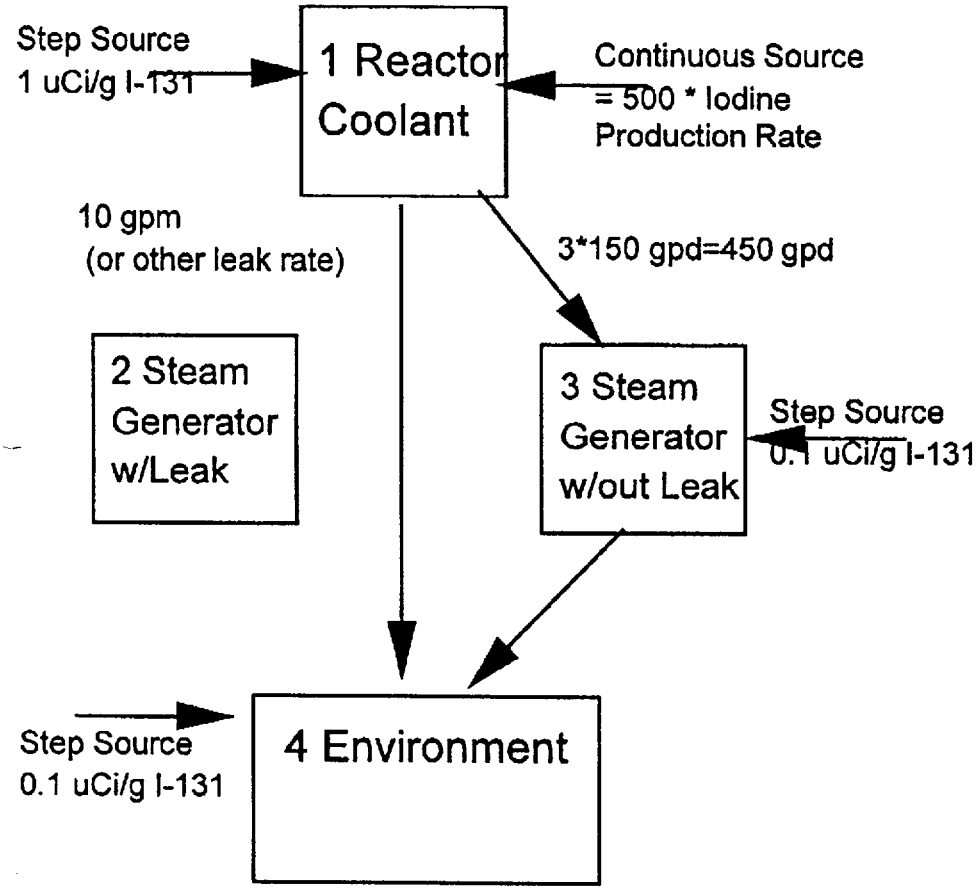


Figure 2: STP Model

Accident Initiated Iodine Spike



Results

The following results are based on a Tritium Production Core (TPC). A case for the conventional core was also performed to show that the TPC bounds. It is also performed to show that the conclusions and limitations are not affected by the choice of cores. The results were (rem):

The results are in Attachment G. DPP 8/9/01

Control room doses (rem) using Halitsky X/Q values:

Pre-accident Iodine spiking case

I-131 equivalent: RCS leak rate:	21 µCi/cc 10/1gpm SG*	limit
gamma	5.765E-03	5
beta	4.845E-02	30
Inhalation (ICRP-2)	2.194E+01	30
Inhalation (ICRP-30)	1.203E+01	30
TEDE	4.044E-01	5

* In this case, the pre-accident reactor coolant leak rate is ~~10~~ 11 gpm, and the primary to secondary side steam generator post accident leak rate in the steam generators is 1 gpm. DJ 8/10/01

Accident Initiated Iodine Spiking (500) case

I-131 equivalent: RCS leak rate:	0.265 µCi/cc 10/1gpm SG*	limit
gamma	8.322E-03	5
beta	6.438E-02	30
Inhalation (ICRP-2)	2.586E+01	30
Inhalation (ICRP-30)	1.378E+01	30
TEDE	4.732E-01	5

* see note (*) above

Control Room Doses (rem) Using ARCON96 X/Q values:

Pre-accident Iodine spiking case

I-131 equivalent: RCS leak rate:	21 µCi/cc 10/1gpm SG*	limit
gamma	6.269E-03	5
beta	5.459E-02	30
Inhalation (ICRP-2)	2.203E+01	30
Inhalation (ICRP-30)	1.209E+01	30
TEDE	4.098E-01	5

* see note (*) above

Accident Initiated Iodine Spiking (500) case

I-131 equivalent: RCS leak rate:	0.265 µCi/cc 10/1gpm SG*	limit
gamma	9.636E-03	5
beta	7.583E-02	30
Inhalation (ICRP-2)	2.734E+01	30
Inhalation (ICRP-30)	1.447E+01	30
TEDE	5.035E-01	5

* see note (*) above

The offsite doses were determined to be (rem):
Pre-accident Iodine spiking case

I-131 equivalent:	21 µCi/cc		
leak rate:	10 gpm, 1gpm SG*		
	2-hr EAB	30-day LPZ	limit
gamma	2.813E-02	9.216E-03	25
beta	8.876E-03	3.395E-03	300
Inhalation (ICRP-2)	4.952E+00	1.923E+00	300
Inhalation (ICRP-30)	2.527E+00	1.011E+00	300
TEDE	1.849E-01	6.960E-02	25

* In this case, the pre-accident reactor coolant leak rate is ~~10~~ 11 gpm, and the primary to secondary side steam generator post accident leak rate in the steam generators is 1 gpm. DPP 8/10/01

Accident Initiated Iodine Spiking (500) case

I-131 equivalent:	0.265 uCi/cc		
leak rate:	10 gpm, 1 gpm SG*		
	2-hr EAB	30-day LPZ	limit
gamma	7.377E-02	6.814E-02	2.5
beta	1.863E-02	1.676E-02	30
Inhalation (ICRP-2)	5.784E+00	6.077E+00	30
Inhalation (ICRP-30)	2.515E+00	2.662E+00	30
TEDE	2.601E-01	2.657E-01	2.5

* see note (*) above

Discussion and Conclusion

The offsite doses due to a MSLB with preaccident iodine spiking has 10CFR100 limits of 25 rem gamma, 300 rem beta, and 300 rem thyroid. The offsite doses due to a MSLB with accident initiated iodine spike (factor of 500) has limits of 10% of the 10CFR100 limits or 2.5 rem gamma, 30 rem beta, and 30 rem thyroid (ref.10). The control room operator doses limits from 10CFR50 App.A GDC 19 are 5 rem gamma, 30 rem beta, and 30 rem thyroid.

With the Technical Specification limits of 1 µCi/gm I-131 equivalent steady state (and 60 µCi/gm maximum), the control room and offsite doses exceed the limits with a 10 gpm leak in the faulted line and 150 gpd in the unfaulted lines, and with either Halitsky or ARCON96 X/Qs.

From the above tables; the limits are: DPP 8/8/01

21 µCi/gm I-131 equivalent 48 hour limit

0.265 µCi/gm I-131 equivalent equilibrium limit

maximum primary to secondary side leak rate: 11 gpm (10 identified, + 1 gpm unidentified) prior to accident, 1 gpm in steam generators post accident

Refer to Appendix G for other optional leakage and concentration cases.

Note: these limits are based on a maximum 0.1 uCi/gm I-131 limit in the secondary side and using ARCON96 X/Q values. If the secondary side limit were to be reduced, then the primary to secondary side leakage and the primary side I-131 concentrations can increase. The results based on ARCON96 X/Q values should be used to determine the concentrations and leak rates because they bound (produce higher doses) than the current Halitsky X/Q values.

The Tritium Production Core (TPC) does not affect the limits above, because the limiting doses are the thyroid doses. The tritium affects only the beta dose and TEDE. The TPC obviously bounds the non-TPC configuration.

This calculation is conservative because it models the mass releases as linear within each time interval.

This allows larger iodine releases for the accident initiated iodine spiking cases because iodine increases over time in the reactor coolant. In reality, the mass releases are greater at the beginning of the accident, and decrease over time. For the pre-existing iodine spike (which is not the limiting case), this has little effect, since the decay of short lived isotopes is compensated by the buildup of iodine in the unfaulted steam generators due to reactor coolant leakage.

Note on methodologies used:

This calculation determined the doses using 3 different methodologies. The gamma, beta and Thyroid (ICRP-2) doses are all based on TID-14844 methodologies utilizing the ICRP-2 iodine dose conversion factors found in TID-14844 and are the current (as of June 2001) licensing basis of the plant. The second methodology is the Thyroid (ICRP-30) dose, which is also based on TID-14844, but uses the ICRP-30 iodine dose conversion factors. The ICRP-30 iodine dose conversion factors are less conservative than the ICRP-2 factors. This methodology is presented for potential future use. Finally, the third methodology used is the TEDE (Total Effective Dose Equivalent). The TEDE presents an overall weighted dose and is more representative of the impact of all isotopes on the body as a whole. The TEDE dose is presented for potential future use, however is not currently (as of June 2001) part of the design basis of the plant. It is important to note that tritium does not impact the thyroid doses utilizing the TID-14844 methodology, because only iodine is applied to the thyroid dose. However, in fact tritium does contribute to the thyroid dose, as well as other organs of the body. This is why the TEDE is a more representative dose when discussing the impact of tritium. It is up to the end user to choose the dose which is to be used, with the understanding that each methodology has a different meaning.

References

1. WBN Technical Specification 3.4.16, Amendment 11
2. WBNNAL3-003 R3 "Reactor Coolant Activities in Accordance with ANSI/ANS-18.1-1984"
3. Computer Code STP R6, code I.D. 262165
4. Computer Code FENCDOSE R4,code I.D. 262358
5. Computer Code COROD R5, code I.D. 262347
6. WBNAPS3-053 R2 "Steam Generator Leakage Detection with the Condenser Vacuum Pump Air Exhaust Monitor (1,2-RM-90-119)"
7. WBNAPS3-043 R1 "Shielding Calculation For the Steam Generator Blowdown Demineralizer System" RIMS# B26 900620 200
8. Memorandum from J.W. Irons to W.L. Elliott, WAT-D-9489, "Verification of Data in FSAR Table 15.5-16" RIMS# T33 930927 823
9. WBNTSR-008 R8 "Control Room Operator and Offsite Dose Due to a Steam Generator Tube Rupture"
10. NUREG-0800 R2 section 15.1.5
11. WAT-D-10690, Nov.9, 1999, Memorandum from John W. Irons to J.E. Maddox "SLB Leak Rates" RIMS# B44 991109 002
12. WAT-D-10724, February 10, 2000, Memorandum from John W. Irons to J.E. Maddox "SLB Leak Rates Conversion" RIMS# T71 000217 928
13. N3-15-4002 R5 System Description For "Steam Generator Blowdown System"
14. FSAR Table 11.1-2 (note: this information is used only for comparison with reference 2, and not used as design input).
15. Lederer and Shirley, "Table of Isotopes", seventh ed.
16. N3-62-4001 R5 System Description for "Chemical and Volume Control System"
17. WBNNAL3-002 R2 "100-Day LOCA-DBA Source Terms for the EGTS and ABGTS Filters, Containment, Sump, and Shield Building Annulus" Note: this calculation is currently at R3, however the information is found in R2.
18. WBNAPS3-050 R2 "Determine the Main Control Room Intake Monitor (0-RE-90-125, -126) Setpoints and Post Accident Air Intake Concentrations"
19. WB-DC-40-70 R1 "Accident Analysis Parameter Checklist (AAPC)", Figures 4.3.2-13 and -25
20. WBNAPS3-104 R0 "WBN Control Room X/Q"
21. WBN Technical Specification 3.4.13
22. NSAL-00-004 "Nonconservatisms in Iodine Spiking Calculations"
23. WBN Technical Specification 3.7.14
24. WBN drawing 1-47W866-4 R36

Appendix A: Justification for Using ANSI/ANS-18.1-1984 Expected Coolant Spectrum

The choice of iodine spectrum is fairly important, since several isotopes have short halflives. Noble gas spectrum is not at important because the noble gasses contribute only to the gamma and beta doses which are orders of magnitude from the regulatory limits, whereas the limiting doses are thyroid (iodine influenced). Results may be affected when accident times are on the order of the decay of the short lived isotopes. There are several possible spectra available. The spectrum chosen for this analysis is the one that most closely resembles the actual spectrum present at WBN. From the surveillance tests 1-SI-68-28 performed on 7/10/00 and 4/9/01 (see Attachment 1), the following concentrations were determined:

RCS activities 7/10/00				RCS activities 4/9/01			
	µCi/gm RCS Gaseous		µCi/gram RCS Degassed		µCi/gm RCS Gaseous		µCi/gram RCS Degassed
Ar-41	1.303E-02	F-18	1.179E-01	Ar-41	2.696E-03	F-18	1.116E-01
Kr-85M	1.915E-04	Na-24	9.169E-04	Kr-85M	2.013E-04	Na-24	2.060E-03
Kr-87	4.575E-04	Mn-56	9.313E-05	Kr-87	4.809E-04	Mn-56	2.088E-04
Xe-133	9.565E-04	Co-58	5.019E-04	Kr-88	4.982E-04	Co-58	6.218E-04
Xe-135	1.429E-03	Nb-95	3.132E-05	Xe-133	1.202E-03	Co-60	2.776E-05
Xe-135M	7.364E-04	I-131	6.070E-05	Xe-135	1.676E-03	Nb-95	2.794E-05
Xe-138	1.796E-03	I-132	1.459E-03	Xe-135M	1.105E-03	I-131	3.881E-05
		I-133	8.208E-04			I-132	1.165E-03
		I-134	2.694E-03			I-133	6.105E-04
		I-135	1.608E-03			I-134	2.334E-03
		Xe-135	8.914E-05			I-135	1.158E-03
		Xe-135M	1.406E-02			Xe-135	1.380E-04
		Cs-138	2.395E-03			Xe-135M	1.972E-02
						Cs-138	2.195E-03

Two potential spectra are from WBNNAL3-003 (Reactor Coolant Activities in Accordance with ANSI/ANS-18.1-1984) and from the FSAR Table 11.1-2 (Historical Design Activities). The iodine concentrations and relative concentrations for each spectrum are as follows:

	7/10/00 WBN actual µCi/gm	7/10/00 WBN actual relative fraction	4/9/01 WBN actual µCi/gm	4/9/01 WBN actual relative fraction
I-131	6.070E-05	0.0091	3.881E-05	0.0073
I-132	1.459E-03	0.2196	1.165E-03	0.2195
I-133	8.208E-04	0.1236	6.105E-04	0.1151
I-134	2.694E-03	0.4056	2.334E-03	0.4399
I-135	1.608E-03	0.2421	1.158E-03	0.2182
sum:	6.643E-03		5.306E-03	

	ANS 18.1 µCi/gm	ANS 18.1 relative fraction	FSAR 11.1-2 µCi/gm	FSAR 11.1-2 relative fraction
I-131	0.0477	0.0448	2.5	0.2461
I-132	0.225	0.2115	0.9	0.0886
I-133	0.149	0.1401	4	0.3937
I-134	0.364	0.3422	0.56	0.0551
I-135	0.278	0.2614	2.2	0.2165
sum:	1.0637		10.16	

As can be seen, the FSAR historical design concentrations do not reflect the actual measured concentrations. The FSAR values are weighted too strongly in favor of I-131 (24.6% of total as opposed to < 1% of the actual total). By comparison, the ANSI/ANS-18.1-1984 fractions are very close to the actual fractions. The worst fit was for I-134 which was 40.1% actual versus ANSI/ANS-18.1-1984 34.22%. The I-131 is slightly over predicted by ANS-18.1 (0.9% on 7/10/00 and 0.7% on 4/9/01 versus 4.48%), however this difference is not as large compared to the FSAR fraction. The ANSI/ANS-18.1-1984 spectrum overall fit is much better than the FSAR spectrum, therefore it can be concluded that the use of the ANSI/ANS-18.1-1984 spectrum is acceptable.

Appendix B: Determination of Letdown Flow Rate Uncertainty

The purpose of this appendix is to determine bounding errors for the measurements performed on the orifice restrictor flows using the Letdown Heat Exchanger Flow loop (1-F-62-82) during Preop Test Instruction PTI-062-03 R0.

Following these tests, a loop check was performed for the computer point F0134A by injecting a signal into the transmitter and reading the display on the computer. To determine the total loop error, the unmeasurable errors must be combined with the errors present at the time of the loop check.

WBN NESSD 1-F-62-1 will be used as a guide for determining the unmeasurable errors for loop 1-F-62-82 since it contains the same model flow element and a similar model transmitter. According to EMPAC, the flow element is a Vickery Simms Model MK-52 and the transmitter is a Foxboro E-13DM.

Millers Flow Measurement Engineering Handbook, Third Edition, Chapter 6, Table 6.1 states that Square Edged orifice flowmeters have an accuracy of ±1-2%URV (upper range value) of the flow rate. A value of ±2% will be used for the orifice.

The loop check performed by WO 94-14264-10 (following pages) gives as found data. The largest error at 50 GPM was 1.36 GPM (50 - 48.64) or 0.68% CS (1.36/200 = 0.68%). The largest error at 100 GPM was 0.48 GPM (100 - 99.52) or 0.24% CS (0.48/200 = 0.24%). The largest error at 150 GPM was 0.06 GPM (150 - 149.94) or 0.03% CS (0.06/200 = 0.03%).

Since the plant had not been started at the time of these tests, radiation was not present and need not be considered. Errors for temperature and power supply effect will need to be included. Since there is no data on actual temperature conditions, an enveloping value must be used. Environmental drawing 47E235-46 R5 gives the max abnormal temperature range as 50 - 110 °F for coordinates UA6 / El 737 where the transmitter is located per EMPAC. The transmitter is a model E-13DM per EMPAC. The product specification sheets (following pages) give the ambient temperature effect as ±1% per 50 °F for any span between 200 to 850" water. The transmitter will normally be calibrated at room temperature which will be between 60 and 80 °F. A temperature shift of + or - 50 °F will encompass the temperature changes seen by the transmitter. Therefore for a temperature range of ±50 °F, the temperature effect will be ±1% CS d/p. The power supply effect is given as 0.1% CS for a 10% change in voltage. Thus Power supply effect is 0.1% CS d/p.

All errors for the computer should be reflected in the loop check.

Utilizing Equation 3-24.8 of W WCAP-12096, Rev. 8 "Westinghouse Setpoint Methodology for Protection Systems, Watts Bar Units 1 and 2, Eagle 21 Version," the unmeasured transmitter errors can be converted from percent error in full scale d/p to error in percent full span at a specified point, where Fm is the maximum flow rate of 200 GPM, and Fn is the nominal flow rate (i.e. 50, 100 or 150 GPM).

EPFS (Flow) = $(Ax_{XX} / 2) * (Fm / Fn)$
$Temp_{err}$(Flow)@50GPM = $(Temp_{err}$ (d/p) / 2) * (200 / 50) = ± 2% CS Flow
$Temp_{err}$(Flow)@100GPM = $(Temp_{err}$ (d/p) / 2) * (200 / 100) = ± 1% CS Flow
$Temp_{err}$(Flow)@150GPM = $(Temp_{err}$ (d/p) / 2) * (200 / 150) = ± 0.67% CS Flow

pwr $supp_{err}$(Flow)@50GPM = (pwr $supp_{err}$ (d/p) / 2) * (200 / 50) = ± 0.2% CS Flow
pwr $supp_{err}$(Flow)@100GPM = (pwr $supp_{err}$ (d/p) / 2) * (200 / 100) = ± 0.1% CS Flow
pwr $supp_{err}$(Flow)@150GPM = (pwr $supp_{err}$ (d/p) / 2) * (200 / 150) = ± 0.067% CS Flow

Thus total loop error = $(FE_{err}^2$ + Loop check $_{err}^2$ +$Temp_{err}$ $(Flow)^2$ +pwr $supp_{err}$ $(Flow)^2)^{0.5}$
Total loop error @ 50 GPM = $(2^2 + 0.68^2 + 2^2 + 0.2^2)^{0.5}$ = ±2.92% CS = ±5.84 GPM
Total loop error @ 100 GPM = $(2^2 + 0.24^2 + 1^2 + 0.1^2)^{0.5}$ = ±2.25% CS = ±4.5 GPM
Total loop error @ 150 GPM = $(2^2 + 0.03^2 + 0.67^2 + 0.067^2)^{0.5}$ = ±2.11% CS = ±4.22 GPM

Total loop error at 120 GPM can be determined by linear interpolation between 100 and 150 GPM. The value will be conservative since the error is nonlinear and is a function of the square root of the d/p values above and the actual loop recorded values which also follow a square root curve.

Total loop error @ 120 GPM = ±| error @ 100 GPM + 20(error @ 150 GPM - error @ 100 GPM) / (150 - 100) |
Total loop error @ 120 GPM = ±[4.5 GPM + 20(4.22 - 4.5)/50] = ±[4.5 GPM + (-0.11)] = ±4.39 GPM

The following references were used in preparation of this appendix. Revisions to these references will not impact this appendix; so the references are 'information only' in lieu of 'design input'.

1 WBN NESSD 1-F-62-1 R1 (Methodology & guidance)
2 EMPAC (Manufacturer, Model number and location)
3 Millers Flow Engineering Handbook, Third Edition, Chapter 6, Table 6.1 (Orifice accuracy)
4 WO 94-14264-10 (loop check data) - see next page
5 Drawing 47E235-46 R5 (environmental data)
6 Foxboro product specification sheets (transmitter accuracy data) - see next pages
7 WCAP-12096 R 8 (methodology for converting d/p error to flow error)

Prepared Lynn Cowan Date 6/4/01
Checked RK Date 6-5-01.

Supporting documents for Appendix B:

WORK ORDER FORM

PAGE 1 OF 10

WO NO: 94-14264-10 ORIGINATION DATE: 06/22/94
RF NO: C254025

ORIGINATOR: JAMES R RIVERS EXTENSION: 3181 PRIORITY: 3C

EQUIPMENT IDENTIFIER : WBN-1-LPF-062-0082-
EQUIPMENT DESCRIPTION: EXCESS LETDOWN HTX FLOW

EQUIPMENT CATEGORY : QR SR 1E

TYPE OF MAINTENANCE: OTHER MAINTENANCE

PROBLEM DESCRIPTION: PERFORM POST TEST CALIBRATION OF SYS 62 70 & 68 INSTRUMENTS LISTED ON THE WR CARD FOR PTI-062-03 ACCEPTANCE CRITERIA

JOB LOCATION : VARIOUS LOCATIONS, SEE SSD
LOCATION CODE : A100 - AB ALL AUXILIARY BUILDING GENERAL AREA

WORK DESCRIPTION : PERFORM POST TEST CALIBRATION OF 1-LPF-062-0082, AS REQUIRED, FOR PTI-062-03 ACCEPTANCE CRITERIA

LCO: YES [ ] NO [X] LENGTH: N/R LCO EXPIRES: N/R
SECT XI R/R: YES [ ] NO [X] NPRDS: YES [ ] NO [X]
RWP REQ : YES [ ] NO [X] RWP #: N/R ALARA: YES [ ] NO [X]

SPECIFIC REQUIREMENTS: NONE N/R

TAGGING REQ: YES [ ] NO [X] H.O. #: N/R SHUTDOWN: YES [ ] NO [X]
SCAFFOLD : YES [ ] NO [X] INSUL: YES [ ] NO [X]

PERMITS REQ: NONE

DISCIPLINE: MIG
EST HOURS : 4.0
PRE-MAINT TEST REQ. : NONE

TASK TOT: 8.0 MAN HOURS
DURATION: 4.0 HOURS

POST-MAINT TEST REQ.: SEE WORK INSTRUCTIONS

SIGNATURES AND DATE

PLANNER: James Rivers 6-22-94
TECH REVIEW: [signature] 6-22-94 N/R
COG SUPV: [signature] 6/23/94
SUT ENGR: [signature] 6/24/94

QA Pass 7-20-94

SSD-1-LPF-62-82-0
PAGE 10 OF 17
REVISION 01

PAGE 10 OF 10

INSTRUMENT LOOP CALIBRATION RECORD

WID NO: WO 94-14264-10

LOOP COMPONENTS

ID: 1-FT-62-82 | INSTRUMENT NO: 1-FI-62-82

HEAD: N/A
M&TE: 540369 | M&TE: VISUAL

TEST POINT	INPUT (IN WC)	REQUIRED (GPM)	AS FOUND LO LIMIT	AS FOUND AS FOUND	AS FOUND HI LIMIT	AS LEFT LO LIMIT	AS LEFT AS LEFT	AS LEFT HI LIMIT
1	12.5	28.3	23.3		33.3	23.3		33.3
2	39.1	50.0	45.0		55.0	45.0		55.0
3	156.3	100.0	95.0		105.0	95.0		105.0
4	351.6	150.0	145.0		155.0	145.0		155.0
5	594.1	195.0	190.0		200.0	190.0		200.0
6	351.6	150.0	145.0		155.0	145.0		155.0
7	156.3	100.0	95.0		105.0	95.0		105.0
8	39.1	50.0	45.0		55.0	45.0		55.0
9	12.5	28.3	23.3		33.3	23.3		33.3

N/R

INSTRUMENT NO: LOG Pt F0134A

M&TE: VISUAL

TEST POINT	REQUIRED (GPM)	AS FOUND LO LIMIT	AS FOUND AS FOUND	AS FOUND HI LIMIT	AS LEFT LO LIMIT	AS LEFT AS LEFT	AS LEFT HI LIMIT
1	28.30	23.18	25.63	32.38	23.18		32.38
2	50.00	47.34	48.88	52.26	47.34		52.26
3	100.00	98.66	99.67	101.14	98.66		101.14
4	150.00	149.08	150.01	150.68	149.08		150.68
5	195.00	194.32	194.72	195.60	194.32		195.60
6	150.00	149.08	149.94	150.68	149.08		150.68
7	100.00	98.66	99.52	101.14	98.66		101.14
8	50.00	47.34	48.64	52.26	47.34		52.26
9	28.30	23.18	25.63	32.38	23.18		32.38

AS FOUND
AS LEFT

Remarks: None

CREW NO 5 | OOT ( ) YES (✓) NO | PC ( ) YES (✓) NO

PERFORMED BY/DATE	REVIEWED BY/DATE (SIMF)	INSTRUCTION NO.	REV. NO.
7-9-94 McKinney, Hunt, Stone	D.E. McCluston 7-9-94	N/R	N/R

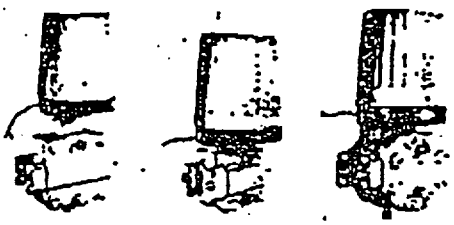
Function: Letdown Heat Exch Flow

Reviewed by: Gary L. Hyden Approved by: Ed Hall EH Date: 03/10/94

FOXBORO

General Specification

The Electronic Series d/p Cell Transmitters measure differential pressure in ranges of 0-5 to 0-850 inches (0-127 to 0-21590 mm) of water at static pressures up to 6000 psi (420 kg/cm²). They transmit a proportional 10 to 50 or 4 to 20 mA d-c signal, over ordinary unshielded leads, to receivers located up to several thousand feet from the point of measurement.



E13DL E13DM E13DH

FEATURES

Time-Proven Design

Trouble-Free Construction

High Performance — Excellent Reproducibility

Ease of Calibration Adjustment — Wide Range Capability

Stable Force Balance System

Positive Overrange Protection

Transmitter Housing Watertight and Moistureproof

Application Versatility

Explosionproof/Intrinsically Safe

PERFORMANCE

Accuracy
- 5 to 525-inch (127 to 13335 mm) ..... ±0.5% of span
- 526 to 850-inch (13360 to 21590 mm) ..... ±0.75% of span

Dead Band ..... 0.05% of span

Repeatability: E13DL Series ..... 0.15% of span
E13DM, E13DH Series ..... 0.10% of span

Hysteresis ..... 0.10% of span

Reproducibility: E13DL Series ..... 0.20% of span
E13DM, E13DH Series ..... 0.15% of span

(Includes effects of Hysteresis, Repeatability, Dead Band and Drift over 1-hr period)

BASE TRANSMITTER STANDARD SPECIFICATIONS
Style B

Span Fully adjustable between range limits of capsule.

Maximum Process Temperature 250 F (120 C) at capsule

Ambient Temperature Limits -40 to +180 F (-40 to +82 C). With remote amplifier, -40 to +250 F (-40 to +120 C).

Bolting Steel cap screws and nuts through body and process connectors

Cover Threaded cast aluminum seated on Buna-N O-ring seal. Blue textured vinyl finish.

Enclosure Classification NEMA 4 watertight

Electronic Transmitter and Amplifier Solid state

Electrical Connections Two 5-foot leads from 1/2-inch female conduit connections

Output Signal

Output Signal (mA d-c)	External Loop Load (ohms)		Nominal Supply Voltage from Separate Unit
	Minimum	Maximum	
4 to 20	0	650	24 V d-c
10 to 50	480 (a)	650	60 V d-c

(a) Foxboro power supplies or distribution panels include a calibrated 0 to 500 ohm load adjustment potentiometer.

Supply Voltage Limits 24 to 60 volts d-c with 4 to 20 mA output and 63 to 100 volts d-c with 10 to 50 mA output from separate power supply unit.

Supply Voltage Effect Zero shift will be less than 0.1% of span for a 10% change in voltage within stated limits.

Electric Classification Explosionproof Class I, Groups C and D, Division 1.

Mounting Direct to process with bracket for 2-inch horizontal or vertical pipe.

Specifications	E13DL Series	E13DM Series	E13DH Series
Range Limits			
Low Range Capsule	0-5 to 0-25" water (0-127 to 0-635 mm)		
Medium Range Capsule	—	0-20 to 0-205" water (0-508 to 0-5207 mm)	0-20 to 0-205" water (0-508 to 0-5207 mm)
High Range Capsule	—	0-200 to 0-850" water (0-5080 to 0-21590 mm)	0-200 to 0-850" water (0-5080 to 0-21590 mm)

Printed in U.S.A.

GS 2A-1C1 E
November 1971

STANDARD SPECIFICATIONS
(Continued)

Specification	E130L Series	E130M Series	E130H Series
Wetted Parts:			
Body and Process Conn	Cadmium plated forged carbon steel or forged 316 SS	Cadmium plated forged carbon steel or forged 316 SS	Cadmium plated forged carbon steel or forged 316 SS
Diaphragm Capsule and Force Bar	316 stainless steel	316 stainless steel	316 stainless steel
Force Bar Seal	Cobalt nickel alloy	Cobalt nickel alloy	Cobalt nickel alloy
Capsule Gasket	316 stainless steel	316 stainless steel	316 stainless steel
Process Conn Gasket	TFE	TFE	Glass filled TFE
Force Bar Seal Gasket	Silicone elastomer	Silicone elastomer	Buna-N
Backup Plate	316 stainless steel	316 stainless steel	316 stainless steel
Maximum Static Pressure	500 psi (35 kg/cm^2)	2000 psi (140 kg/cm^2)	6000 psi (420 kg/cm^2)
Process Connections	1/4 or 1/2 NPT female or 1/2 inch Sch 80 welding neck, as specified.	1/4 or 1/2 NPT female or 1/2 inch Sch 80 welding neck, as specified.	1/4 or 1/2 NPT or body machined to accept 9/16-18 Aminco fittings, as specified.
Ambient Temperature Effect (Zero shift in percent of span)	±1.0% per 100 F (55 C) change at 25" (635 mm) water; ±1.0% per 40 F (22 C) change at 5" (127 mm) water.	Medium Range Capsule: ±1.0% per 100 F (55 C) change at 100" (2540 mm) water; ±1.0% per 125 F (69 C) at 205" (5207 mm) water; ±1.0% per 40 F (22 C) at 25" (635 mm) water. High Range Capsule: Less than ±1% per 50 F (28 C) change for any span between 200 to 850" (5080 to 21590 mm) water.	Medium Range Capsule: ±1.0% per 100 F (55 C) change at 100" (2540 mm) water; ±1.0% per 125 F (69 C) at 205" (5207 mm) water; ±1.0% per 40 F (22 C) at 25" (635 mm) water. High Range Capsule: Less than ±1% per 50 F (28 C) change for any span between 200 to 850" (5080 to 21590 mm) water.
Position	Transmitter should be mounted with capsule in vertical position.		
Position Effect		Maximum of less than 3% zero shift for 90 degree tilt of instrument in any plane	Maximum of less than 3% zero shift for 90 degree tilt of instrument in any plane
Vibration	Less than 1.5% zero shift for vibration to 1.5G in any plane, at frequencies less than 80 Hz.	Less than 1% zero shift for vibration to 2G in any plane.	Less than 1% zero shift for vibration to 2G in any plane.
Static Pressure Effect	Maximum zero shift less than 0.5% of span for 500 psi (35 kg/cm^2) change.	Zero shift less than 0.5% span for 2000 psi (140 kg/cm^2) change at 50 to 850" (1270 to 21590 mm) water; 1.0% span for 1000 psi (70 kg/cm^2) change at 20 to 50" (508 to 1270 mm) water.	Zero shift less than 1.5% span for 0-6000 psi (0-420 kg/cm^2) change at 50 to 850" (1270 to 21590 mm) water or 0.5% span for any 2000 psi (140 kg/cm^2) change; 2.0% span for 0 to 6000 psi (0 to 420 kg/cm^2) change at 20 to 50" (508 to 1270 mm) water or 1.0% span for any 2000 psi (140 kg/cm^2) change*.
Overall Dimensions	16 1/8" (410 mm) H x 6 7/8" (175 mm) W.	13 1/4" (337 mm) H x 6 7/8" (175 mm) W.	14 1/2" (368 mm) H x 6 7/8" (175 mm) W.
Approximate Weight	32 lb (15 kg)	25 lb (11 kg)	40 lb (18 kg)

*ressure varies cyclically, refer to your nearest Foxboro Sales Office.

Appendix C: Example of Pre-Accident Iodine Spike STP Model

```
//APS77S6A JOB 264318,9MBERG.BIN111,MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=LOCAL,CLASS=LB
//JCL JCLLIB ORDER=(APB.NEN.PS264460.PROCLIB)
//     EXEC STP,SOUT='*'
//GO.FT07F001 DD DSN=$KBI988.APS77S6A.OUT,UNIT=ALLOC,
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=6160),SPACE=(TRK,(5,2),RLSE),
//     DISP=(NEW,CATLG,DELETE)
//GO.FT01F001 DD *
NV= 4  MS= 2
//GO.FT11F001 DD *
$    CLASS        DESCRIPTION
$      1              NOBLE GASES
$      2              IODINE
$      3              TRITIUM
NI= 23  NK= 7  NG= 0  NL= 3
   1KRM  83 1 1.0352E-04   10.0           10.0           10.0
   2KRM  85 1 4.2978E-05   10.0           10.0           10.0
   3KR   85 1 2.0470E-09   29.8849E-06    10.0           10.0
   4KR   87 1 1.5141E-04   10.0           10.0           10.0
   5KR   88 1 6.8765E-05   10.0           10.0           10.0
   6KR   89 1 3.6328E-03   10.0           10.0           10.0
   7XEM 131 1 6.7414E-07  131.3039E-08  181.3039E-08   10.0
   8XEM 133 1 3.5656E-06  152.0365E-07  202.0365E-07   10.0
   9XE  133 1 1.5165E-06   83.5656E-06  159.0531E-06  209.0531E-06
  10XEM 135 1 7.3818E-04  174.8062E-06  224.8062E-06   10.0
  11XE  135 1 2.1043E-05  107.3818E-04  172.4322E-05  222.4322E-05
  12XE  138 1 8.1528E-04   10.0           10.0           10.0
  13I   131 2 9.9536E-07   10.0           10.0           10.0
  14I   132 3 8.4448E-05   10.0           10.0           10.0
  15I   133 4 9.2568E-06   10.0           10.0           10.0
  16I   134 5 2.1963E-04   10.0           10.0           10.0
  17I   135 6 2.9129E-05   10.0           10.0           10.0
  18I*  131 2 9.9536E-07   10.0           10.0           10.0
  19I*  132 3 8.4448E-05   10.0           10.0           10.0
  20I*  133 4 9.2568E-06   10.0           10.0           10.0
  21I*  134 5 2.1963E-04   10.0           10.0           10.0
  22I*  135 6 2.9129E-05   10.0           10.0           10.0
  23H     3 7 1.7785E-09   10.0000E+00    10.0000E+00    10.0000E+00
//GO.SYSIN3 DD *
1  'REACTOR COOLANT ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 1.71E-1 3 2.66E-1 4 1.61E-1 5 3.00E-1 6 0.0
 7 6.54E-1 8 7.17E-2 9 2.53E0  10 1.39E-1 11 9.04E-1 12 1.29E-1
 13 4.77E-2 14 2.25E-1 15 1.49E-1 16 3.64E-1 17 2.78E-1
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E1
0
2  'SECONDARY COOL  ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 3.63E-8 3 5.51E-8 4 3.22E-8 5 6.31E-8 6 0.0
 7 1.34E-7 8 1.54E-8 9 5.25E-7 10 2.90E-8 11 1.91E-7 12 2.68E-8
 13 1.41E-6 14 3.37E-6 15 4.03E-6 16 2.93E-6 17 6.19E-6
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E-2
0
T
WBN MSLB, 60 UCI/CC INITIAL CONC, 10 GPM LEAK
NJ= 4  KCONC= 1
1 'REACTOR COOLANT'
2 'STEAM GENERATOR W/LEAK'
3 'STEAM GENERATORS/NO LEAK'
4 'ENVIRONMENT'
-1
INITIALIZATION
V 1 2.4494E8 GM
V 2 4.745E7 GN
V 3 1.424E8 GN
```

```
V 4 1.0 GM
S 1 1 0 1.171E5
S 1 1 1 7.118E3
S 2 3 0 4.466E6
S 1 1 7 2.4494E2
S 2 3 7 1.424E2
S 2 4 1 2.1337E6 2 4 2 2.1337E6 2 4 3 2.1337E6
S 2 4 4 2.1337E6 2 4 5 2.1337E6 2 4 6 2.1337E6
S 2 4 7 6.8039E1
A 4
F 1 3 0 7.098E4 GM/HR
F 3 4 0 1.0886E6 GM/HR
F 3 4 1 1.0886E8 GM/HR
F 3 4 7 1.0886E8 GM/HR
F 1 4 0 2.271E6 GM/HR
20.6 SEC
TIME TO 20.6 SEC
N 4 0
P 1 0 4
2.0 HR
TIME TO 2.0 HR
N 4 0
P 1 0 4
8.0 HR
TIME TO 8.0 HR
F 3 4 0 6.5846E5 GM/HR
F 3 4 1 6.5846E7 GM/HR
F 3 4 7 6.5846E7 GM/HR
P 1 0 4
T
T
/*
//
```

Appendix D: Example of Accident Initiated Iodine Spike (factor of 500 increase) STP Model

```
//APS77S6B JOB 264318,9MBERG.BIN111,MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=LOCAL,CLASS=LB
//JCL JCLLIB ORDER=(APB.NEN.PS264460.PROCLIB)
//     EXEC STP,SOUT='*'
//GO.FT07F001 DD DSN=$KBI988.APS77S6B.OUT,UNIT=ALLOC,
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=6160),SPACE=(TRK,(5,2),RLSE),
//     DISP=(NEW,CATLG,DELETE)
//GO.FT01F001 DD *
NV= 4  MS= 2
//GO.FT11F001 DD *
$    CLASS          DESCRIPTION
$      1                NOBLE GASES
$      2                IODINE
$      3                TRITIUM
NI= 23  NK= 7  NG= 0  NL= 3
   1KRM  83 1 1.0352E-04   10.0            10.0            10.0
   2KRM  85 1 4.2978E-05   10.0            10.0            10.0
   3KR   85 1 2.0470E-09   29.8849E-06     10.0            10.0
   4KR   87 1 1.5141E-04   10.0            10.0            10.0
   5KR   88 1 6.8765E-05   10.0            10.0            10.0
   6KR   89 1 3.6328E-03   10.0            10.0            10.0
   7XEM 131 1 6.7414E-07   131.3039E-08    181.3039E-08    10.0
   8XEM 133 1 3.5656E-06   152.0365E-07    202.0365E-07    10.0
   9XE  133 1 1.5165E-06   83.5656E-06     159.0531E-06    209.0531E-06
  10XEM 135 1 7.3818E-04   174.8062E-06    224.8062E-06    10.0
  11XE  135 1 2.1043E-05   107.3818E-04    172.4322E-05    222.4322E-05
  12XE  138 1 8.1528E-04   10.0            10.0            10.0
  13I   131 2 9.9536E-07   10.0            10.0            10.0
  14I   132 3 8.4448E-05   10.0            10.0            10.0
  15I   133 4 9.2568E-06   10.0            10.0            10.0
  16I   134 5 2.1963E-04   10.0            10.0            10.0
  17I   135 6 2.9129E-05   10.0            10.0            10.0
  18I*  131 2 9.9536E-07   10.0            10.0            10.0
  19I*  132 3 8.4448E-05   10.0            10.0            10.0
  20I*  133 4 9.2568E-06   10.0            10.0            10.0
  21I*  134 5 2.1963E-04   10.0            10.0            10.0
  22I*  135 6 2.9129E-05   10.0            10.0            10.0
  23H     3 7 1.7785E-09   10.0            10.0            10.0
//GO.SYSIN3 DD *
1  'REACTOR COOLANT ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 1.71E-1 3 2.66E-1 4 1.61E-1 5 3.00E-1 6 0.0
 7 6.54E-1 8 7.17E-2 9 2.53E0  10 1.39E-1 11 9.04E-1 12 1.29E-1
 13 4.77E-2 14 2.25E-1 15 1.49E-1 16 3.64E-1 17 2.78E-1
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E1
0
2  'SECONDARY COOL  ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 3.63E-8 3 5.51E-8 4 3.22E-8 5 6.31E-8 6 0.0
 7 1.34E-7 8 1.54E-8 9 5.25E-7 10 2.90E-8 11 1.91E-7 12 2.68E-8
 13 1.41E-6 14 3.37E-6 15 4.03E-6 16 2.93E-6 17 6.19E-6
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E-2
0
T
WBN MSLB, 1 UCI/CC INITIAL CONC, 10 GPM LEAK, 500 IODINE SPIKE
NJ= 4  KCONC= 1
1 'REACTOR COOLANT'
2 'STEAM GENERATOR W/LEAK'
3 'STEAM GENERATORS/NO LEAK'
4 'ENVIRONMENT'
-1
INITILIZATION
V 1 2.4494E8 GM
V 2 4.745E7 GM
V 3 1.424E8 GM
```

```
V 4 1.0 GM
S 1 1 0 1.951E3
S 1 1 1 7.118E3
S 1 1 7 2.4494E2
S 2 3 0 4.466E6
S 1 1 7 2.4494E2
S 2 3 7 1.424E2
S 2 4 1 2.1337E6 2 4 2 2.1337E6 2 4 3 2.1337E6
S 2 4 4 2.1337E6 2 4 5 2.1337E6 2 4 6 2.1337E6
S 2 4 7 6.8039E1
C 1 1 2 1.260E5
C 1 1 3 4.190E5
C 1 1 4 1.548E5
C 1 1 5 8.937E5
C 1 1 6 2.248E5
A 4
F 1 4 0 2.271E6 GM/HR
F 1 3 0 7.098E4 GM/HR
F 3 4 0 1.0886E6 GM/HR
F 3 4 1 1.0886E8 GM/HR
F 3 4 7 1.0886E8 GM/HR
20.6 SEC
TIME TO 20.6 SEC
N 4 0
P 1 0 4
2.0 HR
TIME TO 2.0 HR
N 4 0
P 1 0 4
8.0 HR
TIME TO 8.0 HR
F 3 4 0 6.5846E5 GM/HR
F 3 4 1 6.5846E7 GM/HR
F 3 4 7 6.5846E7 GM/HR
P 1 0 4
T
T
/*
//
```

Appendix E: Example of COROD Input (ARCON96 X/Q)

```
//APS77C6M JOB 264318,9MBERG.BIN111,MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=LOCAL,CLASS=SB
//JCL JCLLIB ORDER=(APB.NEN.EX262358.PROCLIB)
//STEP1 EXEC CORODV5,COND=(4,LT)
//COROD1.FT05F001 DD *
NIT= 23   NR= 1   ITP= 6   FACT= 1.0
COROD-WBN MSLB                                                    S
KRM 83  KRM 85  KR 85  KR 87  KR 88  KR 89
XEM 131  XEM 133  XE 133  XEM 135  XE 135  XE 138
I 131  I 132  I 133  I 134  I 135
I* 131  I* 132  I* 133  I* 134  I* 135  H 3
    4  'ENVIRONMENT                      ' $ TN=  0.5722E-02
         1 0.0          2 1.427E-01    3 2.191E-01    4 1.300E-01    5 2.491E-01
         6 0.0          7 5.355E-01    8 6.024E-02    9 2.086E+00   10 1.168E-01
        11 7.529E-01   12 1.060E-01   13 3.305E+00   14 8.588E+00   15 9.525E+00
        16 8.509E+00   17 1.494E+01   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 8.035E+00
    4  'ENVIRONMENT                      ' $ TN=  0.2000E+01
         1 0.0          2 1.957E+01    3 3.540E+01    4 1.302E+01    5 3.147E+01
         6 0.0          7 8.682E+01    8 9.516E+00    9 3.367E+02   10 8.259E+01
        11 1.527E+02   12 2.877E+00   13 1.020E+02   14 3.618E+02   15 3.095E+02
        16 3.921E+02   17 5.383E+02   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 4.591E+02
    4  'ENVIRONMENT                      ' $ TN=  0.8000E+01
         1 0.0          2 3.179E+01    3 1.031E+02    4 6.231E+00    5 3.710E+01
         6 0.0          7 2.504E+02    8 2.728E+01    9 9.783E+02   10 1.959E+02
        11 6.586E+02   12 8.154E-03   13 2.914E+02   14 3.530E+02   15 7.864E+02
        16 9.890E+01   17 1.043E+03   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 1.314E+03
   -6  'ENVIRONMENT        CURIES      ' $ TN=  0.2400E+02
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
   -6  'ENVIRONMENT        CURIES      ' $ TN=  0.9600E+02
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
   -6  'ENVIRONMENT        CURIES      ' $ TN=  0.7200E+03
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
4.03E-03  4.03E-03  3.35E-03  2.27E-04  1.81E-04  1.45E-04
20.6  7200.0  21600.0  57600.0  259200.0  2246400.0
3200.0  51.0
711.0  51.0
711.0  51.0
711.0  51.0
711.0  51.0
711.0  51.0
0.0  0.0  0.05  0.0  0.0  0.0  3600.0
0.95  0.70  0.95  0.70  0.99  0.0  3600.0
0.95  0.70  0.95  0.70  0.99  0.0  3600.0
0.95  0.70  0.95  0.70  0.99  0.0  3600.0
0.95  0.70  0.95  0.70  0.99  0.0  3600.0
0.95  0.70  0.95  0.70  0.99  0.0  3600.0
100.0  60.0  40.0  1440.0  5760.0 257198.0
```

```
322.0 45.0 17.75 46.0 9.0 4.0 161.0 22.5 4.0 0.0
ROOFFLUX DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE THROUGH ROOF
1000.0 1000.0 1000.0  20.0  20.0 20.0  500.0  500.0  -16.0  2.25
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM AUX BUILDING
270.0 150.0 148.0 27.0 15.0 14.0 135.0 75.0 -25.5  3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM TURBINE BLDG
322.0  112.0  341.0  32.0 11.0 34.0  161.0  56.0  -25.5  3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM SPREADING ROOM
322.0  45.0  26.0 32.0 9.0 5.0  22.5  161.0  -4.67  0.67
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM CR BLDG END
18.0 45.0 460.0 10.0 10.0 100.0 4.0 22.5 -25.5 3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM CR BLDG END
18.0 45.0 460.0 10.0 10.0 100.0 4.0 22.5 -25.5 3.0
/*
//
```

Appendix F: Example of FENCDOSE Model

```
//APS77F6A JOB 264360,'9MBERG.BIN111',MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=LOCAL,CLASS=SB
//JCL JCLLIB ORDER=(APB.NEN.EX262358.PROCLIB)
//STEP1 EXEC FNCDOSV4,COND=(4,LT)
//FNCDOS1.FT05F001 DD *
1
KRM-83  KRM-85  KR-85
KR-87   KR-88   KR-89
XEM-131 XEM-133 XE-133 XEM-135 XE-135 XE-138
I-131   I-132   I-133  I-134   I-135
I*-131  I*-132  I*-133 I*-134  I*-135  H-3
T
.141E-3  .668E-4  .459E-4  .204E-4  .635E-5  6.07E-4
WBN MSLB, 60 UCI/CC INITIAL CONC, 10 GPM LEAK
TIME TO 20.6 SEC
    4  'ENVIRONMENT                        ' $ TN=  0.5722E-02
         1 0.0          2 1.427E-01    3 2.191E-01    4 1.300E-01    5 2.491E-01
         6 0.0          7 5.355E-01    8 6.024E-02    9 2.086E+00   10 1.168E-01
        11 7.529E-01   12 1.060E-01   13 3.305E+00   14 8.588E+00   15 9.525E+00
        16 8.509E+00   17 1.494E+01   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 8.035E+00
WBN MSLB, 60 UCI/CC INITIAL CONC, 10 GPM LEAK
TIME TO 2.0 HR
    4  'ENVIRONMENT                        ' $ TN=  0.2000E+01
         1 0.0          2 1.957E+01    3 3.540E+01    4 1.302E+01    5 3.147E+01
         6 0.0          7 8.682E+01    8 9.516E+00    9 3.367E+02   10 8.259E+01
        11 1.527E+02   12 2.877E+00   13 1.020E+02   14 3.618E+02   15 3.095E+02
        16 3.921E+02   17 5.383E+02   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 4.591E+02
WBN MSLB, 60 UCI/CC INITIAL CONC, 10 GPM LEAK
TIME TO 8.0 HR
    4  'ENVIRONMENT                        ' $ TN=  0.8000E+01
         1 0.0          2 3.179E+01    3 1.031E+02    4 6.231E+00    5 3.710E+01
         6 0.0          7 2.504E+02    8 2.728E+01    9 9.783E+02   10 1.959E+02
        11 6.586E+02   12 8.154E-03   13 2.914E+02   14 3.530E+02   15 7.864E+02
        16 9.890E+01   17 1.043E+03   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 1.314E+03
WBN MSLB
TIME TO 1 DAY
   -6  'ENVIRONMENT        CURIES        ' $ TN=  0.2400E+02
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN MSLB
TIME TO 4 DAYS
   -6  'ENVIRONMENT        CURIES        ' $ TN=  0.9600E+02
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN MSLB
TIME TO 30 DAYS
   -6  'ENVIRONMENT        CURIES        ' $ TN=  0.7200E+03
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
```

Appendix G: Additional Cases

This appendix documents additional cases. It was decided that these cases would be best documented in an appendix so as to not loose the information. Additional cases were performed for the steady state I-131 equivalent limit of 0.265 and 0.177 μCi/gm, and also cases with 60, 21, and 11 μCi/gm maximum. These cases were performed to help establish possible future Technical Specification limits.

There are several cases modeled. The first case has a pre-accident iodine spike where the iodine level in the reactor coolant is at the maximum allowable of 60 μCi/gm I-131 equivalent (ref.1). The second has the reactor coolant at the maximum steady state I-131 equivalent of 1 μCi/gm with an accident initiated iodine spike consisting of a 500 increase in the rate of iodine release from the fuel. In both cases, the primary to secondary side leak is 150 gpd in the unfaulted loops, and the secondary side activity is at the Technical Specification limit of 0.1μCi/gm and the primary to secondary side leak in the faulted loop is 10 gpm which flows directly to the environment to simulate steam generator dryout. Additional cases are performed with a maximum leakage other than 10 gpm, to be determined in this calculation by iteration, so as to not exceed the 10CFR100 or 10CFR50 App.A GDC 19 limits. Finally, other cases were performed with 10 gpm leak (or other maximum leakage, to be determined by trial and error) with maximum allowable iodine concentration of 60*0.35 = 21 μCi/gm I-131, or 11 μCi/gm I-131, or with 0.265, or 0.177 μCi/gm, I-131 equivalent with 500 factor of spiking. These extra cases were performed so as to give additional information for possible future changes in Technical Specifications. In all of the cases, except for two cases, the steady state reactor coolant leakage (all identified leakage) prior to the accident is the same as the maximum allowable primary to secondary side leakage in the steam generators. The unidentified reactor coolant leakage (1 gpm) is not included in the steam generator leakage. The exception to the above is where the maximum reactor coolant leakage is 11 gpm (10 gpm identified + 1 gpm unidentified) prior to the accident, and a maximum of 1 gpm in the steam generators post accident.

Assumptions

Same as in main body of text except for the following:
6. A preaccident iodine spike of 60 μCi/gm I-131 equivalent (or 21 or 11 μCi/gm for the reduced concentration case) is assumed at the start of the accident. In other cases, an accident initiated iodine spike of 500 increase in the iodine release rate from the fuel is assumed in the accident initiated case with the reactor coolant starting at 1 μCi/gm I-131 equivalent (or 0.265, or 0.177 μCi/gm for the reduced concentration cases).
Technical Justification: SRP 15.1.5 subsection 4a specifies the maximum allowable preaccident spike is required (60 uCi/gm is permissible for 48 hours). SRP 15.1.5 subsection 4b specifies that following an accident, the iodine release rate from the fuel to the reactor coolant is increased by a factor of 500. The various cases were performed to provide the leakages and concentrations which would result in acceptable control room and offsite doses.
10. The iodine production rate is based on 10 gpm identified primary side leakage (all leaks) plus 1 gpm unidentified leak, for a total of 11 gpm. Other cases evaluated determined the impact of 5.75 gpm identified primary side leakage (all leaks) plus 1 gpm unidentified leak, for a total of 6.75 gpm, and also 2.15 gpm identified primary side leakage (all leaks) plus 1 gpm unidentified leak, for a total of 3.15 gpm
Technical Justification: This is per Technical Specification 3.4.13 (ref.21), or a potential modification for the Technical Specification, and maximizes the iodine production rates. This methodology is consistent with NSAL-00-004, ref.22.

Calculations

Step Sources:

The following equation is used to set up the initial activities (in Ci) for each component using the initial ANSI/ANS-18.1-1984 source modified for WBN operational parameters (which is in units of μCi/gm):

S = Component Volume [gm] * 1E-6 Ci/μCi * I-131 equivalent conversion factor

To obtain the I-131 equivalent conversion factor, the ANSI/ANS-18.1-1984 spectrum must be converted to I-131 equivalence. From the main text, the I-131 equivalent concentration of the initial RCS ANSI 18.1 source term is 0.1255 uCi/gm, as compared to 1 uCi/gm when the RCS is at the TS allowable concentration. Consequently, to ratio the initial source term up to the TS allowable values, the ANSI 18.1 concentrations must be multiplied by 1/0.1255 or 7.965.

To convert to I-131 equivalence, the secondary side I-131 equivalent conversion factor is (1/3.189E-6) = 3.136E5 gm/μCi (Note: since there is no Technical Specification limit on gross activity for the secondary side like the 100/Ebar for the primary side, this factor is also applied to the secondary side noble gasses in order to retain the proper isotopic ratios).

From the main text, the values for noble gasses in the design reactor coolant will have to be increased by a factor of 169.14/5.82 = 29.06.

The step sources (Ci-gm/μCi) to initialize the reactor coolant and the secondary side activities are:

All cases:

S=2.4494E8 gm*1E-6 Ci/μCi * 29.06 =7.118E3 (noble gasses)

S=2.4494E8 gm*1E-6 Ci/μCi = 2.4494E2 (tritium)

Pre-accident iodine spike case (initial concentration = 60 μCi/gm):

S=2.4494E8 gm*1E-6 Ci/μCi * 7.965 [μCi/gm I-131]$^{-1}$*60 μCi/gm I-131= 1.171E5 (iodines)

Pre-accident iodine spike case (initial concentration = 21 μCi/gm):

S=2.4494E8 gm*1E-6 Ci/μCi * 7.965[μCi/gm I-131]$^{-1}$ *21μCi/gm I-131 = 4.097E4 (iodines)

Pre-accident iodine spike case (initial concentration = 11 μCi/gm):

S=2.4494E8 gm*1E-6 Ci/μCi * 7.965 [μCi/gm I-131]$^{-1}$*11μCi/gm I-131 = 2.146E4 (iodines)

Accident initiated iodine spike case (initial concentration = 1 μCi/gm):

S=2.4494E8 gm*1E-6 Ci/μCi * 7.965 [μCi/gm I-131]$^{-1}$*1μCi/gm I-131 = 1.951E3

Accident initiated iodine spike case (initial concentration = 0.265 μCi/gm):

S=2.4494E8 gm*1E-6 Ci/μCi * 7.965 [μCi/gm I-131]$^{-1}$*0.265 μCi/gm I-131= 5.170E2

Accident initiated iodine spike case (initial concentration = 0.177 μCi/gm):

S=2.4494E8 gm*1E-6 Ci/μCi * 7.965 [μCi/gm I-131]$^{-1}$*0.177μCi/gm I-131 = 3.453E2

Secondary side, all cases, steam generator w/ leak, release to environment. (concentration = 0.1μCi/gm) which is due to dryout (from reference 8, the steam released for a 1 gpm primary to secondary leak case from the defective steam generator is 150,000 lb):

S = 150,000 lb *453.59 g/lb * 1E-6 Ci/μCi * 3.136E5 [μCi/gm I-131]$^{-1}$* 0.1μCi/gm I-131 = 2.1337E6

S = 150,000 lb *453.59 g/lb * 1E-6 Ci/μCi = 6.8039E1 (tritium)

Secondary side, all cases, steam generators without leak (initial concentration = 0.1 μCi/gm):

S = 1.424E8 gm * 1E-6 Ci/μCi * 3.136E5 [μCi/gm I-131]$^{-1}$* 0.1μCi/gm I-131 = 4.466E6

S = 1.424E8 gm*1E-6 Ci/μCi = 1.424E2 (tritium)

Continuous Sources:

For the accident initiated iodine spike case, the iodine spike is 500 times the iodine release rate from the fuel. At steady state, the iodine release (production) rate is equal to the removal rate. The iodine removal is due to a) radioactive decay, b) removal by the letdown system, and c) removal through reactor coolant leakage. These terms are expressed as:

$P = \Sigma$removal rates = decay + letdown + leakage

or $P = \lambda + f_L\varepsilon/V + p_s/V$

where P = production rate [hr^{-1}]

λ = decay constant for the isotope in question [hr^{-1}] = $\ln(2)/T_{1/2}$

f_L = letdown flow rate = 120 gpm + 4.39 gpm = 124.39 gpm

ε = letdown demineralizer efficiency = 1 (assumed so as to maximize removal/production rate)

V = volume of primary coolant = 5.4E5 lb

p_s = removal rate of iodine from the primary side due to preaccident primary side leakage

= 11 gpm (10 gpm identified + 1 gpm unidentified)

or = 6.75 gpm (5.75 gpm identified + 1 gpm unidentified)

or = 3.15 gpm (2.15 gpm identified + 1 gpm unidentified)

$T_{1/2}$ = halflife taken from ref.15

Note: all the above flow rates are converted to mass flow rates at STP:

Production Rates for a Reactor Coolant Leak of 11 gpm (10 gpm identified + 1 gpm unidentified)

	Half Life	λ [1/hr]	$f_L\varepsilon/V$ [1/hr]	p_s/V [1/hr]	prod rate P [1/hr]
I-131	8.04 d	3.59E-03	1.15E-01	1.02E-02	0.1291
I-132	2.28 h	3.04E-01	1.15E-01	1.02E-02	0.4296
I-133	20.9 h	3.32E-02	1.15E-01	1.02E-02	0.1587
I-134	52.6 m	7.91E-01	1.15E-01	1.02E-02	0.9162
I-135	6.61 h	1.05E-01	1.15E-01	1.02E-02	0.2304

Production Rates for a Reactor Coolant Leak of 6.75 gpm (5.75 gpm identified + 1 gpm unidentified)

	Half Life		λ [1/hr]	$f_L\varepsilon/V$ [1/hr]	p_s/V [1/hr]	prod rate P [1/hr]
I-131	8.04	d	3.59E-03	1.15E-01	6.26E-03	0.1252
I-132	2.28	h	3.04E-01	1.15E-01	6.26E-03	0.4256
I-133	20.9	h	3.32E-02	1.15E-01	6.26E-03	0.1548
I-134	52.6	m	7.91E-01	1.15E-01	6.26E-03	0.9123
I-135	6.61	h	1.05E-01	1.15E-01	6.26E-03	0.2265

Production Rates for a Reactor Coolant Leak of 3.15 gpm (2.15 gpm identified + 1 gpm unidentified)

	Half Life		λ [1/hr]	$f_L\varepsilon/V$ [1/hr]	p_s/V [1/hr]	prod rate P [1/hr]
I-131	8.04	d	3.59E-03	1.15E-01	2.92E-03	0.1219
I-132	2.28	h	3.04E-01	1.15E-01	2.92E-03	0.4223
I-133	20.9	h	3.32E-02	1.15E-01	2.92E-03	0.1514
I-134	52.6	m	7.91E-01	1.15E-01	2.92E-03	0.9089
I-135	6.61	h	1.05E-01	1.15E-01	2.92E-03	0.2231

The accident initiated iodine spike of 500 times the increase in the iodine release (production) rate from the fuel is modeled as a continuous source:

C = Volume * 1E-6 Ci/μCi * Prod. Rate * 500 * 1 μCi/gm I-131 equiv. conversion factor*I-131 equiv.

where Volume = 2.4494E8 gm

Prod Rate = see table above

1 μCi/gm I-131 equivalent conversion factor = 7.965 (value determined above, this is to get the ANSI/ANS-18.1-1984 source into 1 μCi/gm I-131 equivalent

I-131 equiv. = 1, 0.265, or 0.177 μCi/gm I-131

Continuous Source [gm-Ci/μCi-hr] for Accident Initiated Iodine Spike:

Reactor Coolant Leak of 11 gpm (10 gpm identified + 1 gpm unidentified)

case:	1 μCi/gm I-131 case	0.265 μCi/gm I-131	0.1727 μCi/gm I-131 case
I-131	1.260E+05	3.338E+04	2.230E+04
I-132	4.190E+05	1.110E+05	7.417E+04
I-133	1.548E+05	4.103E+04	2.740E+04
I-134	8.937E+05	2.368E+05	1.582E+05
I-135	2.248E+05	5.956E+04	3.978E+04

Reactor Coolant Leak of 6.75 gpm (5.75 gpm identified + 1 gpm unidentified)

case:	1 μCi/gm I-131 case	0.265 μCi/gm I-131	0.1727 μCi/gm I-131 case
I-131	1.221E+05	3.236E+04	2.162E+04
I-132	4.152E+05	1.100E+05	7.349E+04
I-133	1.510E+05	4.001E+04	2.672E+04
I-134	8.899E+05	2.358E+05	1.575E+05
I-135	2.209E+05	5.854E+04	3.910E+04

Reactor Coolant Leak of 3.15 gpm (2.15 gpm identified + 1 gpm unidentified)

case:	1 μCi/gm I-131 case	0.265 μCi/gm I-131	0.1727 μCi/gm I-131 case
I-131	1.189E+05	3.150E+04	2.104E+04
I-132	4.119E+05	1.092E+05	7.291E+04
I-133	1.477E+05	3.914E+04	2.615E+04
I-134	8.866E+05	2.350E+05	1.569E+05
I-135	2.177E+05	5.768E+04	3.852E+04

Flow Rates:

The following flow rates/leakage rates for each component are (determined by trial and error with the ultimate goal being to find the flow/leak which would lead to the offsite/control room doses reaching the regulatory limits):

Flow from Reactor Coolant #1 to Environment #4 all classes (10 gpm case):

F = 10 gpm * 60 min/hr * 3785.48 cc/gal * 1g/cc = 2.271E6 g/hr

Flow from Reactor Coolant #1 to Steam Generator w/ Leak #4 all classes (5.75 gpm case):

F = 5.75 gpm * 60 min/hr * 3785.48 cc/gal * 1g/cc = 1.306E6 g/hr

Flow from Reactor Coolant #1 to Steam Generator w/ Leak #4 all classes (2.15 gpm case):

F = 2.15 gpm * 60 min/hr * 3785.48 cc/gal * 1g/cc = 4.883E5 g/hr

Flow from Reactor Coolant #1 to Environment #4 all classes (1 gpm case, note that this case is for 1 gpm leak in the steam generators, however the production rate of iodines is based on 11 gpm=10gpm identified +1gpm unidentified):

F = 1 gpm * 60 min/hr * 3785.48 cc/gal * 1g/cc = 2.271E5 g/hr

Flow from Reactor Coolant #1 to Steam Generator w/ no Leak #3 all classes:

F = 3 steam generators * 150 gpd * 3785.48 cc/gal / 24 hr/day * 1g/cc = 7.098E4 g/hr

From reference 8, the steam released for a 1 gpm primary to secondary leak case from the defective steam generator is 150,000 lb (0-30 min), and 1000 lb (30 min - 8 hr), and from the non-defective steam generators (="steam generators without leak" in this model) is 480,000 lb (0-2 hr), and 871,000 lb (2-8 hr). The accident releases end at eight hours. From reference 11 and 12, the steam released for a 10 gpm primary to secondary leak case is an additional 2509 lb (at STP) in the 0-30 min time period, and a total of 42290 lb (at STP) from 30 min to 8 hr. To take into account uncovery of the faulted steam generator, there is no iodine partitioning in the release to the environment (iodine partition coefficient = 1). The mass release representing 10 gpm primary to secondary side leak is a flow directly to the environment. This is reflected in the flows listed above. For other leak rates, the flow cards will correctly take into account the mass released.

The reactor coolant release to the unfaulted steam generator is small relative to the secondary side mass, therefore partitioning is allowed per the SRP. The iodine partition coefficient due to steaming for the unfaulted steam generators to the environment is 100. These mass releases translate into the following flows:

Flow from Steam Generators w/out Leak #3 to Environment #4:

F = (480,000 lb)(453.59 g/lb)/(2 hr) = 1.0886E8 g/hr (0-2 hr, noble gasses, tritium)

F = (480,000 lb)(453.59 g/lb)/(100*2 hr) = 1.0886E6 g/hr (0-2 hr, iodines)

F = (871,000 lb)(453.59 g/lb)/(6 hr) = 6.5846E7 g/hr (2-8 hr) (noble gasses, tritium)

F = (871,000 lb)(453.59 g/lb)/(100*6 hr) = 6.5846E5 g/hr (2-8 hr) (iodines)

The STP output is used as input to COROD (which determines control room operator dose) and FENCDOSE (which determines 30-day and 2-hour LPZ offsite dose).

Some pertinent information from the COROD and FENCDOSE models used (but not changed) in this analysis are (from ref.9):

30-day LPZ Offsite X/Q values [sec/cum]: 1.41E-4 0-2hr, 6.68E-5 2-8 hr, 4.59E-5 8-24 hr, 2.04E-5 1-4 day, 6.35E-6 4-30 day

2-hr EAB X/Q values: 6.07E-4

Control Room X/Q (Halitsky method): 4.07E-3 0-2 hr, 2.47E-3 2-8 hr, 1.68E-3 8-24 hr, 1.18E-3 1-4 day, 8.89E-4 4-30 day (note: the 8+ hr X/Q values take into account control room vent switching, however it is not important what values are used since there are no 8+ hr releases.)

Control Room X/Q (ARCON96 method): 4.03E-3 0-2 hr, 3.35E-3 2-8 hr, 2.27E-4 8-24 hr, 1.81E-4 1-4 day, 1.45E-4 4-30 day

Control Room volume: 257198 cuft

Control Room makeup/pressurization flow: 711 cfm (3200 cfm prior to isolation, ref.24)

Control Room total flow: 3600 cfm

Control Room unfiltered intake: 51 cfm

Control Room filter efficiency: 95% first pass, 70% second pass, 0% for tritium, 0% all elements prior to isolation

Control Room occupancy factors: 100% 0-24 hr, 60% 1-4 days, 40% 4-30 days

ICRP-2 and ICRP-30 dose conversion factors (internal to the codes)

Results

The following results are based on a Tritium Production Core (TPC). A case for the conventional core was also performed to show that the TPC bounds. It is also performed to show that the conclusions and limitations are not affected by the choice of cores. The results were (rem):

Control room doses (rem) using Halitsky X/Q values:

Pre-accident Iodine spiking case

I-131 equivalent: RCS leak rate:	60 µCi/gm 10 gpm	21 µCi/gm 10 gpm	21 µCi/cc 10/1gpm SG*	11 µCi/gm 10 gpm	21 µCi/gm 5.75 gpm	21 µCi/gm 2.15 gpm	limit
gamma	3.135E-02	2.457E-02	5.765E-03	2.284E-02	1.582E-02	8.223E-03	5
beta	3.148E-01	2.569E-01	4.845E-02	2.420E-01	1.599E-01	7.572E-02	30
Inhalation (ICRP-2)	6.429E+01	3.573E+01	2.194E+01	2.841E+01	2.930E+01	2.374E+01	30
Inhalation (ICRP-30)	3.520E+01	1.958E+01	1.203E+01	1.557E+01	1.606E+01	1.302E+01	30
TEDE	1.303E+00	7.599E-01	4.044E-01	6.207E-01	5.944E-01	4.509E-01	5

* all cases except for this case utilize the same pre-accident leak rate as the post accident primary to secondary side leak rate in the steam generators. In this case, the pre-accident leak rate is 10 gpm, and the primary to secondary side steam generator post accident leak rate in the steam generators is 1 gpm.

Accident Initiated Iodine Spiking (500) case

I-131 equivalent: RCS leak rate:	1 µCi/gm 10 gpm	0.265 µCi/gm 10 gpm	0.265 µCi/cc 10/1gpm SG*	0.265 µCi/gm 5.75 gpm	0.177 µCi/gm 10 gpm	0.177 µCi/gm 2.15 gpm	limit
gamma	1.267E-01	4.895E-02	8.322E-03	2.978E-02	3.965E-02	1.145E-02	5
beta	8.800E-01	3.990E-01	6.438E-02	2.416E-01	3.415E-01	9.414E-02	30
Inhalation (ICRP-2)	2.235E+02	7.418E+01	2.586E+01	5.086E+01	5.631E+01	2.788E+01	30
Inhalation (ICRP-30)	1.074E+02	3.667E+01	1.378E+01	2.558E+01	2.820E+01	1.471E+01	30
TEDE	4.114E+00	1.434E+00	4.732E-01	9.708E-01	1.113E+00	5.211E-01	5

* see note (*) above

Control Room Doses (rem) Using ARCON96 X/Q values:

Pre-accident Iodine spiking case

I-131 equivalent: RCS leak rate:	60 µCi/gm 10 gpm	21 µCi/gm 10 gpm	21 µCi/cc 10/1gpm SG*	11 µCi/gm 10 gpm	21 µCi/gm 5.75 gpm	21 µCi/gm 2.15 gpm	limit
gamma	3.666E-02	2.866E-02	6.269E-03	2.662E-02	1.825E-02	9.203E-03	5
beta	3.759E-01	3.044E-01	5.459E-02	2.860E-01	1.883E-01	8.734E-02	30
Inhalation (ICRP-2)	7.196E+01	3.828E+01	2.203E+01	2.965E+01	3.072E+01	2.416E+01	30
Inhalation (ICRP-30)	3.954E+01	2.102E+01	1.209E+01	1.628E+01	1.687E+01	1.326E+01	30
TEDE	1.484E+00	8.354E-01	4.098E-01	6.690E-01	6.376E-01	4.656E-01	5

* see note (*) above

Accident Initiated Iodine Spiking (500) case

I-131 equivalent: RCS leak rate:	1 µCi/gm 10 gpm	0.265 µCi/gm 10 gpm	0.265 µCi/cc 10/1gpm SG*	0.265 µCi/gm 5.75 gpm	0.177 µCi/gm 10 gpm	0.177 µCi/gm 2.15 gpm	limit
gamma	1.616E-01	6.072E-02	9.636E-03	3.663E-02	4.866E-02	1.349E-02	5
beta	1.125E+00	4.935E-01	7.583E-02	2.970E-01	4.179E-01	1.121E-01	30
Inhalation (ICRP-2)	2.851E+02	9.036E+01	2.734E+01	5.996E+01	6.705E+01	2.998E+01	30
Inhalation (ICRP-30)	1.369E+02	4.440E+01	1.447E+01	2.990E+01	3.333E+01	1.570E+01	30
TEDE	5.256E+00	1.753E+00	5.035E-01	1.150E+00	1.332E+00	5.651E-01	5

* see note (*) above

Accident Initiated Iodine Spiking (500) case, non-TPC core**

I-131 equivalent:	0.177 µCi/gm	
RCS leak rate:	2.15 gpm	limit
gamma	1.349E-02	5
beta	1.104E-01	30
Inhalation (ICRP-2)	2.998E+01	30
Inhalation (ICRP-30)	1.570E+01	30
TEDE	5.373E-01	5

** demonstration run to show that TPC bounds conventional core, and that the impact is only for beta and TEDE. The impact is minimal, and does not affect the conclusions/limits since the limiting doses are the thyroid doses.

The offsite doses were determined to be (rem):

Pre-accident Iodine spiking case

I-131 equivalent:	60 µCi/gm		21 µCi/gm		11 µCi/gm		
leak rate:	10 gpm		10 gpm		10 gpm		
	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	limit
gamma	4.829E-01	1.740E-01	1.877E-01	6.738E-02	1.121E-01	4.006E-02	25
beta	1.331E-01	5.347E-02	6.122E-02	2.524E-02	4.281E-02	1.801E-02	300
Inhalation (ICRP-2)	8.044E+01	3.947E+01	2.957E+01	1.415E+01	1.653E+01	7.658E+00	300
Inhalation (ICRP-30)	4.029E+01	2.075E+01	1.484E+01	7.437E+00	8.319E+00	4.025E+00	300
TEDE	3.042E+00	1.413E+00	1.128E+00	5.118E-01	6.370E-01	2.809E-01	25

Pre-accident Iodine spiking case

I-131 equivalent:	21 µCi/cc		21 µCi/cc		21 µCi/cc		
leak rate:	5.75 gpm		2.15 gpm		10 gpm, 1gpm SG*		
	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	limit
gamma	1.127E-01	4.018E-02	4.866E-02	1.677E-02	2.813E-02	9.216E-03	25
beta	3.661E-02	1.505E-02	1.561E-02	6.241E-03	8.876E-03	3.395E-03	300
Inhalation (ICRP-2)	1.799E+01	8.453E+00	8.120E+00	3.520E+00	4.952E+00	1.923E+00	300
Inhalation (ICRP-30)	9.053E+00	4.445E+00	4.112E+00	1.851E+00	2.527E+00	1.011E+00	300
TEDE	6.843E-01	3.057E-01	3.062E-01	1.273E-01	1.849E-01	6.960E-02	25

* all cases except for this case utilize the same pre-accident leak rate as the post accident primary to secondary side leak rate in the steam generators. In this case, the pre-accident leak rate is 10 gpm, and the primary to secondary side steam generator post accident leak rate in the steam generators is 1 gpm

Accident Initiated Iodine Spiking (500) case

I-131 equivalent:	1 µCi/gm		0.265 µCi/gm		0.265 µCi/gm		
leak rate:	10 gpm		10 gpm		5.75 gpm		
	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	limit
gamma	2.344E+00	2.417E+00	6.422E-01	6.476E-01	3.720E-01	3.726E-01	2.5
beta	5.352E-01	5.621E-01	1.583E-01	1.563E-01	9.195E-02	9.008E-02	30
Inhalation (ICRP-2)	1.371E+02	2.058E+02	3.793E+01	5.493E+01	2.240E+01	3.140E+01	30
Inhalation (ICRP-30)	5.259E+01	8.838E+01	1.477E+01	2.362E+01	8.803E+00	1.347E+01	30
TEDE	6.821E+00	9.432E+00	1.878E+00	2.439E+00	1.101E+00	1.397E+00	2.5

Accident Initiated Iodine Spiking (500) case

I-131 equivalent leak rate:	0.177 µCi/gm 10 gpm		0.177 µCi/gm 2.15 gpm		0.177 µCi/gm, conv.core** 2.15 gpm		
	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	limit
gamma	4.386E-01	4.360E-01	1.015E-01	9.541E-02	1.015E-01	9.541E-02	2.5
beta	1.133E-01	1.078E-01	2.654E-02	2.383E-02	2.644E-02	2.378E-02	30
Inhalation (ICRP-2)	2.607E+01	3.686E+01	7.160E+00	8.149E+00	7.160E+00	8.149E+00	30
Inhalation (ICRP-30)	1.025E+01	1.587E+01	3.019E+00	3.523E+00	3.019E+00	3.523E+00	30
TEDE	1.287E+00	1.638E+00	3.329E-01	3.611E-01	3.313E-01	3.603E-01	2.5

** demonstration run to show that TPC bounds conventional core, and that the impact is only for beta and TEDE. The impact is minimal, and does not affect the conclusions/limits since the limiting doses are the thyroid doses.

Accident Initiated Iodine Spiking (500) case

I-131 equivalent leak rate:	0.265 uCi/cc 10 gpm, 1 gpm SG*		
	2-hr EAB	30-day LPZ	limit
gamma	7.377E-02	6.814E-02	2.5
beta	1.863E-02	1.676E-02	30
Inhalation (ICRP-2)	5.784E+00	6.077E+00	30
Inhalation (ICRP-30)	2.515E+00	2.662E+00	30
TEDE	2.601E-01	2.657E-01	2.5

* see note (*) above

Discussion and Conclusion

The offsite doses due to a MSLB with preaccident iodine spiking has 10CFR100 limits of 25 rem gamma, 300 rem beta, and 300 rem thyroid. The offsite doses due to a MSLB with accident initiated iodine spike (factor of 500) has limits of 10% of the 10CFR100 limits or 2.5 rem gamma, 30 rem beta, and 30 rem thyroid (ref.10). The control room operator doses limits from 10CFR50 App.A GDC 19 are 5 rem gamma, 30 rem beta, and 30 rem thyroid.

With the Technical Specification limits of 1 µCi/gm I-131 equivalent steady state (and 60 µCi/gm maximum), the control room and offsite doses exceed the limits with a 10 gpm leak in the faulted line and 150 gpd in the unfaulted lines, and with either Halitsky or ARCON96 X/Qs.

Using current design basis ICRP-2 iodine dose conversion factors, the limits in order to not exceed the control room and offsite doses are:

21 µCi/gm I-131 equivalent 48 hour limit

0.177 µCi/gm I-131 equivalent equilibrium limit

maximum primary to secondary side leak rate post accident in steam generator: 2.15 gpm

Note: this will require a Tech Spec change so that the maximum reactor coolant leakage is 2.15 gpm identified plus 1 gpm unidentified.

-or-

21 µCi/gm I-131 equivalent 48 hour limit

0.265 µCi/gm I-131 equivalent equilibrium limit

maximum primary to secondary side leak rate: 11 gpm (10 gpm identified, + 1 gpm unidentified) prior to accident, 1 gpm in steam generators post accident

Using ICRP-30 iodine dose conversion factors the limits increase to:

21 uCi/gm I-131 equivalent 48 hour limit

0.265 uCi/gm I-131 equivalent equilibrium limit

maximum primary to secondary side leak rate in steam generator post accident: 5.75 gpm

Note: this will require a Tech Spec change so that the maximum reactor coolant leakage is 5.75 gpm identified plus 1 gpm unidentified.

-or-

21 μCi/gm I-131 equivalent 48 hour limit

0.265 μCi/gm I-131 equivalent equilibrium limit

maximum primary to secondary side leak rate: 11 gpm (10 gpm identified, + 1 gpm unidentified) prior to accident, 1 gpm in steam generators post accident

Note: these limits are based on a maximum 0.1 uCi/gm I-131 limit in the secondary side and using ARCON96 X/Q values. If the secondary side limit were to be reduced, then the primary to secondary side leakage and the primary side I-131 concentrations can increase. The results based on ARCON96 X/Q values should be used to determine the concentrations and leak rates because they bound (produce higher doses) than the current Halitsky X/Q values.

The Tritium Production Core (TPC) does not affect the limits above, because the limiting doses are the thyroid doses. The tritium affects only the beta dose and TEDE. The TPC obviously bounds the non-TPC configuration.

This calculation is conservative because it models the mass releases as linear within each time interval. This allows larger iodine releases for the accident initiated iodine spiking cases because iodine increases over time in the reactor coolant. In reality, the mass releases are greater at the beginning of the accident, and decrease over time. For the pre-existing iodine spike (which is not the limiting case), this has little effect, since the decay of short lived isotopes is compensated by the buildup of iodine in the unfaulted steam generators due to reactor coolant leakage.

Attachment 1: Surveillance test 1-SI-68-28 performed on 7/10/00

JUL-24-2000 13:52 TVA PLANT MGRS OFC 423 365 1984 P.02/07

SURVEILLANCE TASK SHEET (SPP-8.2) PAGE 1 OF

WORK ORDER: 00067930
SI KEY: P0531
PROCEDURE#: 1-SI-68-28
TITLE: PRIMARY RADIOCHEMISTRY REQUIREMENTS
PERF SECT: CSM
TEST REASON: PERIODIC PERFORMANCE
DUE: 07/10/00
MIN EXT: 07/11/00
MAX EXT: FORM SPP-8.2-2
FREQ: W
EO: N
ASME XI: N
APP MODE: 123
PERF MODE: 1234
SUBSCNT RVWS:
INSTRUCTIONS: Do NOT start prior to scheduled due date

N/A
AUTHORIZATION TO BEGIN: SNO — DATE — N/A TIME

7/10/00 / 0920
START DATE / TIME

7/10/00 / 1118
COMPLETION DATE / TIME

NAME	TEST PERFORMERS SIGNATURE	INIT	SECT
Lynda Mannore	Lynda Mannore	LM	CHEM

WAS THIS A COMPLETE OR PARTIAL PERFORMANCE? (EXPLAIN "PARTIAL" IN REMARKS) COMPLETE: ✓ PARTIAL: ___

WERE ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT REQ ACCEPTANCE CRITERIA SATISFIED? YES: ✓ NO: ___ N/A: ___

WERE ALL OTHER ACCEPTANCE CRITERIA SATISFIED? YES: ___ NO: ___ N/A: ✓

ALERT SCHEDULING REQUIRED? YES: ___ NO: ___ N/A: X

IF ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT REQ WERE NOT SATISFIED, WAS AN LCO/TR/ODCM/OR ACTION REQD? (EXPLAIN IN REMARKS) YES: ___ NO: ___ N/A: ✓

Lynda Mannore 7/10/00
TEST DIRECTOR / LEAD PERFORMER — DATE

N/A
ACCEPTANCE CRITERIA REVIEW: GBO — N/A DATE / TIME

7/11/00
CHEM SUPV IND REVIEW — DATE

REMARKS:

COPY OF STS SENT TO SCHEDULING: BLD / 7/11/00
INITIALS / DATE

SECTION/WHEN/DUR HRS
SECTION/WHEN/DUR HRS
SECTION/WHEN/DUR HRS
SECTION/WHEN/DUR HRS

RECORDS TRANSMITTAL#:

JUL-24-2000 13:52 TVA PLANT MGRS OFC 423 365 1904 P.03/07

10-JUL-2000 09:23:05.19
TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT
****

SAMPLE TITLE : U1 - RCS - GASEOUS ACTIVTY
FILE IDENT : DKB600:[TVA.SAMPLE.CHEM.NEW]W0007108796_C401.CNF;1

SAMPLE ID : W0007108796_C401
SAMPLE TIME : 10-JUL-2000 08:53
SAMPLE TYPE : 1240 CC GAS MARI

* OPERATOR : LLMANNONE
* SAMPLE GEOMETRY : GM1K
* SHELF HEIGHT : 0
* EFFICIENCY FILE : GM1K0
* SAMPLE QUANTITY : 1.00000E+00 CC

****

ACQ DATE & TIME : 10-JUL-2000 09:12
PRESET LIVE TIME : 0 00:10:00
ELASPED REAL TIME : 0 00:10:01
ELAPSED LIVE TIME : 0 00:10:00

* DEADTIME (%) : 0.3%
* SENSITIVITY : 4.00000
* GAUSSIAN SEN : 10.00000
* NBR ITERATIONS : 10

****

DETECTOR : DET #3, GSS-3286
EFFIC CAL DATE : 29-JUL-1994 13:47
DCAL DATE & TIME : 9-JUL-2000 15:52:
KEV/CHAN : 4.99928E-01
OFFSET : -1.48334E-01 keV
Q COEFFICIENT : 3.22120E-08
PEAK START CHAN : 140

* LIBRARY : NOBLEGAS
* EFFIC CERT DATE : 29-JUL-1994 13:47
* ENERGY TOLER : 1.25
* HALF LIFE RATIO : 8.00000
* ABUNDANCE LIMIT : 80.0%
* CORRECTION FACTOR : 1.00000E+00
* PEAK END CHAN : 4096

****

ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8

****

COUNTED ON : LION
COLLECTED BY :
COUNTED BY : LLMANNONE
REVIEWED BY :
COMMENTS :

****

Post-NID Peak Search Report

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	%Err	Fit	Nuclides
0	81.12	230	92	1.01	162.55	157	12	10.8		XE-133
0	151.37	88	53	0.97	303.07	299	8	17.7		XR-85M
0	196.38	70	80	0.88	393.10	388	10	26.7		
0	227.79	22	47	1.35	455.92	448	10	62.9		
0	249.81	549	83	0.94	499.98	494	12	5.4		XE-135
0	258.71	72	40	0.89	517.78	514	10	20.2		XE-138
0	305.21	19	34	0.76	610.77	607	8	57.2		XR-85M
0	402.80	48	34	2.39	805.96	801	12	29.3		KR-87
0	435.19	26	16	1.31	870.75	866	11	35.3		XE-138
0	511.06	390	49	2.28	1022.51	1014	18	6.6		
0	526.45	39	24	1.21	1053.28	1048	12	29.8		XE-135M
0	898.31	22	16	1.29	1796.96	1791	9	38.8		
0	1293.58	904	9	1.60	2587.40	2578	16	3.4		AR-41

JUL-24-2000 13:53 TVA PLANT MGRS OFC 423 365 1904 P.04/07
REPORT DATE : 10-JUL-2000 09:23
REQUESTOR : LLMANNONE

TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT

POST NID QA ANALYSIS

TITLE : U1 - RCS - GASEOUS ACTIVTY

SAMPLE No. : W0007108796 C401
SAMPLE TYPE : 1240 CC GAS MARI
COUNT TIME : 10-JUL-2000 09:12:51
SAMPLE TIME : 10-JUL-2000 08:53:00
LIBRARY : NOBLEGAS

OPERATOR NAME : LLMANNONE
SAMPLE GEOMETRY : GM1K
SAMPLE QUANTITY : 1.00000E+00
DETECTOR : DET #3, GSS-3286

ISOTOPE	PEAK ENERGY	ENERGY DIFF (KEV)	DECAY CORR uCi/CC	COMMENTS
AR-41	1293.64	-0.06	1.303E-02	QA Results OK
XR-85M	151.18	0.19	1.915E-04	QA Results OK
XR-87	402.58	0.22	4.575E-04	QA Results OK
XE-133	81.00	0.12	9.565E-04	QA Results OK
XE-135	249.79	0.02	1.429E-03	QA Results OK
XE-135M	526.56	-0.11	7.364E-04	QA Results OK
XE-138	258.31	0.40	1.796E-03	QA Results OK
AVG ENERGY DIFF =		0.11	1.859E-02 = TOTAL GAMMA ACTIVITY	
			0.000E+00 = Total DGL Activity	
			1.859E-02 = Total Gas Activity	

UNIDENTIFIED/REJECTED PEAKS

ENERGY	NET AREA	FWHM	GAMMA/SEC	GAMMA/SEC /CC	% ERROR	FLAG	POTENTIAL ID	ACTIVITY
196.38	70.	0.88	4.728E+00	4.728E+00	25.7	R	KR-88	5.438E-04
227.79	22.	1.35	1.675E+00	1.675E+00	62.9	U	TE-132	5.163E-05
						U	CS-138	5.110E-03
						U	NP-239	4.252E-04
511.06	390.	2.28	7.016E+01	7.016E+01	6.60	U	ANNIL	0.000E+00
898.31	22.	1.29	7.079E+00	7.079E+00	38.8	U	RB-88	1.512E-03
						U	Y-88	2.049E-04

No Peaks of interest
7/10/00

JUL-24-2000 13:53 TVA PLANT MGRS OFC 423 365 1904 P.05/07

10-JUL-2000 09:37:45.71
TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT

SAMPLE TITLE : U1 - RCS - DEGASSED LIQUID ACTIVITY
FILE IDENT : DKB600:[TVA.SAMPLE.CHEM.NEW]W0007108795_C402.CNF;1

SAMPLE ID : W0007108795_C402
SAMPLE TIME : 10-JUL-2000 07:25

SAMPLE TYPE : RCS 20ML LSV

* OPERATOR : LLMANNONE
* SAMPLE GEOMETRY : LSV20
* SHELF HEIGHT : 1
* EFFICIENCY FILE : LSV201
* SAMPLE QUANTITY : 5.00000E+00 GRAMS

ACQ DATE & TIME : 10-JUL-2000 08:36
PRESET LIVE TIME : 0 01:00:00
ELASPED REAL TIME : 0 01:01:20
ELAPSED LIVE TIME : 0 01:00:00

* DEADTIME (%) : 2.2%
* SENSITIVITY : 4.00000
* GAUSSIAN SEN : 10.00000
* NBR ITERATIONS : 10

DETECTOR : DET #4, GSS-3310
EFFIC CAL DATE : 5-AUG-1994 11:11:
DCAL DATE & TIME : 9-JUL-2000 15:52:
KEV/CHAN : 5.00474E-01
OFFSET : -3.73924E-01 keV
Q COEFFICIENT : -1.14092E-07
PEAK START CHAN : 140

* LIBRARY : RCSLIQUID
* EFFIC CERT DATE : 5-AUG-1994 11:11:
* ENERGY TOLER : 1.25
* HALF LIFE RATIO : 8.00000
* ABUNDANCE LIMIT : 80.0%
* CORRECTION FACTOR : 1.00000E+00
* PEAK END CHAN : 4096

ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8

COUNTED ON : LION
COLLECTED BY :
COUNTED BY : LLMANNONE
REVIEWED BY :
COMMENTS :

Post-NID Peak Search Report

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	%Err	Fit	Nuclides
0	135.60	697	25268	0.92	271.70	269	7	38.0		I-134
0	249.64	887	20225	0.79	499.61	498	6	25.6		XE-135
0	287.87	540	22521	0.98	576.01	574	7	46.3		I-135
0	364.21	455	13323	1.06	728.61	726	8	44.3		I-135
0	405.43	310	6932	1.05	810.99	808	8	46.9		I-131
0	417.67	485	6009	1.20	835.46	832	8	28.1		I-134
0	462.73	545	5368	1.28	925.53	922	8	23.7		I-135
0	511.00	838084	22601	2.65	1022.01	1014	19	0.1		CS-138
0	522.65	824	999	1.38	1045.31	1043	7	7.3		F-18
1	526.58	1048	823	1.29	1053.15	1050	18	5.2	1.06E+00	I-132 I-135
1	529.88	4510	1009	1.34	1059.77	1050	18	1.9		XE-135M I-133

JUL-24-2000 13:53 TVA PLANT MGRS OFC 423 365 1904 P.06/07

REPORT DATE : 10-JUL-2000 09:37
REQUESTOR : LLMANNONE

TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT

POST NID QA ANALYSIS

TITLE : U1 - RCS - DEGASSED LIQUID ACTIVITY

SAMPLE No. : W0007108795 C402
SAMPLE TYPE : RCS 20ML LSV
COUNT TIME : 10-JUL-2000 08:36:15
SAMPLE TIME : 10-JUL-2000 07:25:00
LIBRARY : RCSLIQUID

OPERATOR NAME : LLMANNONE
SAMPLE GEOMETRY : LSV20
SAMPLE QUANTITY : 5.00000E+00
DETECTOR : DET #4, GSS-3310

ISOTOPE	PEAK ENERGY	ENERGY DIFF (KEV)	DECAY CORR uCi/GRAM	COMMENTS
F-18	511.00	0.00	1.179E-01	QA Results OK
NA-24	1368.53	0.07	9.169E-04	QA Results OK
MN-56	1810.69	-0.63	9.313E-05	QA Results OK
CO-58	810.76	-0.01	5.019E-04	QA Results OK
NB-95	765.79	0.89	3.132E-05	QA Results OK
I-131	364.48	-0.27	6.070E-05	QA Results OK
I-132	667.69	0.03	1.459E-03	QA Results OK
I-133	529.87	0.01	8.208E-04	QA Results OK
I-134	847.03	-0.05	2.694E-03	QA Results OK
I-135	1260.41	0.03	1.608E-03	QA Results OK
XE-135	249.79	-0.16	8.914E-05	QA Results OK
XE-135M	526.56	0.02	1.406E-02	QA Results OK
CS-138	1435.86	-0.11	2.395E-03	QA Results OK
AVG ENERGY DIFF =		-0.01	1.426E-01	= TOTAL GAMMA ACTIVITY
			1.218E-01	= Total DGL Activity
			2.427E-03	= Total FP Activity
			1.512E-03	= Total AP Activity
			1.415E-02	= Total Gas Activity
			6.643E-03	= Total HFP Activity

Dose Equivalent Iodine-131 = 2.905E-04
Iodine 131/133 Ratio = 7.395E-02
Iodine 133/135 Ratio = 5.105E-01

DGA = 3.94E-3

287.87 KeV Peak was used in identifying 2 isotopes
526.58 KeV Peak was used in identifying 2 isotopes
546.88 KeV Peak was used in identifying 2 isotopes
766.68 KeV Peak was used in identifying 2 isotopes
810.75 KeV Peak was used in identifying 2 isotopes
846.97 KeV Peak was used in identifying 2 isotopes
857.15 KeV Peak was used in identifying 2 isotopes
1136.29 KeV Peak was used in identifying 2 isotopes

Surveillance test 1-SI-68-28 performed on 4/9/01

SURVEILLANCE TASK SHEET (SPP-8.2)

PAGE 1 OF 29

WORK ORDER: 010028300
SI KEY: P0531
PROCEDURE#: 1-SI-68-28
TITLE: PRIMARY RADIOCHEMISTRY REQUIREMENTS
PERF SECT: CEM
TEST REASON: PERIODIC PERFORMANCE
DUE: 04/09/01
WBN EXT: 04/10/01
MAX EXT: FORM SPP-8.2-2
FREQ: W
EQ: N
ASME XI: N
APP MODE: 123
PERF MODE: 1234
SUBSQNT RVWS:
INSTRUCTIONS: Do NOT start prior to scheduled due date

N/A
AUTHORIZATION TO BEGIN: SRO

N/A
DATE / TIME

4/9/01, 0745
START DATE / TIME

4/9/01, 1500
COMPLETION DATE / TIME

TEST PERFORMERS

NAME	SIGNATURE	INIT	SECT
Jim Clontz	[signature]	[illegible]	[illegible]
Daniel Kerns	[signature]	DK	CEM

WAS THIS A COMPLETE OR PARTIAL PERFORMANCE? (EXPLAIN "PARTIAL" IN REMARKS) COMPLETE: X PARTIAL: ___

WERE ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT REQ ACCEPTANCE CRITERIA SATISFIED? YES: X NO: ___ N/A: ___

WERE ALL OTHER ACCEPTANCE CRITERIA SATISFIED? YES: ___ NO: ___ N/A: X

ALERT SCHEDULING REQUIRED? YES: ___ NO: ___ N/A: X

IF ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT REQ WERE NOT SATISFIED, WAS AN LCO/TR/ODCM/OR ACTION REQ? (EXPLAIN IN REMARKS) YES: ___ NO: ___ N/A: X

[signature]
TEST DIRECTOR / LEAD PERFORMER

4/9/01
DATE

N/A
ACCEPTANCE CRITERIA REVIEW: SRO

N/A
DATE / TIME

[signature]
CHEM SUPV (NO REVIEW)

4/12/01
DATE

REMARKS:

COPY OF STS SENT TO SCHEDULING: ST, 4/12
INITIALS / DATE

SECTION/#MEN/DUR HRS

SECTION/#MEN/DUR HRS

SECTION/#MEN/DUR HRS

SECTION/#MEN/DUR HRS

RECORDS TRANSMITTAL#:

```
*****************************************
9-APR-2001 14:25:02.67
TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT
*****************************************

SAMPLE TITLE  : U1 - RCS - GASEOUS ACTIVTY
FILE IDENT    : DKB600:[TVA.SAMPLE.CHEM.NEW]W0104095767_C401.CNF;1

SAMPLE ID     : W0104095767_C401        * OPERATOR         : DRKERNS
SAMPLE TIME   : 9-APR-2001 13:25:       * SAMPLE GEOMETRY  : GM1K
                                        * SHELF HEIGHT     : 0
                                        * EFFICIENCY FILE  : GM1K0
SAMPLE TYPE   : 1240 CC GAS MARI        * SAMPLE QUANTITY  : 2.51000E+00 CC
*******************************************************************************

ACQ DATE & TIME    : 9-APR-2001 14:14:  * DEADTIME (%)     : 0.1%
PRESET  LIVE TIME  : 0 00:10:00         * SENSITIVITY      : 4.00000
ELASPED REAL TIME  : 0 00:10:00         * GAUSSIAN SEN     : 10.00000
ELAPSED LIVE TIME  : 0 00:10:00         * NBR ITERATIONS   : 10
*******************************************************************************

DETECTOR           : DET #4, GSS-3310   * LIBRARY            : NOBLEGAS
EFFIC CAL DATE     : 2-AUG-1994 11:26:  * EFFIC CERT DATE    : 2-AUG-1994 11:26:
DCAL DATE & TIME   : 9-APR-2001 02:40:  * ENERGY TOLER       : 1.25
KEV/CHAN           : 5.00516E-01        * HALF LIFE RATIO    : 8.00000
OFFSET             : 1.44837E-01 keV    * ABUNDANCE LIMIT    : 80.0%
Q COEFFICIENT      : -1.10914E-07       * CORRECTION FACTOR  : 1.00000E+00
PEAK START CHAN    : 140                * PEAK END CHAN      : 4096
*******************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
*******************************************************************************

COUNTED ON    : LION
COLLECTED BY  :
COUNTED BY    : DRKERNS
REVIEWED BY   :
COMMENTS      :

*******************************************************************************
```

Post-NID Peak Search Report

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	%Err	Fit	Nuclides
0	80.94	902	374	1.03	161.44	157	10	5.2		XE-133
0	151.17	294	315	1.07	301.75	297	10	12.8		KR-85M
0	166.01	57	226	1.10	331.42	328	8	47.7		KR-88
0	196.08	202	345	1.03	391.51	387	10	18.5		KR-88
0	249.77	2313	340	1.12	498.78	494	12	2.6		XE-135
0	258.57	59	201	1.04	516.37	513	8	43.2		
0	402.62	160	50	1.21	804.27	800	8	11.0		KR-87
0	510.99	7378	174	2.34	1020.88	1013	19	1.2		
0	526.86	66	31	1.08	1052.60	1048	11	20.7		XE-135M
0	609.00	34	35	0.87	1216.79	1209	16	43.6		XE-135
0	677.82	14	17	1.85	1354.36	1348	9	61.5		
0	834.68	38	12	1.75	1667.96	1662	12	24.5		KR-88
0	897.59	24	13	2.20	1793.76	1789	9	34.3		

REPORT NAME : QA_CHECK (V10.4) PAGE : 1
REPORT DATE : 9-APR-2001 14:25
REQUESTOR : DRKERNS

TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT

POST NID QA ANALYSIS

TITLE : U1 - RCS - GASEOUS ACTIVTY

SAMPLE No. : W0104095767_C401 OPERATOR NAME : DRKERNS
SAMPLE TYPE : 1240 CC GAS MARI SAMPLE GEOMETRY : GM1K
COUNT TIME : 9-APR-2001 14:14:53. SAMPLE QUANTITY : 2.51000E+00
SAMPLE TIME : 9-APR-2001 13:25:00. DETECTOR : DET #4, GSS-3310
LIBRARY : NOBLEGAS

ISOTOPE	PEAK ENERGY	ENERGY DIFF (KEV)	DECAY CORR uCi/CC	COMMENTS
AR-41	1293.64	-0.10	2.696E-03	QA Results OK
KR-85M	151.18	-0.01	2.013E-04	QA Results OK
KR-87	402.58	0.04	4.809E-04	QA Results OK
KR-88	196.32	-0.24	4.982E-04	QA Results OK
XE-133	81.00	-0.05	1.202E-03	QA Results OK
XE-135	249.79	-0.03	1.676E-03	QA Results OK
XE-135M	526.56	0.30	1.105E-03	QA Results OK
AVG ENERGY DIFF =		-0.01	7.859E-03 = TOTAL GAMMA ACTIVITY	
			0.000E+00 = Total DGL Activity	
			7.859E-03 = Total Gas Activity	

UNIDENTIFIED/REJECTED PEAKS

ENERGY	NET AREA	FWHM	GAMMA/SEC	GAMMA/SEC /CC	% ERROR	FLAG	POTENTIAL ID	ACTIVITY
258.57	59.	1.04	3.448E+00	1.374E+00	43.2	R	XE-138	1.724E-03
510.99	7378.	2.34	7.643E+02	3.045E+02	1.25	U	F-18	6.016E-03
						U	ANNIL	0.000E+00
677.82	14.	1.85	1.829E+00	7.289E-01	61.5	U	AG-110M	1.845E-04
						U	I-134	4.949E-04
897.59	24.	2.20	4.089E+00	1.629E+00	34.3	U	RB-88	3.932E-04
						U	Y-88	4.716E-05
1835.84	17.	2.13	5.418E+00	2.159E+00	24.3	U	RB-88	3.408E-04
						U	Y-88	5.872E-05

DK 4/9/01

```
*****************************************
9-APR-2001 10:48:39.98
TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT
*****************************************

SAMPLE TITLE  : U1 - RCS - DEGASSED LIQUID ACTIVITY
FILE IDENT    : DKB600:[TVA.SAMPLE.CHEM.NEW]W0104095766_C402.CNF;1

SAMPLE ID     : W0104095766_C402          * OPERATOR        : WNCLONTZ
SAMPLE TIME   : 9-APR-2001 08:20:         * SAMPLE GEOMETRY : 65ML
                                          * SHELF HEIGHT    : 1
                                          * EFFICIENCY FILE : 65ML1
SAMPLE TYPE   : RCS 65ML BOTTLE           * SAMPLE QUANTITY : 1.58100E+01 GRAMS
*******************************************************************************

ACQ DATE & TIME    : 9-APR-2001 09:45:    * DEADTIME (%)     : 4.6%
PRESET  LIVE TIME  : 0 01:00:00           * SENSITIVITY      : 4.00000
ELASPED REAL TIME  : 0 01:02:52           * GAUSSIAN SEN     : 10.00000
ELAPSED LIVE TIME  : 0 01:00:00           * NBR ITERATIONS   : 10
*******************************************************************************

DETECTOR           : DET #4, GSS-3310     * LIBRARY            : RCSLIQUID
EFFIC CAL DATE     : 19-JUL-2000 20:26    * EFFIC CERT DATE    : 19-JUL-2000 20:26
DCAL DATE & TIME   : 9-APR-2001 02:40:    * ENERGY TOLER       : 1.25
KEV/CHAN           : 5.00516E-01          * HALF LIFE RATIO    : 8.00000
OFFSET             : 1.44837E-01 keV      * ABUNDANCE LIMIT    : 80.0%
Q COEFFICIENT      : -1.10914E-07         * CORRECTION FACTOR  : 1.00000E+00
PEAK START CHAN    : 140                  * PEAK END CHAN      : 4096
*******************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
*******************************************************************************

COUNTED ON    : LION
COLLECTED BY  :
COUNTED BY    : WNCLONTZ
REVIEWED BY   :
COMMENTS      :                                   DGA = 7.224E-3
*******************************************************************************
```

Post-NID Peak Search Report

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	%Err	Fit	Nuclides
0	134.65	991	52495	0.82	268.75	266	7	38.5		W-187
										I-134
0	249.78	2586	43764	1.22	498.80	496	7	13.6		XE-135
0	364.48	569	19365	0.96	728.04	726	6	39.0		I-131
0	405.26	542	12870	1.06	809.53	807	7	35.0		I-134
0	433.34	305	11020	0.97	865.66	863	7	57.4		I-134
0	462.88	898	11840	1.08	924.71	921	8	21.3		CS-138
0	478.53	2028	19343	2.93	955.98	948	13	14.3		BE-7
										W-187
0	510.97	1460805	45497	2.66	1020.82	1013	18	0.1		F-18
0	522.71	1163	2480	1.33	1044.29	1041	8	8.0		I-132
2	526.52	1531	2060	1.17	1051.91	1048	16	5.5	9.34E-01	I-135
										XE-135M

```
*****************************************
          9-APR-2001 10:48:39.98
       TENNESSEE VALLEY AUTHORITY
        WATTS BAR NUCLEAR PLANT
*****************************************

SAMPLE TITLE  : U1 - RCS - DEGASSED LIQUID ACTIVITY
FILE IDENT    : DKB600:[TVA.SAMPLE.CHEM.NEW]W0104095766_C402.CNF;1

SAMPLE ID     : W0104095766_C402        * OPERATOR         : WNCLONTZ
SAMPLE TIME   : 9-APR-2001 08:20:       * SAMPLE GEOMETRY  : 65ML
                                        * SHELF HEIGHT     : 1
                                        * EFFICIENCY FILE  : 65ML1
SAMPLE TYPE   : RCS 65ML BOTTLE         * SAMPLE QUANTITY  : 1.58100E+01 GRAMS
*******************************************************************************

ACQ DATE & TIME   : 9-APR-2001 09:45:   * DEADTIME (%)     : 4.6%
PRESET  LIVE TIME : 0 01:00:00          * SENSITIVITY      : 4.00000
ELASPED REAL TIME : 0 01:02:52          * GAUSSIAN SEN     : 10.00000
ELAPSED LIVE TIME : 0 01:00:00          * NBR ITERATIONS   : 10
*******************************************************************************

DETECTOR          : DET #4, GSS-3310    * LIBRARY              : RCSLIQUID
EFFIC CAL DATE    : 19-JUL-2000 20:26   * EFFIC CERT DATE      : 19-JUL-2000 20:26
DCAL DATE & TIME  : 9-APR-2001 02:40:   * ENERGY TOLER         : 1.25
KEV/CHAN          : 5.00516E-01         * HALF LIFE RATIO       : 8.00000
OFFSET            : 1.44837E-01 keV     * ABUNDANCE LIMIT       : 80.0%
Q COEFFICIENT     : -1.10914E-07        * CORRECTION FACTOR     : 1.00000E+00
PEAK START CHAN   : 140                 * PEAK END CHAN         : 4096
*******************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/XEY V1.8
*******************************************************************************

COUNTED ON    : LION
COLLECTED BY  :
COUNTED BY    : WNCLONTZ
REVIEWED BY   :
COMMENTS      :                                   DGA = 7.224E-3
*******************************************************************************
```

Post-NID Peak Search Report

It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	%Err	Fit	Nuclides
0	134.65	991	52495	0.82	268.75	266	7	38.5		W-187
										I-134
0	249.78	2586	43764	1.22	498.80	496	7	13.6		XE-135
0	364.48	569	19365	0.96	728.04	726	6	39.0		I-131
0	405.26	542	12870	1.06	809.53	807	7	35.0		I-134
0	433.34	305	11020	0.97	865.66	863	7	57.4		I-134
0	462.88	898	11840	1.08	924.71	921	8	21.3		CS-138
0	478.53	2028	19343	2.93	955.98	948	13	14.3		BE-7
										W-187
0	510.97	1460805	45497	2.66	1020.82	1013	18	0.1		F-18
0	522.71	1163	2480	1.33	1044.29	1041	8	8.0		I-132
2	526.52	1531	2060	1.17	1051.91	1048	16	5.5	9.34E-01	I-135
										XE-135M

REPORT NAME : QA_CHECK (V10.4) PAGE : 1
REPORT DATE : 9-APR-2001 10:48
REQUESTOR : WNCLONTZ

TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT

POST NID QA ANALYSIS

TITLE : U1 - RCS - DEGASSED LIQUID ACTIVITY

SAMPLE No. : W0104095766_C402 OPERATOR NAME : WNCLONTZ
SAMPLE TYPE : RCS 65ML BOTTLE SAMPLE GEOMETRY : 65ML
COUNT TIME : 9-APR-2001 09:45:36. SAMPLE QUANTITY : 1.58100E+01
SAMPLE TIME : 9-APR-2001 08:20:00. DETECTOR : DET #4, GSS-3310
LIBRARY : RCSLIQUID

ISOTOPE	PEAK ENERGY	ENERGY DIFF (KEV)	DECAY CORR uCi/GRAM	COMMENTS
F-18	511.00	-0.03	1.116E-01	QA Results OK
NA-24	1368.53	0.05	2.060E-03	QA Results OK
MN-56	1810.69	0.33	2.088E-04	QA Results OK
CO-58	810.76	0.00	6.218E-04	QA Results OK
CO-60	1173.22	0.28	2.776E-05	QA Results OK
NB-95	765.79	0.46	2.794E-05	QA Results OK
I-131	364.48	0.00	3.881E-05	QA Results OK
I-132	667.69	0.00	1.165E-03	QA Results OK
I-133	529.87	0.01	6.105E-04	QA Results OK
I-134	847.03	-0.04	2.334E-03	QA Results OK
I-135	1260.41	-0.03	1.158E-03	QA Results OK
XE-135	249.79	-0.02	1.380E-04	QA Results OK
XE-135M	526.56	-0.04	1.972E-02	QA Results OK
CS-138	1435.86	-0.20	2.195E-03	QA Results OK
AVG ENERGY DIFF =		0.06	1.419E-01	= TOTAL GAMMA ACTIVITY
			1.168E-01	= Total DGL Activity
			2.223E-03	= Total FP Activity
			2.918E-03	= Total AP Activity
			1.986E-02	= Total Gas Activity
			5.307E-03	= Total HFP Activity

Dose Equivalent Iodine-131 = 2.098E-04
Iodine 131/133 Ratio = 6.357E-02
Iodine 133/135 Ratio = 5.274E-01

134.65 KeV Peak was used in identifying 2 isotopes
478.53 KeV Peak was used in identifying 2 isotopes
526.52 KeV Peak was used in identifying 2 isotopes
546.50 KeV Peak was used in identifying 2 isotopes
766.25 KeV Peak was used in identifying 2 isotopes
772.62 KeV Peak was used in identifying 2 isotopes
810.76 KeV Peak was used in identifying 2 isotopes
835.61 KeV Peak was used in identifying 2 isotopes
846.98 KeV Peak was used in identifying 2 isotopes

ENCLOSURE 1
ATTACHMENT 4

WATTS BAR NUCLEAR PLANT UNIT 1
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
ATMOSPHERIC DISPERSION VALUES (χ/Q) ARCON96 CALCULATION

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE: calculations(nuclear)	EDMS ACCESSION NO (N/A for REV. 0) T71 010228 800

Calc Title: **WBN CONTROL ROOM X/Q**

CALC ID	TYPE	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISIONAPPLICABILITY
CURRENT							
NEW	CN	WBN	NTB	WBNAPS3-104		0	Entire calc ☒ Selected pages ☐

ACTION	NEW ☒ REVISION ☐	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (D. V. & Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS	SYSTEMS	UNIDS
1 and 2	N/A	N/A

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION: Essential
E-50629A		

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☒ No ☐

PREPARER PHONE NO	PREPARING ORG (BRANCH)	DESIGN VERIFICATION METHOD:
751-8024	TVAN (MECH. DESIGN)	Design Review

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
[signature]	12/23/00	[signature]	12-28-00
DESIGN VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
[signature]	12-28-00	[signature]	2/13/2001

STATEMENT OF PROBLEM/ABSTRACT

This revision was performed to compare control room WBN X/Q values calculated by Stone & Webster (using the ARCON96 calculation, Attachment A) with control room X/Q values used in Watts Bar Calc. No's. TI-RPS-198 (Attachment B) and WBNTSR-008 (Attachment C). Determine the difference between old (Halitsky) and new (ARCON96) methodologies. The comparison is for LOCA/FHA (containment stack releases) and for MSLB/SGTR (main steam valve vault release) X/Q values.

The analysis shows that the old Halitsky X/Q values used in Watts Bar have substantial margin of conservatism. The Stone & Webster calculation used the latest philosophy to estimate dispersion from nuclear power plants following an accident, using the computer code ARCON96 approved and recommended by NRC. This analysis leads to the final conclusion that using the X/Q calculated by ARCON96 can significantly reduce estimated doses to control room personnel, although using the older Halitsky X/Q values will be conservative.

MICROFICHE/EFICHE Yes ☐ No ☒ FICHE NUMBER(S)

☐ LOAD INTO EDMS AND DESTROY
☐ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS:
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

CALC ID	TYPE	PLANT	BRANCH	NUMBER	REV
	CN	WBN	NTB	WBNAPS3-104	0

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report Yes ☐
NA	NA	NA	NA	TVA	

CATEGORIES

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN
A	X/Q Concentration	A	Control Room
A	LOCA	A	SGTR

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	CN	WBN	NTB	TI-RPS-198	15
A	P	CN	WBN	NTB	WBNTSR-008	7
A	P	CO	WBN	NTB	ARCON96	0

CCRIS ONLY UPDATES:
Following are required only when making keywords/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
PREPARER PHONE NO. 751-8024	EDMS ACCESSION NO.		

TVAN CALCULATION RECORD OF REVISION	
CALCULATION IDENTIFIER: WBNAPS33-104	
Title	WBN Control Room X/Q
Revision No.	DESCRIPTION OF REVISION
0	Initial issue. R0: 113 total pages

TVAN CALCULATION DESIGN VERIFICATION FORM

Calculation Identifier WBNAPS3-104 Revision 0

Method of design verification used:

1. Design Review ☒
2. Alternate Calculation ☐
3. Qualification Test ☐

Design Verifier Marc C. Begg Date 12-28-00

Comments:

This calculation compares 2 different methodologies for H/O (control room) determination. It was found that the older Halitsky methodology was conservative compared to the newer ARCON96 method. Although in the SGTR cases, there were several instances where the values ~~values~~ were almost identical. The methodologies used in the comparisons were simple division, and therefore acceptable. The calculation is technically adequate.

MCB 12-28-00

TVAN CALCULATION TABLE OF CONTENTS

Calculation Identifier: WBNAPS3-104	Revision: 0	

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SECTION	TITLE	PAGE
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	Calculation Design Verification Form	4
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	Special Requirements/Limiting Conditions	10
	Calculations	10
	Results	11
	Conclusions:	12
	References	13
	Attachment A TI-RPS-198 R15, "Dose to Control Room Personnel Due to a Regulatory Guide 1.4 Loss of Coolant Accident"	A1-A76
	Attachment B WBNTSR-008 R7, "Control Room Operator and Offsite Dose Due to a Steam Generator Tube Rupture"	B1-B15
	Attachment C WM(B)-001 R0, "Normalized Concentrations (X/Qs) at the Unit 1 and Unit 2 Control Room Air Intakes for LOCA Releases from the Containment Vents and SGTR Releases from Exhaust Stacks".	C1-C09

TVAN COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document WBNAPS3-104	Rev.	Plant: WBN	

Subject:
WBN Control Room X/Q

☐ Electronic storage of the input files for this calculation is not required. Comments:

☒ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

The metheorological data input files for the attached Stone & Webster calculation (Attachment A) are stored permanently in FILEKEEPER file No. 303363.

☐ Microfiche/eFiche

TVAN COMPUTER OUTPUT
MICROFICHE INFORMATION SHEET

Document WBNAPS-104	Rev. 0	Plant: WBN	

Subject:
WBN Control Room X/Q

Microfiche	Description
	All computer output is attached.

PURPOSE

The purpose of this calculation is to compare control room X/Q values calculated by Stone & Webster (calculation Attachment A) with control room X/Q values used earlier at Watts Bar (calculation TI-RPS-198, Attachment B and WBNTSR-008, Attachment C), and determine the difference between old (Halitsky) and new ACRON96 methodologies. The X/Q values are used to determine doses to control room personnel from plant releases during normal operation and accident conditions.

INTRODUCTION

This analysis compares X/Q values to the control room intakes (emergency and normal intakes) for various accident scenarios using two different methodologies: (a) utilizing Halitsky methodology, and (b) the most recently developed ARCON96 methodology.

The conventions used in this analysis are as follows:

X/Q for LOCA/FHA = X/Q for containment stack/vent release
X/Q for SGTR/MSLB = X/Q for main steam valve vault release

DESIGN INPUT DATA

The results of X/Q calculations are compiled in the Tables shown below. Table No. 1 (results are extracted from calculation TI-RPS-198, R15) and Table No. 2 (results are from Stone & Webster calculation WM(B)-001, R0) show X/Q values used for a LOCA/FHA; Table No. 3 (results are taken from calculation WBNTSR-008, R7) and Table No. 4 (results are taken from Stone & Webster calculation WM(B)-001, R0) show X/Q values used for SGTR/MSLB.

Table No. 1

X/Q values used in calculation TI-RPS-198, R15 (Attachment A) to estimate doses to control room personnel after LOCA/FHA using Halitsky method

			0-2 hr	2-8 hr	8-24 hr	1-4 day	4-30 days	Air intake No/location
Unit 1	Case No. 1	Full Rx Bldg	3.11E-03	1.84E-03	1.09E-03	5.72E-04	1.40E-04	1/East
	Case No. 2	Full Rx Bldg	2.15E-03	1.31E-03	[illegible]	[illegible]	[illegible]	2/West
Unit 2	Case No. 3	Full Rx Bldg	1.50E-03	1.02E-03	7.01E-04	3.80E-04	9.63E-05	1/East
	Case No. 4	Full Rx Bldg	1.32E-03	8.58E-04	5.89E-04	3.17E-04	7.55E-05	2/West

Shaded areas show the worst X/Q values for time intervals up to 8 hours. For WBN at 8 hours the operator switch intakes to the more favorable vent (per TI-RPS-198).

Table No. 2

X/Q values determined in Stone & Webster calculation WM(B)-001, R0 (Attachment C) using ARCON96 methodology to calculate doses to control room personnel after LOCA/FHA

			0-2 hr	2-8 hr	8-24 hr	1-4 day	4-30 days	Air intake No/location
Unit 1	Case No. 1	Full Rx Bldg	4.47E-04	2.81E-04	1.21E-04	9.36E-05	7.77E-05	1/East
Unit 1	Case No. 2	Full Rx Bldg	1.09E-03	9.50E-04	4.56E-04	3.09E-04	2.35E-04	2/West
		1/2 Rx Bldg	1.09E-03	9.59E-04	4.60E-04	3.09E-04	2.37E-04	2/West
		1/4 Rx Bldg	1.09E-03	9.72E-04	4.65E-04	3.10E-04	2.39E-04	2/West
		1/8 Rx Bldg	1.12E-03	9.78E-04	4.73E-04	3.10E-04	2.41E-04	2/West
		No Bldg Area	1.29E-03	1.16E-03	5.55E-04	3.35E-04	2.84E-04	2/West
Unit 2	Case No. 3	Full Rx Bldg	8.28E-04	7.69E-04	3.90E-04	2.98E-04	2.17E-04	1/East
		1/2 Rx Bldg	8.28E-04	7.75E-04	3.94E-04	2.99E-04	2.18E-04	1/East
		1/4 Rx Bldg	8.63E-04	7.69E-04	4.01E-04	2.99E-04	2.19E-04	1/East
		1/8 Rx Bldg	8.85E-04	7.73E-04	4.09E-04	3.00E-04	2.21E-04	1/East
		No Bldg Area	9.78E-04	9.08E-04	4.71E-04	3.21E-04	2.36E-04	1/East
Unit 2	Case No. 4	Full Rx Bldg	4.13E-04	3.54E-04	1.90E-04	1.43E-04	1.03E-04	2/West

Shaded areas show the worst X/Q values for time intervals up to 8 hours. For WBN at 8 hours the operator switch intakes to the more favorable vent (per TI-RPS-198).

Table No. 3

X/Q values used in calculation WBNTSR-008, R7 (Attachment B) to estimate doses to control room personnel after SGTR/MSLB using Halitsky method

			0-2 hr	2-8 hr	8-24 hr	1-4 day	4-30 days	Air intake No/location
Unit 1	Case No. 1	Full Rx Bldg	3.84E-03	2.03E-03	1.00E-03	8.18E-03	6.93E-04	1/East
	Case No. 2	Full Rx Bldg	4.07E-03	2.47E-03	1.97E-03	1.37E-03	9.84E-04	2/West
Unit 2	Case No. 3	Full Rx Bldg	2.53E-03	1.72E-03	1.48E-03	1.04E-03	7.23E-04	1/East
	Case No. 4	Full Rx Bldg	1.70E-03	1.10E-03	9.44E-04	6.73E-04	4.84E-04	2/West

Shaded areas show the worst X/Q values for time intervals up to 8 hours. For WBN at 8 hours the operator switch intakes to the more favorable vent (per TI-RPS-198).

Table No. 4

X/Q values estimated in Stone & Webster calculation WM(B)-001, R0 (Attachment C) using ARCON96 methodology to calculate doses to control room personnel due to SGTR/MSLB

			0-2 hr	2-8 hr	8-24 hr	1-4 day	4-30 days	Air intake No/location
Unit 1	Case No. 5	Full Rx Bldg	7.96E-04	4.68E-04	2.23E-04	1.78E-04	1.44E-04	1/East
		1/2 Rx Bldg	8.01E-04	4.70E-04	2.23E-04	1.79E-04	1.44E-04	1/East
		1/4 Rx Bldg	8.07E-04	4.72E-04	2.25E-04	1.80E-04	1.45E-04	1/East
		1/8 Rx Bldg	8.13E-04	4.75E-04	2.27E-04	1.81E-04	1.45E-04	1/East
		No Bldg Area	8.96E-04	5.16E-04	2.47E-04	1.95E-04	1.55E-04	1/East
Unit 1	Case No. 6	Full Rx Bldg	4.03E-03	3.35E-03	1.54E-03	1.05E-03	8.81E-04	2/West
Unit 2	Case No. 7	Full Rx Bldg	2.60E-03	2.16E-03	1.02E-03	6.96E-04	5.71E-04	1/East
		1/2 Rx Bldg	2.60E-03	2.17E-03	1.02E-03	6.97E-04	5.73E-04	1/East
		1/4 Rx Bldg	2.61E-03	2.18E-03	1.02E-03	6.99E-04	5.74E-04	1/East
		1/8 Rx Bldg	2.62E-03	2.19E-03	1.03E-03	7.01E-04	5.76E-04	1/East
		No Bldg Area	2.87E-03	2.46E-03	1.14E-03	7.55E-04	6.22E-04	1/East
Unit 2	Case No. 8	Full Rx Bldg	5.85E-04	3.89E-04	1.93E-04	1.47E-04	1.17E-04	2/West
		1/2 Rx Bldg	5.87E-04	3.91E-04	1.93E-04	1.47E-04	1.17E-04	2/West
		1/4 Rx Bldg	5.92E-04	3.92E-04	1.95E-04	1.48E-04	1.18E-04	2/West
		1/8 Rx Bldg	5.97E-04	3.94E-04	1.96E-04	1.49E-04	1.18E-04	2/West
		No Bldg Area	6.38E-04	4.10E-04	2.07E-04	1.55E-04	1.21E-04	2/West

Shaded areas show the worst X/Q values for time intervals up to 8 hours. For WBN at 8 hours the operator switch intakes to the more favorable vent (per TI-RPS-198).

ASSUMPTIONS

See References 1, 2 and 3.

SPECIAL REQUIREMENTS/LIMITING CONDITIONS

There are no special requirements or limiting conditions in this calculation.

CALCULATIONS

X/Q values are used to determine the doses to control room personnel. The earlier calculation (WBNTSR-008 R7 and TI-RPS-198 R15) used Halitsky methodology to calculate X/Q atmospheric dispersion due to SGTR and LOCA accidents. Recently Stone and Webster performed X/Q determination using the latest version of the Atmospheric Relative CONcentration (ARCON96 computer code documented as Stone & Webster EN-292, V00, L00, see Reference. 1). This method is approved and recommended by NRC.

These two different calculating philosophies were compared. The X/Q values calculated using Halitsky methodology were divided by X/Q values estimated using ARCON96 methodology. The evaluation was performed for LOCA/FHA and SGTR/MSLB scenarios. The final results are compiled in Tables 5, 6, 7 and 8.

RESULTS

The calculated numbers show that the X/Q values estimated using Halitsky methodology contain significant margin of conservatism for all time intervals except for time interval 4-30 days in Tables 5 and 6.

All other Halitsky calculated numbers are conservative and significantly exceed the safety margin established by using ARCON96 methodology.

Table No. 5

Ratio of LOCA/FHA X/Q cases 1 and 2 from calculation TI-RPS-198 (Halitsky) to cases 1 and 2 from S&W (ARCON96)

	Ratio		0-2 hr	2-8 hr	8-24 hr	1-4 day	4-30 days	Air intake No/location
1	Case No. 1/1	Full Rx Bldg	6.96	5.84	9.01	6.11	1.80	1/East
2	Case No. 2/2	Full Rx Bldg	1.97	1.38	1.83	1.41	0.45	2/West
		1/2 Rx Bldg	1.97	1.37	1.81	1.41	0.45	2/West
		1/4 Rx Bldg	1.97	1.35	1.79	1.41	0.44	2/West
		1/8 Rx Bldg	1.92	1.34	1.76	1.41	0.44	2/West
		No Bldg Area	1.67	1.13	1.50	1.30	0.40	2/West

Table No. 6

Ratio of LOCA/FHA X/Q cases 3 and 4 from calculation TI-RPS-198 (Halitsky) to cases 3 and 4 from S&W (ARCON96)

	Ratio		0-2 hr	2-8 hr	8-24 hr	1-4 day	4-30 days	Air intake No/location
3	Case No. 3/3	Full Rx Bldg	1.81	1.23	1.80	1.28	0.44	2/West
		1/2 Rx Bldg	1.81	1.23	1.78	1.27	0.44	1/East
		1/4 Rx Bldg	1.74	1.18	1.75	1.27	0.44	1/East
		1/8 Rx Bldg	1.69	1.18	1.71	1.27	0.44	1/East
		No Bldg Area	1.53	1.04	1.49	1.18	0.41	1/East
4	Case No. 4/4	Full Rx Bldg	3.20	2.42	3.10	2.22	0.73	2/West

Table No. 7

Ratio of SGTR/MSLB X/Q cases 1 and 2 from calculation WBNTSR-008 (Halitsky) to cases 5 and 6 from S&W (ARCON96)

	Ratio		0-2 hr	2-8 hr	8-24 hr	1-4 day	4-30 days	Air intake No/location
5	Case No. 1/5	Full Rx Bldg	4.82	4.34	7.53	6.63	6.17	1/East
		1/2 Rx Bldg	4.79	4.32	7.53	6.59	6.17	1/East
		1/4 Rx Bldg	4.76	4.30	7.47	6.56	6.13	1/East
		1/8 Rx Bldg	4.71	4.27	7.40	6.52	6.13	1/East
		No Bldg Area	4.29	3.93	6.80	6.05	5.74	1/East
6	Case No. 2/6	Full Rx Bldg	1.01	0.74	1.28	1.30	1.12	2/West

Table No. 8

Ratio of SGTR/MSLB X/Q cases 3 and 4 from calculation WBNTSR-008 (Halitsky) to cases 7 and 8 from S&W (ARCON96)

	Ratio		0-2 hr	2-8 hr	8-24 hr	1-4 day	4-30 days	Air intake No/location
7	Case No. 3/7	Full Rx Bldg	0.97	0.80	1.43	1.49	1.27	1/East
		1/2 Rx Bldg	0.97	0.79	1.43	1.49	1.26	1/East
		1/4 Rx Bldg	0.97	0.79	1.43	1.49	1.26	1/East
		1/8 Rx Bldg	0.97	0.79	1.42	1.48	1.26	1/East
		No Bldg Area	0.88	0.70	1.28	1.38	1.16	1/East
8	Case No. 4/8	Full Rx Bldg	2.91	2.83	4.89	4.58	3.97	2/West
		1/2 Rx Bldg	2.90	2.81	4.89	4.58	3.97	2/West
		1/4 Rx Bldg	2.87	2.81	4.84	4.55	3.93	2/West
		1/8 Rx Bldg	2.85	2.79	4.82	4.52	3.93	2/West
		No Bldg Area	2.66	2.68	4.56	4.34	3.83	2/West

CONCLUSIONS

Based on calculated results it can be concluded that the X/Q values using Halitsky methodology envelope the X/Q values calculated by ARCON96 method.

REFERENCES

1. S&W CALC NO. Job#13090.0100 WM(B)-001 R0, "Normalized Concentrations (X/Qs) at the Unit 1 and Unit 2 Control Room Air Intakes for LOCA Releases from Containment Vents and SGTR Releases from Exhaust Stacks" (Attachment A).

2. TI-RPS-198 R15, "Dose to Control Room Personnel Due to a Regulatory Guide 1.4 Loss of Coolant Accident" (Attachment B).

3. WBNTSR-008 R7, "Control Room Operator and Offsite Dose Due to a Steam Generator Tube Rupture" (Attachment C).

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ATTACHMENT A
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STONE & WEBSTER ENGINEERING CORPORATION
CALCULATION TITLE PAGE

CLIENT & PROJECT:	PAGE 1 of 68 Total Pages: 77 w/attachments pages 9
TENNESSEE VALLEY AUTHORITY- WATTS BAR NUCLEAR PLANT	
CALCULATION TITLE: Normalized Concentrations (X/Qs) at the Unit 1 and Unit 2 Control Room Air Intakes for LOCA Releases from the Containment Vents and SGTR Releases from Exhaust Stacks	QA CATEGORY (✓) ☑ I ☐ II

CALCULATION IDENTIFICATION NUMBER				OPTIONAL WORK PACKAGE NO.
JOB ORDER NO.	DISCIPLINE	CURRENT CALC NO	OPTIONAL TASK CODE	
13090.0100	WM(B)	001		

APPROVALS - SIGNATURE & DATE			REVISION NO. OR NEW CALCULATION NO.	SUPERSEDES CALCULATION NO. OR REVISON NO.	CONFIRMATION REQUIRED (✓)	
PREPARES(S) / DATE(S)	REVIEWER(S) / DATES(S)	INDEPENDENT REVIEWER(S) / DATE(S)			YES	NO
Stephen A. Vigeant Stephen A. Vigeant 12/18/00	Carl A. Mazzola Carl A. Mazzola 12/19/00	Carl A. Mazzola Carl A. Mazzola 12/19/00	0			✓

DISTRIBUTION

GROUP	NAME & LOCATION	COPY SENT (✓)	GROUP	NAME & LOCATION	COPY SENT (✓)
Record Mgmt. File (or Fire File if none)					
Project Engineer	C. Mazzola: Augusta, GA	cc			
Specialist	Stephen A. Vigeant: Boston - 3	cc			
TVA-Corporate	M. Berg	Original			

WBNAPS3-104, R0
ATTACHMENT A,
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STONE & WEBSTER ENGINEERING CORPORATION
CALCULATION SHEET

5010.65

CALCULATION IDENTIFICATION NUMBER				
JOB ORDER NO. 13090.0100	DISCIPLINE WM(B)	CALCULATION NO. 001	REVISION NUMBER 0	PAGE 2 OF 68

CHANGE HISTORY PAGE

REVISION NO.	DESCRIPTION OF CHANGES	PAGES REVISED	PAGES ADDED	PAGES REPLACED
0	0	N/A	N/A	N/A

CALCULATION IDENTIFICATION NUMBER				
JOB ORDER NO. 13090.0100	DISCIPLINE WM(B)	CALCULATION NO. 001	REVISION NUMBER 0	PAGE 3 OF 68

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ATTACHMENT A - E-mail from Kenneth Wastrack (TVA) to Stephen Vigeant (S&W) dated 9/29/00, 10:17:47 AM transmitting 1976-1993 Watts Bar meteorological data in ARCON96 format ..... A-1 – A-3

ATTACHMENT B - TVA Drawing No. 47W200-1, "Equipment Plans - Roof", Watts Bar Nuclear Plant, Rev. 12 ..... B-1

ATTACHMENT C - TVA Drawing No. 47W200-8, "Equipment Traverse Section A8-A8", Watts Bar Nuclear Plant, Rev. 7 ..... C-1

ATTACHMENT D - TVA Drawing No. 47W200-9, "Equipment Longitudinal Section B9-B9", Watts Bar Nuclear Plant, Rev. 6 ..... D-1

ATTACHMENT E - TVA Drawing No. 47W415-1, "Mechanical Main Steam Relief & Saftey Valve Vents", Watts Bar Nuclear Plant, Rev. 10 ..... E-1

ATTACHMENT F - TVA Drawing No. 41N718-1, "Concrete Dome Outline", Watts Bar Nuclear Plant, Rev. 9 ..... F-1

ATTACHMENT G - TVA Drawing No. 41N712-1, "Concrete Exterior Wall Outline", Watts Bar Nuclear Plant, Rev. E G-1

OBJECTIVE

To calculate normalized atmospheric dispersion values (i.e., X/Qs) at the Watts Bar normal and emergency control room air intakes for gaseous radiological releases from the Unit 1 and Unit 2 reactor vents following a Loss of Coolant (LOCA) accident and from the Unit 1 and Unit 2 exhaust stacks following a Steam Generator Tube Rupture (SGTR). These X/Q calculations also determine the sensitivity of the X/Q values to the cross-sectional building area used as input to the ARCON96 program.

The specific release-receptor combinations for which X/Q values are calculated are as follows:

1. Unit 1Reactor Vent to Emergency Control Room Air Intake (LOCA)
2. Unit 1Reactor Vent to Normal Control Room Air Intake (LOCA)
3. Unit 2Reactor Vent to Emergency Control Room Air Intake (LOCA)
4. Unit 2Reactor Vent to Normal Control Room Air Intake (LOCA)
5. Unit 1Exhaust Stacks to Emergency Control Room Air Intake (SGTR)
6. Unit 1Exhaust Stacks to Normal Control Room Air Intake (SGTR)
7. Unit 2Exhaust Stacks to Emergency Control Room Air Intake (SGTR)
8. Unit 2Exhaust Stacks to Normal Control Room Air Intake (SGTR)

METHODOLOGY

The control room intake X/Q values for the aforementioned eight (8) release/receptor combinations are calculated using the latest version of the "**A**tmospheric Relative **CON**centrations in Building Wakes" (ARCON96) methodology (Ref. 1). Input data include: hourly on-site meteorological data; release characteristics including release height and the building area affecting the release; and receptor information such as distance and direction from the release to the control room air intake and intake height.

This methodology is able to evaluate ground-level, vent, and elevated stack releases and treats building wake effects and low wind speed plume meander effects when applicable. A mixed mode approach is used in the case of vent releases to determine if the release should be treated as ground level or elevated. This methodology is also able to evaluate area source releases, as in this case of multiple vents spread over a roof top, using the virtual point source technique where initial values of the dispersion coefficients are assigned based on the size of the area source. The various averaging time X/Q values are calculated directly from running averages of the hourly X/Q values.

A continuous temporally representative 18-year period of hourly data from Watts Bar's meteorological tower (i.e., January 1, 1976 through December 31, 1993) is used in this calculation (Ref. 2). Each hour of data, at a minimum, must have a validated wind speed and direction at the 10-meter level and a temperature difference between the 45- and 10-meter levels. The release/receptor information is taken from Refs. 3 through 8.

All releases are conservatively treated as ground-level as there are no releases at this site that are high enough to escape the aerodynamic effects of the plant buildings (i.e., 2.5 times Containment Building height, Ref. 9). The reactor building area having an effect on the dispersion of the applicable releases is evaluated for its effect on the calculated X/Q values. The full reactor cross-sectional area, along with 1/2, 1/4 and 1/8 of the reactor cross-sectional area, are used as input to the calculation. The effect of using no building cross-sectional area on the calculated X/Q values is also evaluated. The sensitivity of X/Q values to building area is not evaluated for Release/Receptor combinations 1, 4, and 6 as the use of the full reactor building cross-sectional area is clearly justified for these orientations (see Ref. 3).

The building area sensitivity analysis, along with a review of U.S. NRC NUREGS and technical papers dealing with building wake effects relative to X/Q calculations (Refs. 10-15), are used as the basis for selecting the cross-sectional building areas for this calculation that are considered defensible to the U.S. NRC.

ASSUMPTIONS

1. The plume centerline from each release is conservatively transported directly over the control room air intake.

2. The reactor building cross-sectional areas used as input to the calculation include the full cross-sectional area along with 1/2, 1/4, and 1/8 of the building area. No building area is also used. Release/Receptor combinations 1, 4, and 6 are excluded from the building area analysis as the use of the full reactor building cross-sectional area is clearly justified for these orientations (see Ref. 3).

3. The ARCON96 default wind direction range of 90° centered on the direction that transports the gaseous effluents from the release points to either of the intakes is used in the calculation. The ARCON default calm wind speed value of 0.5 m/sec is also used in this calculation.

4. The ARCON96 default values for surface roughness length (i.e., 0.10 meter), representative of the topography in the vicinity of the Watts Bar Plant, and sector averaging constant (4.0) are used in the calculation.

5. All releases are conservatively treated as ground level releases as there are no release conditions that merit categorization as an elevated release (i.e., 2.5 times Containment Building height, Ref. 9) at this site.

6. Given that the SGTR stack releases are from multiple sources, the distance from each set of stacks to each control room air intake is conservatively based on the stack closest to the air intake.

INPUT DATA

Meteorological Data (Ref. 2):

Parameter	Units
9.7-meter wind speed	0.1 mi/hr
9.7-meter wind direction	degrees azimuth
Atmospheric stability class (based on 45.6-9.5 meter temperature difference)	P-G stability class (1-7)

Wind speed assigned to calm = 0.5 m/sec (ARCON96 default)
Data Period: January 1, 1976 through December 31, 1993

Release/Receptor Data:

1. Unit 1 Reactor Vent to Emergency Control Room Air Intake (LOCA)

Distance from Reactor Vent to emergency control room air intake = 108.7 meters - (Ref. 3)
Wind direction from Reactor Vent to emergency control room air intake = 304° azimuth - (Ref. 3)
Plant grade elevation = 728.0 ft - (Ref. 5)
Emergency control room air intake elevation = 775.0 ft - (Refs. 3 & 4)
Emergency control room air intake elevation above grade = 775.0 ft - 728.0 ft = 47.0 ft (14.33 m)
Reactor Vent elevation = 857.6 ft - (Ref. 7)
Reactor Vent height above grade = 857.6 ft - 728.0 ft = 129.6 ft (39.5 m)
Reactor Building height up to dome base = 862 ft - 728 ft = 134 ft - (Ref. 8)
Reactor Building diameter (d) = 131.08 ft - (Ref. 7)
Reactor Building area (up to dome curvature) = 134.0 ft x 131.08 ft = 17,564.7 ft^2 (1,631.8 m^2)
Reactor Building dome area $= \pi r^2 (\theta/360) - [r^2 \sin(\theta)]/2$; where
$\theta = 2\cos^{-1}(d/r)$, and
d = distance from the origin of the dome sphere to the top of the dome base
Elevation of the origin of the dome sphere = 790.01 ft (Ref. 7)
Distance (d) from the origin of the dome sphere to the top of the dome base = 862.0 ft - 790.01 ft =71.99 ft
Reactor Building dome radius (r) = 89.03 ft (Ref. 7)
$\theta = 2\cos^{-1}(71.99\ ft/89.03\ ft) = 72.08$ degrees
Reactor Building dome area $= \pi(89.03\ ft)^2 (72.08/360) - [(89.03)^2 \sin(72.08)]/2 = 1{,}214.9\ ft^2$
Full Reactor Building area (total) = 17,564.7 ft^2 + 1,214.9 ft^2 = 18,779.6 ft^2 (1,744.7 m^2)
1/2 Reactor Building area = (1,744.7 m^2)/2 = 872.4 m^2
1/4 Reactor Building area = (1,744.7 m^2)/4 = 436.2 m^2
1/8 Reactor Building area = (1,744.7 m^2)/8 = 218.1 m^2

2. Unit 1 Reactor Vent to Normal Control Room Air Intake (LOCA)

Distance from Reactor Vent to normal control room air intake = 67.9 meters - (Ref. 3)
Wind direction from Reactor Vent to normal control room air intake = 346° azimuth - (Ref. 3)
Plant grade elevation = 728 ft - (Ref.5)
Normal control room air intake elevation = 775 ft - (Refs. 3 & 4)
Normal control room air intake elevation above grade = 775 ft - 728 ft = 47.0 ft (14.33 m)
Reactor Vent elevation = 857.6 ft - (Ref. 7)
Reactor Vent height above grade = 857.6 ft - 728.0 ft = 129.6 ft (39.5 m)
Reactor Building area - see Release/Receptor No. 1

3. Unit 2 Reactor Vent to Emergency Control Room Air Intake (LOCA)

Distance from Reactor Vent to emergency control room air intake = 79.6 meters - (Ref. 3)
Wind direction from Reactor Vent to emergency control room air intake = 8° azimuth - (Ref. 3)
Plant grade elevation = 728.0 ft - (Ref. 5)
Emergency control room air intake elevation = 775.0 ft - (Refs. 3 & 4)
Emergency control room air intake elevation above grade = 775.0 ft - 728.0 ft = 47.0 ft (14.33 m)
Reactor Vent elevation = 857.6 ft - (Ref. 7)
Reactor Vent height above grade = 857.6 ft - 728.0 ft = 129.6 ft (39.5 m)
Reactor Building area - see Release/Receptor No. 1

4. Unit 2 Reactor Vent to Normal Control Room Air Intake (LOCA)

Distance from Reactor Vent to normal control room air intake = 119.3 meters - (Ref. 3)
Wind direction from Reactor Vent to normal control room air intake = 46° azimuth - (Ref. 3)
Plant grade elevation = 728.0 ft - (Ref. 5)
Normal control room air intake elevation = 775.0 ft - (Refs. 3 & 4)
Normal control room air intake elevation above grade = 775.0 ft - 728.0 ft = 47.0 ft (14.33 m) - (Ref. 10)
Reactor Vent elevation = 857.6 ft - (Ref. 7)
Reactor Vent height above grade = 857.6 ft - 728.0 ft = 129.6 ft (39.5 m)
Reactor Building area - see Release/Receptor No. 1

5. Unit 1 Exhaust Stacks to Emergency Control Room Air Intake (SGTR)

Distance from Exhaust Stack to emergency control room air intake = 81.1 meters - (Ref. 3)
Wind direction from Exhaust Stack to emergency control room air intake = 292° azimuth - (Ref. 3)
Plant grade elevation = 728.0 ft - (Ref. 5)
Emergency control room air intake elevation = 775.0 ft - (Refs. 3 & 4)
Emergency control room air intake elevation above grade = 775.0 ft - 728.0 ft = 47.0 ft (14.33 m)
Exhaust Stack elevation = 796.0 ft - (Ref. 6)
Exhaust Stack height above grade = 796.0 ft - 728.0 ft = 68.0 ft (20.7 m)
Reactor Building area - see Release/Receptor No. 1

6. Unit 1 Exhaust Stacks to Normal Control Room Air Intake (SGTR)

Distance from Exhaust Stack to emergency control room air intake = 35.5 meters - (Ref. 3)
Wind direction from Exhaust Stack to emergency control room air intake = 358° azimuth - (Ref. 3)
Plant grade elevation = 728.0 ft - (Ref. 5)
Normal control room air intake elevation = 775.0 ft - (Refs. 3 & 4)
Normal control room air intake elevation above grade = 775.0 ft - 728.0 ft = 47.0 ft (14.33 m)
Exhaust Stack elevation = 796.0 ft - (Ref. 6)
Exhaust Stack height above grade = 796.0 ft - 728.0 ft = 68.0 ft (20.7 m)
Reactor Building area - see Release/Receptor No. 1

7. Unit 2 Exhaust Stacks to Emergency Control Room Air Intake (SGTR)

Distance from Exhaust Stack to emergency control room air intake = 45.1 meters - (Ref. 3)
Wind direction from Exhaust Stack to emergency control room air intake = 12° azimuth - (Ref. 3)
Plant grade elevation = 728.0 ft - (Ref.5)
Emergency control room air intake elevation = 775.0 ft - (Refs. 3 & 4)
Emergency control room air intake elevation above grade = 775.0 ft - 728.0 ft = 47.0 ft (14.33 m)
Exhaust Stack elevation = 796.0 ft - (Ref. 6)
Exhaust Stack height above grade = 796.0 ft - 728.0 ft = 68.0 ft (20.7 m)
Reactor Building area - see Release/Receptor No. 1

8. Unit 2 Exhaust Stacks to Normal Control Room Air Intake (SGTR)

Distance from Exhaust Stack to emergency control room air intake = 96.5 meters - (Ref. 3)
Wind direction from Exhaust Stack to emergency control room air intake = 60° azimuth - (Ref. 3)
Plant grade elevation = 728.0 ft - (Ref. 5)
Normal control room air intake elevation = 775.0 ft - (Refs. 3 & 4)
Normal control room air intake elevation above grade = 775.0 ft - 728.0 ft = 47.0 ft (14.33 m) - (Ref. 10)
Exhaust Stack elevation = 796.0 ft - (Ref. 6)
Exhaust Stack height above grade = 796.0 ft - 728.0 ft = 68.0 ft (20.7 m)
Reactor Building area - see Release/Receptor No. 1

ARCON96 CALCULATION

1. Unit 1 Reactor Vent to Emergency Control Room Air Intake (LOCA):

Program Title: ARCON96. **(Full Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

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Code Documentation: NUREG/CR-6331 Rev. 1

The program was prepared for an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibilities for any third party's use, or the results of such use, of any portion of this program or represents that its use by such third party would not infringe privately owned rights.

Program Run 12/15/2000 at 12:48:08

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =   1744.7
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      304
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   259 - 349
   Distance to intake (m)               =    108.7
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wblocal.log
     wblocal.cfd
```

```
     Minimum Wind Speed (m/s)                =       .5
     Surface roughness length (m)            =       .10
     Sector averaging constant               =      4.0

     Initial value of sigma y                =       .00
     Initial value of sigma z                =       .00

     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  20017
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  26345
     Hours direction not in window or calm   = 105454

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03
1.00E-03   1.00E-03   1.00E-03   1.00E-03
      LOW LIM.    1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07
1.00E-07   1.00E-07   1.00E-07   1.00E-07
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      46362.     60567.     77721.     98756.     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
39.        0.         0.         0.
          ZERO      ******     90130.     70907.     46071.     31645.     11800.
248.       59.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       30.54      40.19      52.29      68.19      78.62      91.95
99.82      99.96     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   4.47E-04   4.16E-04   3.60E-04   3.22E-04   2.64E-04   1.88E-04
1.17E-04   1.03E-04   9.02E-05   8.30E-05

     95% X/Q for standard averaging intervals

     0 to 2 hours        4.47E-04
     2 to 8 hours        2.81E-04
     8 to 24 hours       1.21E-04
     1 to 4 days         9.36E-05
     4 to 30 days        7.77E-05

                                 HOURLY VALUE RANGE
                              MAX X/Q              MIN X/Q
          CENTERLINE         6.83E-04             3.90E-05
          SECTOR-AVERAGE     4.28E-04             2.44E-05

 NORMAL PROGRAM COMPLETION
```

2. Unit 1 Reactor Vent to Normal Control Room Air Intake (LOCA):

Program Title: ARCON96. **(Full Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 12:51:08

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =   1744.7
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      346
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   301 - 031
   Distance to intake (m)               =     67.9
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbloca2.log
     wbloca2.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0
```

```
     Initial value of sigma y              =        .00
     Initial value of sigma z              =        .00

     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  38963
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  26345
     Hours direction not in window or calm   =  86508

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96         168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      65308.     80388.     96381.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
           ZERO      86508.     70309.     52247.     32293.     21597.      7816.
143.         0.         0.         0.
    TOTAL X/Qs       ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO        43.02      53.34      64.85      77.70      85.41      94.67
99.90     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                    1.09E-03   1.07E-03   1.04E-03   9.85E-04   8.21E-04   6.32E-04
3.90E-04   3.30E-04   2.81E-04   2.56E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        1.09E-03
     2 to 8 hours        9.50E-04
     8 to 24 hours       4.56E-04
     1 to 4 days         3.09E-04
     4 to 30 days        2.35E-04

                                HOURLY VALUE RANGE
                              MAX X/Q              MIN X/Q
          CENTERLINE         1.56E-03             1.39E-04
          SECTOR-AVERAGE     9.75E-04             8.72E-05

 NORMAL PROGRAM COMPLETION
```

5010.65

STONE & WEBSTER ENGINEERING CORPORATION
CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER				
JOB ORDER NO. 13090.0100	DISCIPLINE WM(B)	CALCULATION NO. 001	REVISION NUMBER 0	PAGE 13 OF 68

Program Title: ARCON96. **(1/2 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 12:52:21

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =    872.4
   Effluent vertical velocity (m/s)     =      .00
   Vent or stack flow  (m^3/s)          =      .00
   Vent or stack radius (m)             =      .00

   Direction .. intake to source (deg)  =      346
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   301 - 031
   Distance to intake (m)               =     67.9
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbloca2a.log
     wbloca2a.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =      .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =      .00
   Initial value of sigma z             =      .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  38963
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  26345
     Hours direction not in window or calm   =  86508

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      65308.     80388.     96381.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
        ZERO        86508.     70309.     52247.     32293.     21597.      7816.
143.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       43.02      53.34      64.85      77.70      85.41      94.67
99.90     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   1.09E-03   1.07E-03   1.05E-03   9.91E-04   8.27E-04   6.37E-04
3.91E-04   3.31E-04   2.83E-04   2.57E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        1.09E-03
     2 to 8 hours        9.59E-04
     8 to 24 hours       4.60E-04
     1 to 4 days         3.09E-04
     4 to 30 days        2.37E-04

                                HOURLY VALUE RANGE
                              MAX X/Q              MIN X/Q
          CENTERLINE         1.57E-03             1.41E-04
          SECTOR-AVERAGE     9.85E-04             8.81E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/4 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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e-mail: jjh@nrc.gov
L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 12:53:34

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =    436.2
   Effluent vertical velocity (m/s)     =      .00
   Vent or stack flow  (m^3/s)          =      .00
   Vent or stack radius (m)             =      .00

   Direction .. intake to source (deg)  =      346
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   301 - 031
   Distance to intake (m)               =     67.9
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbloca2b.log
     wbloca2b.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =      .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =      .00
   Initial value of sigma z             =      .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  38963
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  26345
     Hours direction not in window or calm   =  86508

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      65308.     80388.     96381.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
         ZERO      86508.     70309.     52247.     32293.     21597.      7816.
143.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       43.02      53.34      64.85      77.70      85.41      94.67
99.90     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   1.09E-03   1.08E-03   1.06E-03   1.00E-03   8.37E-04   6.44E-04
3.93E-04   3.34E-04   2.85E-04   2.59E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        1.09E-03
     2 to 8 hours        9.72E-04
     8 to 24 hours       4.65E-04
     1 to 4 days         3.10E-04
     4 to 30 days        2.39E-04

                              HOURLY VALUE RANGE
                            MAX X/Q                MIN X/Q
         CENTERLINE        1.59E-03               1.42E-04
         SECTOR-AVERAGE    9.98E-04               8.92E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/8 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 12:54:31

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =    218.1
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      346
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   301 - 031
   Distance to intake (m)               =     67.9
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbloca2c.log
     wbloca2c.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =       .00
   Initial value of sigma z             =       .00
```

5010.65

STONE & WEBSTER ENGINEERING CORPORATION
CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER				
JOB ORDER NO.	DISCIPLINE	CALCULATION NO.	REVISION NUMBER	PAGE
13090.0100	WM(B)	001	0	18 OF 68

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  38963
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  26345
     Hours direction not in window or calm   =  86508

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      65308.     80388.     96381.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      86508.     70309.     52247.     32293.     21597.      7816.
143.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       43.02      53.34      64.85      77.70      85.41      94.67
99.90     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   1.12E-03   1.08E-03   1.06E-03   1.01E-03   8.48E-04   6.53E-04
3.96E-04   3.38E-04   2.87E-04   2.62E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        1.12E-03
     2 to 8 hours        9.78E-04
     8 to 24 hours       4.73E-04
     1 to 4 days         3.10E-04
     4 to 30 days        2.41E-04

                                 HOURLY VALUE RANGE
                              MAX X/Q              MIN X/Q
          CENTERLINE         1.62E-03             1.45E-04
          SECTOR-AVERAGE     1.02E-03             9.07E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(No Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 12:55:32

```
******* ARCON INPUT ***********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =       .0
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      346
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   301 - 031
   Distance to intake (m)               =     67.9
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbloca2d.log
     wbloca2d.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =       .00
   Initial value of sigma z             =       .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  38963
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  26345
     Hours direction not in window or calm   =  86508

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.            1          2          4          8         12         24
96         168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE           0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE       65308.     80388.     96381.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE           0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO       86508.     70309.     52247.     32293.     21597.      7816.
143.         0.         0.         0.
    TOTAL X/Qs       ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO        43.02      53.34      64.85      77.70      85.41      94.67
99.90     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                    1.29E-03   1.27E-03   1.25E-03   1.19E-03   9.95E-04   7.66E-04
4.43E-04   3.76E-04   3.16E-04   2.88E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        1.29E-03
     2 to 8 hours        1.16E-03
     8 to 24 hours       5.55E-04
     1 to 4 days         3.35E-04
     4 to 30 days        2.64E-04

                              HOURLY VALUE RANGE
                            MAX X/Q              MIN X/Q
          CENTERLINE        2.37E-03             1.76E-04
          SECTOR-AVERAGE    1.49E-03             1.10E-04

 NORMAL PROGRAM COMPLETION
```

3. Unit 2 Reactor Vent to Emergency Control Room Air Intake (LOCA):

Program Title: ARCON96. **(Full Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 12:56:49

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =   1744.7
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      008
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   323 - 053
   Distance to intake (m)               =     79.6
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbloca3.log
     wbloca3.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0
```

```
     Initial value of sigma y              =        .00
     Initial value of sigma z              =        .00

     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  46613
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  26345
     Hours direction not in window or calm   =  78858

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      72958.     85670.     98394.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      78858.     65027.     50234.     32980.     23298.      9314.
171.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       48.06      56.85      66.20      77.23      84.26      93.64
99.88     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   8.28E-04   8.22E-04   8.11E-04   7.84E-04   6.64E-04   5.21E-04
3.54E-04   2.99E-04   2.58E-04   2.35E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        8.28E-04
     2 to 8 hours        7.69E-04
     8 to 24 hours       3.90E-04
     1 to 4 days         2.98E-04
     4 to 30 days        2.17E-04

                              HOURLY VALUE RANGE
                            MAX X/Q                MIN X/Q
          CENTERLINE       1.19E-03               1.07E-04
          SECTOR-AVERAGE   7.43E-04               6.70E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/2 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 12:57:50

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =    872.0
   Effluent vertical velocity (m/s)     =      .00
   Vent or stack flow  (m^3/s)          =      .00
   Vent or stack radius (m)             =      .00

   Direction .. intake to source (deg)  =      008
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =  323 - 053
   Distance to intake (m)               =     79.6
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbloca3a.log
     wbloca3a.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =      .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =      .00
   Initial value of sigma z             =      .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  46613
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  26345
     Hours direction not in window or calm   =  78858

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      72958.     85670.     98394.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
         ZERO       78858.     65027.     50234.     32980.     23298.      9314.
171.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       48.06      56.85      66.20      77.23      84.26      93.64
99.88     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   8.28E-04   8.23E-04   8.13E-04   7.88E-04   6.69E-04   5.25E-04
3.55E-04   3.00E-04   2.59E-04   2.36E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        8.28E-04
     2 to 8 hours        7.75E-04
     8 to 24 hours       3.94E-04
     1 to 4 days         2.99E-04
     4 to 30 days        2.18E-04

                         HOURLY VALUE RANGE
                        MAX X/Q              MIN X/Q
         CENTERLINE     1.20E-03             1.08E-04
         SECTOR-AVERAGE 7.51E-04             6.77E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/4 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 12:59:02

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =    436.2
   Effluent vertical velocity (m/s)     =      .00
   Vent or stack flow  (m^3/s)          =      .00
   Vent or stack radius (m)             =      .00

   Direction .. intake to source (deg)  =      008
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =  323 - 053
   Distance to intake (m)               =     79.6
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbloca3b.log
     wbloca3b.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =      .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =      .00
   Initial value of sigma z             =      .00
```

5010.65

STONE & WEBSTER ENGINEERING CORPORATION
CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER				
JOB ORDER NO.	DISCIPLINE	CALCULATION NO.	REVISION NUMBER	PAGE
13090.0100	WM(B)	001	0	26 OF 68

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  46613
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  26345
     Hours direction not in window or calm   =  78858

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      72958.     85670.     98394.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      78858.     65027.     50234.     32980.     23298.      9314.
171.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       48.06      56.85      66.20      77.23      84.26      93.64
99.88     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   8.63E-04   8.30E-04   8.18E-04   7.93E-04   6.75E-04   5.32E-04
3.57E-04   3.02E-04   2.60E-04   2.37E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        8.63E-04
     2 to 8 hours        7.69E-04
     8 to 24 hours       4.01E-04
     1 to 4 days         2.99E-04
     4 to 30 days        2.19E-04

                              HOURLY VALUE RANGE
                            MAX X/Q              MIN X/Q
          CENTERLINE       1.22E-03             1.10E-04
          SECTOR-AVERAGE   7.63E-04             6.87E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/8 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 12:59:52

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =    218.1
   Effluent vertical velocity (m/s)     =      .00
   Vent or stack flow  (m^3/s)          =      .00
   Vent or stack radius (m)             =      .00

   Direction .. intake to source (deg)  =      008
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   323 - 053
   Distance to intake (m)               =     79.6
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbloca3c.log
     wbloca3c.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =      .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =      .00
   Initial value of sigma z             =      .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  46613
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  26345
     Hours direction not in window or calm   =  78858

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE         0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE     72958.     85670.     98394.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE         0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
         ZERO     78858.     65027.     50234.     32980.     23298.      9314.
171.         0.         0.         0.
    TOTAL X/Qs     ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO      48.06      56.85      66.20      77.23      84.26      93.64
99.88     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                  8.85E-04   8.60E-04   8.29E-04   8.01E-04   6.83E-04   5.39E-04
3.60E-04   3.04E-04   2.62E-04   2.39E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        8.85E-04
     2 to 8 hours        7.73E-04
     8 to 24 hours       4.09E-04
     1 to 4 days         3.00E-04
     4 to 30 days        2.21E-04

                          HOURLY VALUE RANGE
                        MAX X/Q              MIN X/Q
         CENTERLINE     1.24E-03             1.12E-04
         SECTOR-AVERAGE 7.78E-04             7.01E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(No Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:00:36

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =       .0
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      008
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   323 - 053
   Distance to intake (m)               =     79.6
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbloca3d.log
     wbloca3d.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =       .00
   Initial value of sigma z             =       .00
```

```
Expanded output for code testing not selected

Total number of hours of data processed = 157800
Hours of missing data                   =   5984
Hours direction in window               =  46613
Hours elevated plume w/ dir. in window  =      0
Hours of calm winds                     =  26345
Hours direction not in window or calm   =  78858

DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
   AVER. PER.          1          2          4          8         12         24
96        168        360        720
   UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
     LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
  ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
     IN RANGE      72958.     85670.     98394.     ******     ******     ******
******     ******     ******     ******
  BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
        ZERO      78858.     65027.     50234.     32980.     23298.      9314.
171.         0.         0.         0.
   TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
   % NON ZERO       48.06      56.85      66.20      77.23      84.26      93.64
99.88     100.00     100.00     100.00

95th PERCENTILE X/Q VALUES
                  9.78E-04   9.72E-04   9.59E-04   9.26E-04   7.82E-04   6.23E-04
3.97E-04   3.34E-04   2.82E-04   2.58E-04

95% X/Q for standard averaging intervals

0 to 2 hours        9.78E-04
2 to 8 hours        9.08E-04
8 to 24 hours       4.71E-04
1 to 4 days         3.21E-04
4 to 30 days        2.36E-04

                          HOURLY VALUE RANGE
                        MAX X/Q              MIN X/Q
      CENTERLINE        1.82E-03             1.35E-04
      SECTOR-AVERAGE    1.14E-03             8.46E-05

NORMAL PROGRAM COMPLETION
```

4. Unit 2 Reactor Vent to Normal Control Room Air Intake (LOCA):

Program Title: ARCON96. **(Full Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
e-mail: jyl1@nrc.gov
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e-mail: jjh@nrc.gov
L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:01:33

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     39.5
   Building Area (m^2)                  =   1744.7
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      046
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   001 - 091
   Distance to intake (m)               =    119.3
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbloca4.log
     wbloca4.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0
```

```
     Initial value of sigma y              =        .00
     Initial value of sigma z              =        .00

     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  43947
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  26345
     Hours direction not in window or calm   =  81524

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03
1.00E-03   1.00E-03   1.00E-03   1.00E-03
      LOW LIM.    1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07
1.00E-07   1.00E-07   1.00E-07   1.00E-07
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      70292.     81917.     93833.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      81524.     68780.     54795.     37791.     28161.     12884.
309.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       46.30      54.36      63.13      73.91      80.97      91.21
99.78     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   4.13E-04   3.98E-04   3.86E-04   3.69E-04   3.13E-04   2.49E-04
1.70E-04   1.43E-04   1.24E-04   1.12E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        4.13E-04
     2 to 8 hours        3.54E-04
     8 to 24 hours       1.90E-04
     1 to 4 days         1.43E-04
     4 to 30 days        1.03E-04

                              HOURLY VALUE RANGE
                            MAX X/Q              MIN X/Q
          CENTERLINE        5.78E-04             7.39E-05
          SECTOR-AVERAGE    3.62E-04             4.63E-05

 NORMAL PROGRAM COMPLETION
```

5. Unit 1 Exhaust Stacks to Emergency Control Room Air Intake (SGTR):

Program Title: ARCON96. **(Full Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
e-mail: jyl1@nrc.gov
J. J. Hayes Phone: (301) 415 3167
e-mail: jjh@nrc.gov
L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:07:55

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =   1744.7
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      292
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   247 - 337
   Distance to intake (m)               =     81.1
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr1.log
     wbsgtr1.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0
```

```
     Initial value of sigma y              =        .00
     Initial value of sigma z              =        .00

     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  29263
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  99166

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.            1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      52650.     68022.     85388.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      99166.     82675.     63240.     38800.     24935.      8175.
15.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       34.68      45.14      57.45      73.21      83.15      94.42
99.99     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   7.96E-04   7.16E-04   6.19E-04   5.50E-04   4.54E-04   3.32E-04
2.16E-04   1.90E-04   1.67E-04   1.54E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        7.96E-04
     2 to 8 hours        4.68E-04
     8 to 24 hours       2.23E-04
     1 to 4 days         1.78E-04
     4 to 30 days        1.44E-04

                                HOURLY VALUE RANGE
                             MAX X/Q                MIN X/Q
          CENTERLINE        1.24E-03               1.03E-04
          SECTOR-AVERAGE    7.79E-04               6.48E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/2 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:08:47

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =    872.4
   Effluent vertical velocity (m/s)     =      .00
   Vent or stack flow  (m^3/s)          =      .00
   Vent or stack radius (m)             =      .00

   Direction .. intake to source (deg)  =      292
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =  247 - 337
   Distance to intake (m)               =     81.1
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr1a.log
     wbsgtr1a.cfd

   Minimum Wind Speed (m/s)             =      .5
   Surface roughness length (m)         =      .10
   Sector averaging constant            =     4.0

   Initial value of sigma y             =      .00
   Initial value of sigma z             =      .00
```

```
Expanded output for code testing not selected

Total number of hours of data processed = 157800
Hours of missing data                   =   5984
Hours direction in window               =  29263
Hours elevated plume w/ dir. in window  =      0
Hours of calm winds                     =  23387
Hours direction not in window or calm   =  99166

DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
   AVER. PER.          1          2          4          8         12         24
96        168        360        720
   UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
     LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
  ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
     IN RANGE      52650.     68022.     85388.     ******     ******     ******
******     ******     ******     ******
  BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
        ZERO      99166.     82675.     63240.     38800.     24935.      8175.
15.         0.         0.         0.
   TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
   % NON ZERO       34.68      45.14      57.45      73.21      83.15      94.42
99.99     100.00     100.00     100.00

95th PERCENTILE X/Q VALUES
                  8.01E-04   7.20E-04   6.23E-04   5.53E-04   4.56E-04   3.33E-04
2.17E-04   1.91E-04   1.68E-04   1.54E-04

95% X/Q for standard averaging intervals

0 to 2 hours        8.01E-04
2 to 8 hours        4.70E-04
8 to 24 hours       2.23E-04
1 to 4 days         1.79E-04
4 to 30 days        1.44E-04

                          HOURLY VALUE RANGE
                        MAX X/Q              MIN X/Q
      CENTERLINE        1.26E-03             1.05E-04
      SECTOR-AVERAGE    7.89E-04             6.56E-05

NORMAL PROGRAM COMPLETION
```

STONE & WEBSTER ENGINEERING CORPORATION
CALCULATION SHEET

5010.65

CALCULATION IDENTIFICATION NUMBER				
JOB ORDER NO. 13090.0100	DISCIPLINE WM(B)	CALCULATION NO. 001	REVISION NUMBER 0	PAGE 37 OF 68

Program Title: ARCON96. **(1/4 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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e-mail: jjh@nrc.gov
L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:09:40

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =    436.2
   Effluent vertical velocity (m/s)     =      .00
   Vent or stack flow  (m^3/s)          =      .00
   Vent or stack radius (m)             =      .00

   Direction .. intake to source (deg)  =      292
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =  247 - 337
   Distance to intake (m)               =     81.1
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr1b.log
     wbsgtr1b.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =      .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =      .00
   Initial value of sigma z             =      .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  29263
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  99166

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      52650.     68022.     85388.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      99166.     82675.     63240.     38800.     24935.      8175.
15.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       34.68      45.14      57.45      73.21      83.15      94.42
99.99     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   8.07E-04   7.25E-04   6.27E-04   5.55E-04   4.59E-04   3.35E-04
2.19E-04   1.92E-04   1.68E-04   1.54E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        8.07E-04
     2 to 8 hours        4.72E-04
     8 to 24 hours       2.25E-04
     1 to 4 days         1.80E-04
     4 to 30 days        1.45E-04

                              HOURLY VALUE RANGE
                            MAX X/Q              MIN X/Q
          CENTERLINE       1.28E-03             1.06E-04
          SECTOR-AVERAGE   8.02E-04             6.66E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/8 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:10:27

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =    218.1
   Effluent vertical velocity (m/s)     =      .00
   Vent or stack flow  (m^3/s)          =      .00
   Vent or stack radius (m)             =      .00

   Direction .. intake to source (deg)  =      292
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =  247 - 337
   Distance to intake (m)               =     81.1
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr1c.log
     wbsgtr1c.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =      .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =      .00
   Initial value of sigma z             =      .00
```

```
Expanded output for code testing not selected

Total number of hours of data processed = 157800
Hours of missing data                   =   5984
Hours direction in window               =  29263
Hours elevated plume w/ dir. in window  =      0
Hours of calm winds                     =  23387
Hours direction not in window or calm   =  99166

DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
   AVER. PER.          1          2          4          8         12         24
96        168        360        720
   UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
     LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
  ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
     IN RANGE      52650.     68022.     85388.     ******     ******     ******
******     ******     ******     ******
  BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
        ZERO      99166.     82675.     63240.     38800.     24935.      8175.
15.         0.         0.         0.
   TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
   % NON ZERO       34.68      45.14      57.45      73.21      83.15      94.42
99.99     100.00     100.00     100.00

95th PERCENTILE X/Q VALUES
                 8.15E-04   7.30E-04   6.35E-04   5.60E-04   4.62E-04   3.38E-04
2.20E-04   1.93E-04   1.69E-04   1.55E-04

95% X/Q for standard averaging intervals

0 to 2 hours        8.15E-04
2 to 8 hours        4.75E-04
8 to 24 hours       2.27E-04
1 to 4 days         1.81E-04
4 to 30 days        1.45E-04

                          HOURLY VALUE RANGE
                        MAX X/Q              MIN X/Q
      CENTERLINE        1.31E-03             1.09E-04
      SECTOR-AVERAGE    8.19E-04             6.80E-05

NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(No Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:11:10

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =       .0
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      292
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   247 - 337
   Distance to intake (m)               =     81.1
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr1d.log
     wbsgtr1d.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =       .00
   Initial value of sigma z             =       .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  29263
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  99166

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      52650.     68022.     85388.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      99166.     82675.     63240.     38800.     24935.      8175.
15.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       34.68      45.14      57.45      73.21      83.15      94.42
99.99     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   8.96E-04   7.91E-04   6.96E-04   6.11E-04   5.04E-04   3.68E-04
2.38E-04   2.07E-04   1.82E-04   1.66E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        8.96E-04
     2 to 8 hours        5.16E-04
     8 to 24 hours       2.47E-04
     1 to 4 days         1.95E-04
     4 to 30 days        1.55E-04

                                 HOURLY VALUE RANGE
                              MAX X/Q              MIN X/Q
          CENTERLINE         1.91E-03             1.35E-04
          SECTOR-AVERAGE     1.20E-03             8.43E-05

 NORMAL PROGRAM COMPLETION
```

6. Unit 1 Exhaust Stacks to Normal Control Room Air Intake (SGTR):

Program Title: ARCON96. **(Full Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:11:55

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =   1744.7
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      358
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   313 - 043
   Distance to intake (m)               =     35.5
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr2.log
     wbsgtr2.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0
```

```
     Initial value of sigma y              =        .00
     Initial value of sigma z              =        .00

     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  39425
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  89004

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      62812.     79410.     96020.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      89004.     71287.     52608.     33081.     22558.      8114.
102.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       41.37      52.70      64.60      77.16      84.76      94.46
99.93     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   4.03E-03   3.90E-03   3.76E-03   3.52E-03   2.92E-03   2.20E-03
1.33E-03   1.16E-03   1.02E-03   9.42E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        4.03E-03
     2 to 8 hours        3.35E-03
     8 to 24 hours       1.54E-03
     1 to 4 days         1.05E-03
     4 to 30 days        8.81E-04

                              HOURLY VALUE RANGE
                            MAX X/Q              MIN X/Q
          CENTERLINE        5.98E-03             6.00E-04
          SECTOR-AVERAGE    3.75E-03             3.76E-04

 NORMAL PROGRAM COMPLETION
```

7. Unit 2 Exhaust Stacks to Emergency Control Room Air Intake (SGTR):

Program Title: ARCON96. **(Full Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:12:55

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =   1744.7
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      012
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   327 - 057
   Distance to intake (m)               =     45.1
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr3.log
     wbsgtr3.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0
```

```
     Initial value of sigma y              =        .00
     Initial value of sigma z              =        .00

     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  38796
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  89633

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      62183.     77891.     93578.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      89633.     72806.     55050.     35841.     25411.      9901.
174.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       40.96      51.69      62.96      75.25      82.83      93.24
99.88     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   2.60E-03   2.53E-03   2.43E-03   2.27E-03   1.90E-03   1.43E-03
8.81E-04   7.61E-04   6.63E-04   6.13E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        2.60E-03
     2 to 8 hours        2.16E-03
     8 to 24 hours       1.02E-03
     1 to 4 days         6.96E-04
     4 to 30 days        5.71E-04

                                HOURLY VALUE RANGE
                              MAX X/Q              MIN X/Q
          CENTERLINE         3.54E-03             3.95E-04
          SECTOR-AVERAGE     2.22E-03             2.47E-04

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/2 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

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L. A Brown Phone: (301) 415 1232
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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:13:41

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =    872.4
   Effluent vertical velocity (m/s)     =      .00
   Vent or stack flow  (m^3/s)          =      .00
   Vent or stack radius (m)             =      .00

   Direction .. intake to source (deg)  =      012
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   327 - 057
   Distance to intake (m)               =     45.1
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr3a.log
     wbsgtr3a.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =      .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =      .00
   Initial value of sigma z             =      .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  38796
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  89633

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      62183.     77891.     93578.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      89633.     72806.     55050.     35841.     25411.      9901.
174.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       40.96      51.69      62.96      75.25      82.83      93.24
99.88     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   2.60E-03   2.54E-03   2.44E-03   2.28E-03   1.90E-03   1.44E-03
8.82E-04   7.64E-04   6.65E-04   6.14E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        2.60E-03
     2 to 8 hours        2.17E-03
     8 to 24 hours       1.02E-03
     1 to 4 days         6.97E-04
     4 to 30 days        5.73E-04

                              HOURLY VALUE RANGE
                            MAX X/Q              MIN X/Q
          CENTERLINE        3.55E-03             3.99E-04
          SECTOR-AVERAGE    2.23E-03             2.50E-04

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/4 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:14:31

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =    436.2
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      012
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   327 - 057
   Distance to intake (m)               =     45.1
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr3b.log
     wbsgtr3b.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =       .00
   Initial value of sigma z             =       .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  38796
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  89633

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      62183.     77891.     93578.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      89633.     72806.     55050.     35841.     25411.      9901.
174.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       40.96      51.69      62.96      75.25      82.83      93.24
99.88     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   2.61E-03   2.55E-03   2.45E-03   2.28E-03   1.91E-03   1.44E-03
8.85E-04   7.66E-04   6.67E-04   6.16E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        2.61E-03
     2 to 8 hours        2.18E-03
     8 to 24 hours       1.02E-03
     1 to 4 days         6.99E-04
     4 to 30 days        5.74E-04

                                HOURLY VALUE RANGE
                              MAX X/Q              MIN X/Q
          CENTERLINE         3.57E-03             4.05E-04
          SECTOR-AVERAGE     2.24E-03             2.54E-04

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/8 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:15:16

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =    218.1
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      012
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   327 - 057
   Distance to intake (m)               =     45.1
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr3c.log
     wbsgtr3c.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =       .00
   Initial value of sigma z             =       .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  38796
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  89633

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      62183.     77891.     93578.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
          ZERO      89633.     72806.     55050.     35841.     25411.      9901.
174.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       40.96      51.69      62.96      75.25      82.83      93.24
99.88     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   2.62E-03   2.57E-03   2.47E-03   2.29E-03   1.92E-03   1.45E-03
8.89E-04   7.71E-04   6.69E-04   6.18E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        2.62E-03
     2 to 8 hours        2.19E-03
     8 to 24 hours       1.03E-03
     1 to 4 days         7.01E-04
     4 to 30 days        5.76E-04

                                HOURLY VALUE RANGE
                              MAX X/Q              MIN X/Q
          CENTERLINE         3.59E-03             4.13E-04
          SECTOR-AVERAGE     2.25E-03             2.59E-04

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(No Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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e-mail: jjh@nrc.gov
L. A Brown Phone: (301) 415 1232
e-mail: lab2@nrc.gov

Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:15:56

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =       .0
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      012
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   327 - 057
   Distance to intake (m)               =     45.1
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr3d.log
     wbsgtr3d.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =       .00
   Initial value of sigma z             =       .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  38796
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  89633

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02   1.00E-02
1.00E-02   1.00E-02   1.00E-02   1.00E-02
      LOW LIM.    1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06   1.00E-06
1.00E-06   1.00E-06   1.00E-06   1.00E-06
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      62183.     77891.     93578.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
39.        0.         0.         0.
         ZERO      89633.     72806.     55050.     35841.     25411.      9901.
135.       0.         0.         0.
    TOTAL X/Qs     ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO      40.96      51.69      62.96      75.25      82.83      93.24
99.90     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                  2.87E-03   2.84E-03   2.77E-03   2.57E-03   2.14E-03   1.61E-03
9.70E-04   8.35E-04   7.23E-04   6.68E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        2.87E-03
     2 to 8 hours        2.46E-03
     8 to 24 hours       1.14E-03
     1 to 4 days         7.55E-04
     4 to 30 days        6.22E-04

                         HOURLY VALUE RANGE
                        MAX X/Q              MIN X/Q
          CENTERLINE    5.13E-03             4.81E-04
          SECTOR-AVERAGE 3.21E-03            3.02E-04

 NORMAL PROGRAM COMPLETION
```

8. Unit 2 Exhaust Stacks to Normal Control Room Air Intake (SGTR):

Program Title: ARCON96. **(Full Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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L. A Brown Phone: (301) 415 1232
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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
e-mail: j_ramsdell@pnl.gov

Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:16:52

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =   1744.7
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      060
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   015 - 105
   Distance to intake (m)               =     96.5
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr4.log
     wbsgtr4.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0
```

```
     Initial value of sigma y              =        .00
     Initial value of sigma z              =        .00

     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  31685
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  96744

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.            1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03
1.00E-03   1.00E-03   1.00E-03   1.00E-03
      LOW LIM.    1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07
1.00E-07   1.00E-07   1.00E-07   1.00E-07
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      55072.     70302.     85858.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
213.         0.         0.         0.
         ZERO      96744.     80395.     62770.     43042.     32299.     14674.
44.         0.         0.         0.
    TOTAL X/Qs     ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO      36.28      46.65      57.77      70.28      78.18      89.99
99.97     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                  5.85E-04   5.52E-04   4.83E-04   4.38E-04   3.63E-04   2.75E-04
1.79E-04   1.57E-04   1.38E-04   1.25E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        5.85E-04
     2 to 8 hours        3.89E-04
     8 to 24 hours       1.93E-04
     1 to 4 days         1.47E-04
     4 to 30 days        1.17E-04

                              HOURLY VALUE RANGE
                            MAX X/Q              MIN X/Q
         CENTERLINE         8.84E-04             1.19E-04
         SECTOR-AVERAGE     5.54E-04             7.45E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/2 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:17:40

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =    872.4
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      060
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   015 - 105
   Distance to intake (m)               =     96.5
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr4a.log
     wbsgtr4a.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =       .00
   Initial value of sigma z             =       .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  31685
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  96744

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03
1.00E-03   1.00E-03   1.00E-03   1.00E-03
      LOW LIM.    1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07
1.00E-07   1.00E-07   1.00E-07   1.00E-07
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      55072.     70302.     85858.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
        ZERO       96744.     80395.     62770.     43042.     32299.     14674.
257.         0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       36.28      46.65      57.77      70.28      78.18      89.99
99.82     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   5.87E-04   5.55E-04   4.85E-04   4.40E-04   3.65E-04   2.76E-04
1.79E-04   1.57E-04   1.39E-04   1.26E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        5.87E-04
     2 to 8 hours        3.91E-04
     8 to 24 hours       1.93E-04
     1 to 4 days         1.47E-04
     4 to 30 days        1.17E-04

                              HOURLY VALUE RANGE
                            MAX X/Q                MIN X/Q
          CENTERLINE        8.92E-04               1.20E-04
          SECTOR-AVERAGE    5.59E-04               7.51E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/4 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:18:29

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =    436.2
   Effluent vertical velocity (m/s)     =      .00
   Vent or stack flow  (m^3/s)          =      .00
   Vent or stack radius (m)             =      .00

   Direction .. intake to source (deg)  =      060
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =  015 - 105
   Distance to intake (m)               =     96.5
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr4b.log
     wbsgtr4b.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =      .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =      .00
   Initial value of sigma z             =      .00
```

```
     Expanded output for code testing not selected

     Total number of hours of data processed = 157800
     Hours of missing data                   =   5984
     Hours direction in window               =  31685
     Hours elevated plume w/ dir. in window  =      0
     Hours of calm winds                     =  23387
     Hours direction not in window or calm   =  96744

     DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
    AVER. PER.          1          2          4          8         12         24
96        168        360        720
    UPPER LIM.    1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03
1.00E-03   1.00E-03   1.00E-03   1.00E-03
      LOW LIM.    1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07
1.00E-07   1.00E-07   1.00E-07   1.00E-07
   ABOVE RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
      IN RANGE      55072.     70302.     85858.     ******     ******     ******
******     ******     ******     ******
   BELOW RANGE          0.         0.         0.         0.         0.         0.
42.        0.         0.         0.
          ZERO      96744.     80395.     62770.     43042.     32299.     14674.
215.       0.         0.         0.
    TOTAL X/Qs      ******     ******     ******     ******     ******     ******
******     ******     ******     ******
    % NON ZERO       36.28      46.65      57.77      70.28      78.18      89.99
99.85     100.00     100.00     100.00

     95th PERCENTILE X/Q VALUES
                   5.92E-04   5.57E-04   4.87E-04   4.42E-04   3.66E-04   2.77E-04
1.80E-04   1.58E-04   1.39E-04   1.26E-04

     95% X/Q for standard averaging intervals

     0 to 2 hours        5.92E-04
     2 to 8 hours        3.92E-04
     8 to 24 hours       1.95E-04
     1 to 4 days         1.48E-04
     4 to 30 days        1.18E-04

                                 HOURLY VALUE RANGE
                              MAX X/Q              MIN X/Q
          CENTERLINE         9.03E-04             1.21E-04
          SECTOR-AVERAGE     5.66E-04             7.58E-05

 NORMAL PROGRAM COMPLETION
```

Program Title: ARCON96. **(1/8 Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:19:17

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =    218.1
   Effluent vertical velocity (m/s)     =      .00
   Vent or stack flow  (m^3/s)          =      .00
   Vent or stack radius (m)             =      .00

   Direction .. intake to source (deg)  =      060
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   015 - 105
   Distance to intake (m)               =     96.5
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr4c.log
     wbsgtr4c.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =      .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =      .00
   Initial value of sigma z             =      .00
```

Expanded output for code testing not selected

Total number of hours of data processed = 157800
Hours of missing data = 5984
Hours direction in window = 31685
Hours elevated plume w/ dir. in window = 0
Hours of calm winds = 23387
Hours direction not in window or calm = 96744

DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL

AVER. PER.	1	2	4	8	12	24	96	168	360	720
UPPER LIM.	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
LOW LIM.	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07
ABOVE RANGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN RANGE	55072.	70302.	85858.	******	******	******	******	******	******	******
BELOW RANGE	0.	0.	0.	0.	0.	0.	26.	0.	0.	0.
ZERO	96744.	80395.	62770.	43042.	32299.	14674.	231.	0.	0.	0.
TOTAL X/Qs	******	******	******	******	******	******	******	******	******	******
% NON ZERO	36.28	46.65	57.77	70.28	78.18	89.99	99.84	100.00	100.00	100.00

95th PERCENTILE X/Q VALUES

5.97E-04	5.61E-04	4.91E-04	4.45E-04	3.69E-04	2.79E-04	1.81E-04	1.58E-04	1.40E-04	1.27E-04

95% X/Q for standard averaging intervals

0 to 2 hours	5.97E-04
2 to 8 hours	3.94E-04
8 to 24 hours	1.96E-04
1 to 4 days	1.49E-04
4 to 30 days	1.18E-04

HOURLY VALUE RANGE

	MAX X/Q	MIN X/Q
CENTERLINE	9.17E-04	1.22E-04
SECTOR-AVERAGE	5.75E-04	7.67E-05

NORMAL PROGRAM COMPLETION

STONE & WEBSTER ENGINEERING CORPORATION
5010.65 **CALCULATION SHEET**

CALCULATION IDENTIFICATION NUMBER				
JOB ORDER NO. 13090.0100	DISCIPLINE WM(B)	CALCULATION NO. 001	REVISION NUMBER 0	PAGE 63 OF 68

Program Title: ARCON96. **(No Building Area)**

Developed For: U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Reactor Program Management

Date: June 25, 1997 11:00 a.m.

NRC Contacts: J. Y. Lee Phone: (301) 415 1080
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Code Developer: J. V. Ramsdell Phone: (509) 372 6316
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Code Documentation: NUREG/CR-6331 Rev. 1

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Program Run 12/15/2000 at 13:19:54

```
******* ARCON INPUT **********

   Number of Meteorological Data Files  =  1
   Meteorological Data File Names
     C:\ARCON96\METDATA\WBNP.MET

   Height of lower wind instrument (m)  =      9.7
   Height of upper wind instrument (m)  =     46.4
   Wind speeds entered as miles per hour

   Ground-level release
   Release height (m)                   =     20.7
   Building Area (m^2)                  =       .0
   Effluent vertical velocity (m/s)     =       .00
   Vent or stack flow  (m^3/s)          =       .00
   Vent or stack radius (m)             =       .00

   Direction .. intake to source (deg)  =      060
   Wind direction sector width (deg)    =       90
   Wind direction window (deg)          =   015 - 105
   Distance to intake (m)               =     96.5
   Intake height  (m)                   =     14.3
   Terrain elevation difference (m)     =       .0

   Output file names
     wbsgtr4d.log
     wbsgtr4d.cfd

   Minimum Wind Speed (m/s)             =       .5
   Surface roughness length (m)         =       .10
   Sector averaging constant            =      4.0

   Initial value of sigma y             =       .00
   Initial value of sigma z             =       .00
```

```
Expanded output for code testing not selected

Total number of hours of data processed = 157800
Hours of missing data                   =   5984
Hours direction in window               =  31685
Hours elevated plume w/ dir. in window  =      0
Hours of calm winds                     =  23387
Hours direction not in window or calm   =  96744

DISTRIBUTION SUMMARY DATA BY AVERAGING INTERVAL
   AVER. PER.          1          2          4          8         12         24
96        168        360        720
   UPPER LIM.    1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03   1.00E-03
1.00E-03   1.00E-03   1.00E-03   1.00E-03
     LOW LIM.    1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07   1.00E-07
1.00E-07   1.00E-07   1.00E-07   1.00E-07
  ABOVE RANGE          8.         2.         0.         0.         0.         0.
0.         0.         0.         0.
     IN RANGE      55064.     70300.     85858.     ******     ******     ******
******     ******     ******     ******
  BELOW RANGE          0.         0.         0.         0.         0.         0.
0.         0.         0.         0.
        ZERO      96744.     80395.     62770.     43042.     32299.     14674.
257.         0.         0.         0.
   TOTAL X/Qs     ******     ******     ******     ******     ******     ******
******     ******     ******     ******
   % NON ZERO      36.28      46.65      57.77      70.28      78.18      89.99
99.82     100.00     100.00     100.00

95th PERCENTILE X/Q VALUES
                  6.38E-04   5.87E-04   5.20E-04   4.67E-04   3.88E-04   2.94E-04
1.90E-04   1.67E-04   1.44E-04   1.30E-04

95% X/Q for standard averaging intervals

0 to 2 hours        6.38E-04
2 to 8 hours        4.10E-04
8 to 24 hours       2.07E-04
1 to 4 days         1.55E-04
4 to 30 days        1.21E-04

                          HOURLY VALUE RANGE
                        MAX X/Q              MIN X/Q
      CENTERLINE        1.73E-03             1.35E-04
      SECTOR-AVERAGE    1.08E-03             8.47E-05

NORMAL PROGRAM COMPLETION
```

RESULTS

The X/Qs values for all release-receptor combinations as a function of building cross-sectional area are summarized below:

Release/Receptor Combination	X/Q (sec/m^3) 0-2 hr	2-8 hr	8-24 hr	1-4 day	4-30 day
1. Unit 1 Vent/Emerg. CR Air Intake (LOCA)					
Full Bldg. Area	4.47E-4	2.81E-4	1.21E-4	9.36E-5	7.77E-5
2. Unit 1 Vent/Normal CR Air Intake (LOCA)					
Full Bldg. Area	1.09E-3	9.50E-4	4.56E-4	3.09E-4	2.35E-4
1/2 Bldg. Area	1.09E-3	9.59E-4	4.60E-4	3.09E-4	2.37E-4
1/4 Bldg. Area	1.09E-3	9.72E-4	4.65E-4	3.10E-4	2.39E-4
1/8 Bldg. Area	1.12E-3	9.78E-4	4.73E-4	3.10E-4	2.41E-4
No Bldg. Area	1.29E-3	1.16E-3	5.55E-4	3.35E-4	2.64E-4
3. Unit 2 Vent/Emerg. CR Air Intake (LOCA)					
Full Bldg. Area	8.28E-4	7.69E-4	3.90E-4	2.98E-4	2.17E-4
1/2 Bldg. Area	8.28E-4	7.75E-4	3.94E-4	2.99E-4	2.18E-4
1/4 Bldg. Area	8.63E-4	7.69E-4	4.01E-4	2.99E-4	2.19E-4
1/8 Bldg. Area	8.85E-4	7.73E-4	4.09E-4	3.00E-4	2.21E-4
No Bldg. Area	9.78E-4	9.08E-4	4.71E-4	3.21E-4	2.36E-4
4. Unit 2 Vent/Normal CR Air Intake (LOCA)					
Full Bldg. Area	4.13E-4	3.54E-4	1.90E-4	1.43E-4	1.03E-4
5. Unit 1 Stack/Emerg. CR Air Intake (SGTR)					
Full Bldg. Area	7.96E-4	4.68E-4	2.23E-4	1.78E-4	1.44E-4
1/2 Bldg. Area	8.01E-4	4.70E-4	2.23E-4	1.79E-4	1.44E-4
1/4 Bldg. Area	8.07E-4	4.72E-4	2.25E-4	1.80E-4	1.45E-4
1/8 Bldg. Area	8.15E-4	4.75E-4	2.27E-4	1.81E-4	1.45E-4
No Bldg. Area	8.96E-4	5.16E-4	2.47E-4	1.95E-4	1.55E-4
6. Unit 1 Stack/Normal CR Air Intake (SGTR)					
Full Bldg. Area	4.03E-3	3.35E-3	1.54E-3	1.05E-3	8.81E-4
7. Unit 2 Stack/Emerg. CR Air Intake (SGTR)					
Full Bldg. Area	2.60E-3	2.16E-3	1.02E-3	6.96E-4	5.71E-4
1/2 Bldg. Area	2.60E-3	2.17E-3	1.02E-3	6.97E-4	5.73E-4
1/4 Bldg. Area	2.61E-3	2.18E-3	1.02E-3	6.99E-4	5.74E-4
1/8 Bldg. Area	2.62E-3	2.19E-3	1.03E-3	7.01E-4	5.76E-4
No Bldg. Area	2.87E-3	2.46E-3	1.14E-3	7.55E-4	6.22E-4
8. Unit 2 Stack/Normal CR Air Intake (SGTR)					
Full Bldg. Area	5.85E-4	3.89E-4	1.93E-4	1.47E-4	1.17E-4
1/2 Bldg. Area	5.87E-4	3.91E-4	1.93E-4	1.47E-4	1.17E-4
1/4 Bldg. Area	5.92E-4	3.92E-4	1.95E-4	1.48E-4	1.18E-4
1/8 Bldg. Area	5.97E-4	3.94E-4	1.96E-4	1.49E-4	1.18E-4
No Bldg. Area	6.38E-4	4.10E-4	2.07E-4	1.55E-4	1.21E-4

CONCLUSIONS

The results of the building area sensitivity analysis clearly show very little effect of building cross-sectional area on the calculated X/Q values. This outcome indicates that the low wind speed plume meander effect accounted for in the ARCON96 methodology is the dominant factor in these X/Q calculations and that the selection of building cross-sectional area is not critical to this calculation.

In addition, the review of the building wake effect literature (Refs. 10-15) revealed that field and wind tunnel studies did not specifically address the issue of the release location relative to the obstructing building as it pertains to the fraction of cross-sectional area disrupting the wind flow. These studies focused on developing analytical expressions that account for the enhanced turbulence generated by the entire building cross-sectional area disrupting the wind flow. Furthermore, the ARCON96 documentation (Ref. 1) does not provide any guidance in selecting partial building areas as input to the analysis, implying that only full building areas should be used if they can reasonably be assumed to effect the dispersion of the release. In the case of Environmental Protection Agency (EPA) dispersion modeling practices, the EPA-approved Industrial Source Complex (ISC) dispersion model (Ref. 15) assumes that building wake effect is applicable to a stack emission that is located within ½ times the lesser of the building height or maximum projected width. Applying this standard to the Watts Bar reactor building would result in a release, within approximately 65 feet of the reactor building, being treated as effected by building downwash.

Therefore, given the insensitivity of the calculated X/Q values to building cross-sectional area and the implication from the cited literature that the full reactor building area may be applicable to all releases, it is reasonable and conservative to apply the 1/8 reactor building area to Release/Receptor combinations 2, 3, 5, 7, and 8. Therefore, the X/Q values selected for use in this calculation are as follows:

	X/Q (sec/m^3)				
Release/Receptor Combination	0-2 hr	2-8 hr	8-24 hr	1-4 day	4-30 day
1. Unit 1 Vent/Emerg. CR Air Intake (LOCA) Full Bldg. Area	4.47E-4	2.81E-4	1.21E-4	9.36E-5	7.77E-5
2. Unit 1 Vent/Normal CR Air Intake (LOCA) 1/8 Bldg. Area	1.12E-3	9.78E-4	4.73E-4	3.10E-4	2.41E-4
3. Unit 2 Vent/Emerg. CR Air Intake (LOCA) 1/8 Bldg. Area	8.85E-4	7.73E-4	4.09E-4	3.00E-4	2.21E-4
4. Unit 2 Vent/Normal CR Air Intake (LOCA) Full Bldg. Area	4.13E-4	3.54E-4	1.90E-4	1.43E-4	1.03E-4
5. Unit 1 Stack/Emerg. CR Air Intake (SGTR) 1/8 Bldg. Area	8.15E-4	4.75E-4	2.27E-4	1.81E-4	1.45E-4
6. Unit 1 Stack/Normal CR Air Intake (SGTR) Full Bldg. Area	4.03E-3	3.35E-3	1.54E-3	1.05E-3	8.81E-4
7. Unit 2 Stack/Emerg. CR Air Intake (SGTR) 1/8 Bldg. Area	2.62E-3	2.19E-3	1.03E-3	7.01E-4	5.76E-4
8. Unit 2 Stack/Normal CR Air Intake (SGTR) 1/8 Bldg. Area	5.97E-4	3.94E-4	1.96E-4	1.49E-4	1.18E-4

REFERENCES

1. Ramsdell, J. V. Jr. and C. A. Simonen, "Atmospheric Relative Concentrations in Building Wakes". Prepared by Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission, PNL-10521, NUREG/CR-6331, Rev. 1, May, 1997. ARCON96 documented as Stone & Webster computer program EN-292, V00, L00.

2. E-mail from Kenneth Wastrack (TVA) to Stephen Vigeant (S&W) dated 9/29/00, 10:17:47 AM transmitting 1976-1993 Watts Bar on-site meteorological data in ARCON96 format. See Attachment A.

3. TVA Drawing No. 47W200-1, "Equipment Plans - Roof", Watts Bar Nuclear Plant, Rev. 12, 9/16/71. See Attachment B.

4. TVA Drawing No. 47W200-8, "Equipment Traverse Section A8-A8", Watts Bar Nuclear Plant, Rev. 7, 9/16/71. See Attachment C.

5. TVA Drawing No. 47W200-9, "Equipment Longitudinal Section B9-B9", Watts Bar Nuclear Plant, Rev. 6, 9/16/71. See Attachment D.

6. TVA Drawing No. 47W415-1, "Mechanical Main Steam Relief & Safety Valve Vents", Watts Bar Nuclear Plant, Rev. 10, 2/10/75. See Attachment E.

7. TVA Drawing No. 41N718-1, "Concrete Dome Outline", Watts Bar Nuclear Plant, Rev. 9, 12/3/71. See Attachment F.

8. TVA Drawing No. 41N712-1, "Concrete Exterior Wall Outline", Watts Bar Nuclear Plant, Rev. E, 12/3/71. See Attachment G.

9. U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants", Revision 1, November 1982.

10. Ramsdell, J. V. Jr. and C. J. Fosmire, "Atmospheric Dispersion Estimates in the Vicinity of Buildings". Prepared by Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission, PNL-10286, January 1995.

11. Meroney, R. N., J. A. Peterka, and K. M. Kothari, "Wind-Tunnel Measurements of Dispersion and Turbulence in the Wakes of Nuclear Reactor Plants". Prepared by Colorado State University, Department of Civil Engineering for the U.S. Nuclear Regulatory Commission, NUREG/CR-1475, September 1980.

12. Kothari, K. M., R. N. Meroney and J. B. Bouwmeester, "An Algorithm to Estimate Field Concentrations in the Wake of a Power Plant Complex under Nonsteady Meteorological Conditions from Wind-Tunnel Experiments". Journal of Applied Meteorology, Vol. 20, No. 8, August 1981.

13. Allwine, K. J., R. N. Meroney and J. A. Peterka. "Rancho Seco Building Wake Effects on Atmospheric Diffusion: Simulation in a Meteorological Wind Tunnel". Prepared by Colorado State University, Department of Civil Engineering for the U.S. Nuclear Regulatory Commission, NUREG/CR-1286, February 1980.

14. Kothari, K. M., J. A. Peterka and R. N. Meroney. "Stably Stratified Building Wakes". Prepared by Colorado State University, Department of Civil Engineering for the U.S. Nuclear Regulatory Commission, NUREG/CR-1247, January 1980.

15. U. S. Environmental Protection Agency, "User's Guide for the Industrial Source Complex (ISC3) Dispersions Models, Volume II – Description of Model Algorithms". Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, North Carolina, EPA-454/B-95-003b, September 1995.

P. A-1
13090.0100
WM(B)-001
Rev. 0

ATTACHMENT A

"Wastrack, Kenneth G." <kgwastrack@tva.gov> on 09/29/2000 10:17:47 AM

WBNAPS3-104, R0
ATTACHMENT A
p. A69 of A76

To: Steven Vigeant/Environmental/SWEC@SWEC
cc: "Berg, Marc C." <mcberg@tva.gov>, "Pittman, Doyle E" <depittman2@tva.gov>
Subject ARCON96 Meteorological Data
:

Steve,

Here is the meteorological data we have produced from the Watts Bar Nuclear Plant (WBN) meteorological tower. As we discussed, the data used in the WBN FSAR for 1/u calculations covers 1974-1993. However, the middle-level winds data were not collected for 1974-1975, so the data files do not include those years.

<<metwbnp.zip>> <<format.txt>>
metwbnp.zip -- meteorological data files in ARCON96 format (1976-1993).
format.txt -- describes meteorological data files.

Also, as you requested, here are the sensor heights for the data in the meteorological data files:

Lower winds -- 9.7 meters
Mid-level winds -- 46.4 meters
Lower temperature -- 9.5 meters
Mid-level temperature -- 45.6 meters

If there is any other information you need related the these files, please let me know.

Thank you,

Kenneth G. (Ken) Wastrack
Tennessee Valley Authority
Reservation Road, CEB 2A
P. O. Box 1010
Muscle Shoals, AL 35662-1010

(kgwastrack@tva.gov)
(256) 386-3835

- metwbnp.zip
- format.txt

P. A-2
13090.0100
WM(B)-001
Rev. 0

format.txt

File format for meteorological data files

WBNAPS 3-104, R0
ATTACHMENT A
p. A70 of A76

Start Column	End Column	Length	Field
2	6	5	Location identifier
8	9	2	Year
10	12	3	Julian day (1-366)
13	14	2	Hour (0-23)
17	19	3	lower-level (10-meter) wind direction
20	23	4	lower-level (10-meter) wind speed (mph)
25	26	2	stability class (1-8)
29	31	3	mid-level (46-meter) wind direction
32	35	4	mid-level (46-meter) wind speed (mph)

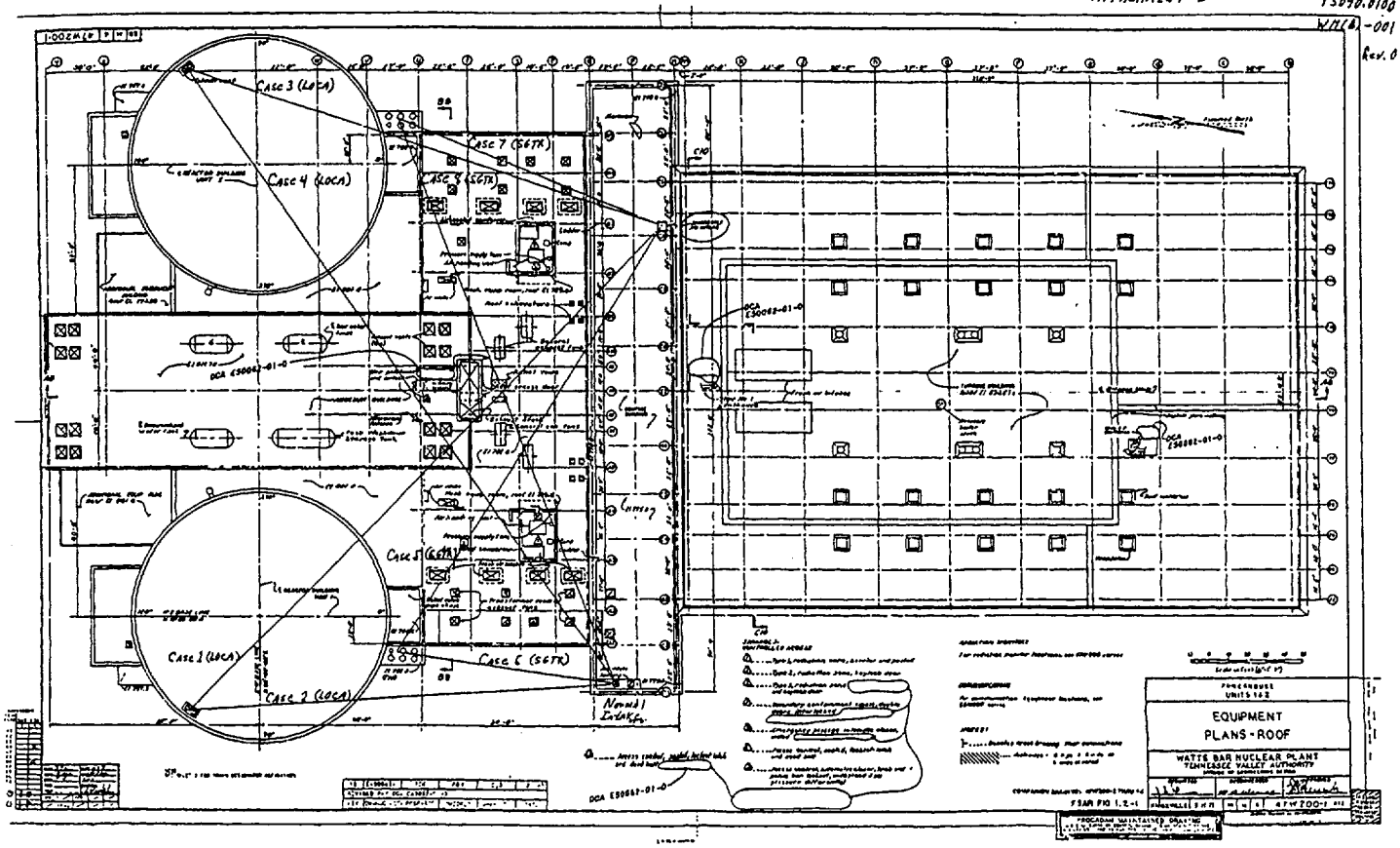
Wind directions are entered in degrees.
A north wind (wind from the north) is entered as 360.
A south wind is entered as 180.
Valid values are 1-360.
Missing values are entered as 999.

Wind speeds are entered to the nearest tenth of a reporting unit witho
ut the decimal.
A wind speed of 5.3 mph would be entered as 53, while a speed of 5 mph
would be entered as 50.
Missing values are entered as 9999.

Atmospheric stability is entered as a number from 1 through 8.
Stability is based on the following table
(DT = difference between mid-level and lower-level temperatures in deg
rees Celsius)

1	DT<=-1.9
2	-1.9<DT<=-1.7
3	-1.7<DT<=-1.5
4	-1.5<DT<=-0.5
5	-0.5<DT<=+1.5
6	+1.5<DT<=+4.0
7	DT> +4.0
8	LOST RECORD

WBNAPSB-1A, R0
ATTACHMENT A, pA71 of A76 P. B-1
ATTACHMENT B
13090.0100
W/(B)-001
Rev. 0



WBN A23-104, R0
ATTACHMENT A, 1 of 476 P. C-1
ATTACHMENT C
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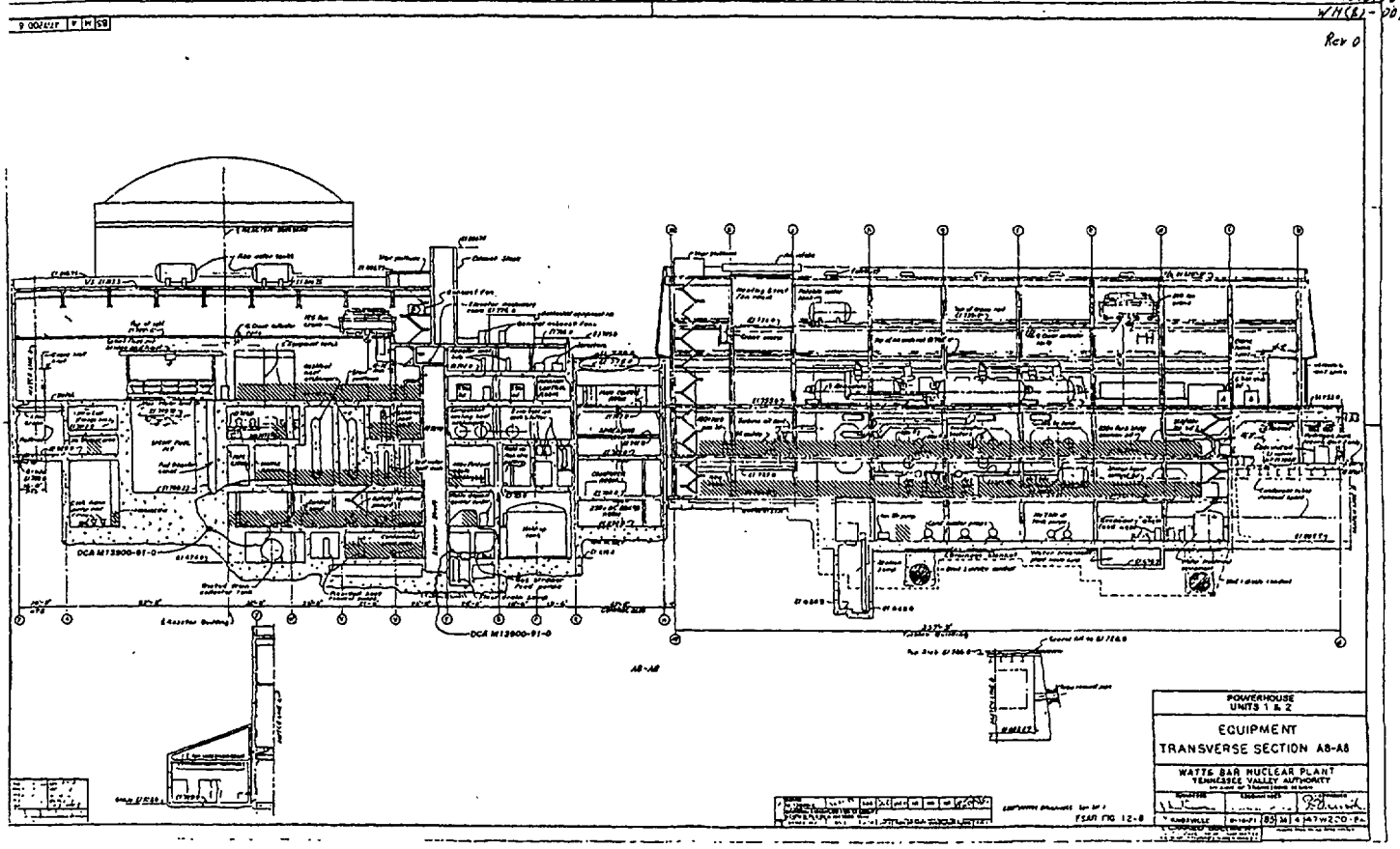
Rev 0



WBN APS3-109, Rev
ATTACHMENT A, p. A73 & A76
ATTACHMENT D

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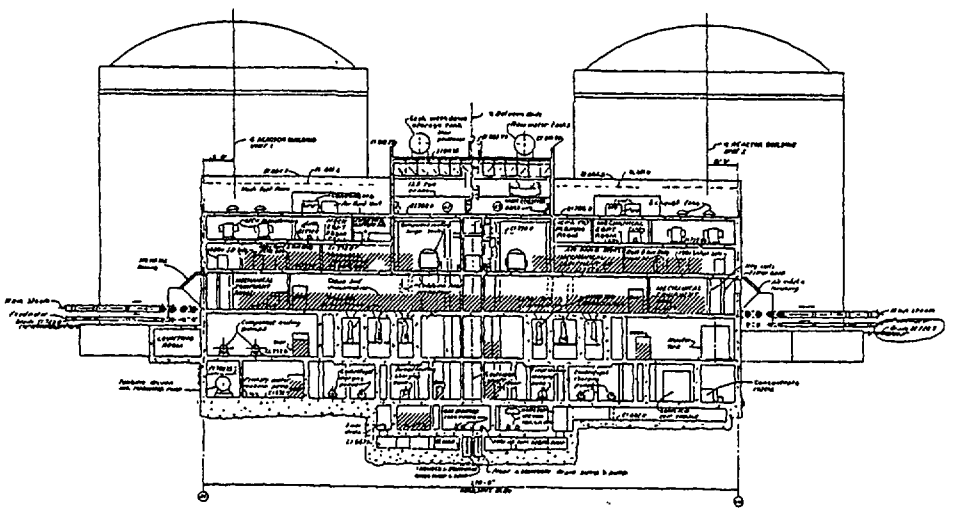
Rev. 0



POWER HOUSE
UNITS 1 & 2

EQUIPMENT
LONGITUDINAL SECTION 89-89

WATTS BAR NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY

47W200-9

PSAR FIG. 1.2-8

WBNAPS3-104, R0
ATTACHMENT A
P. A74 of A76
ATTACHMENT E

P. E-1
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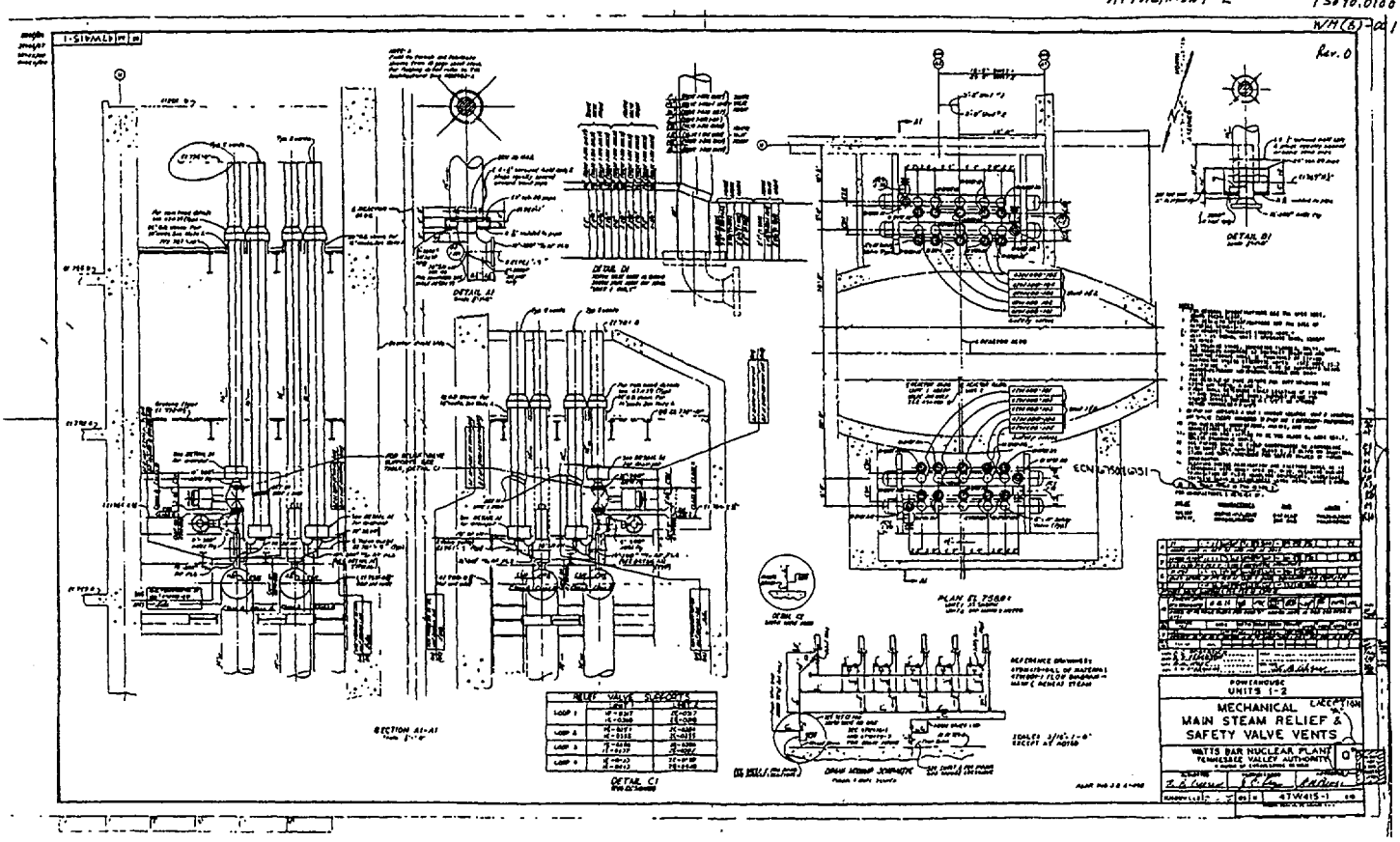
W/H(B)-001
Rev. 0



WBNMS3-104 R0
ATTACHMENT A
P-KTS of 1976
ATTACHMENT F

P.F-1
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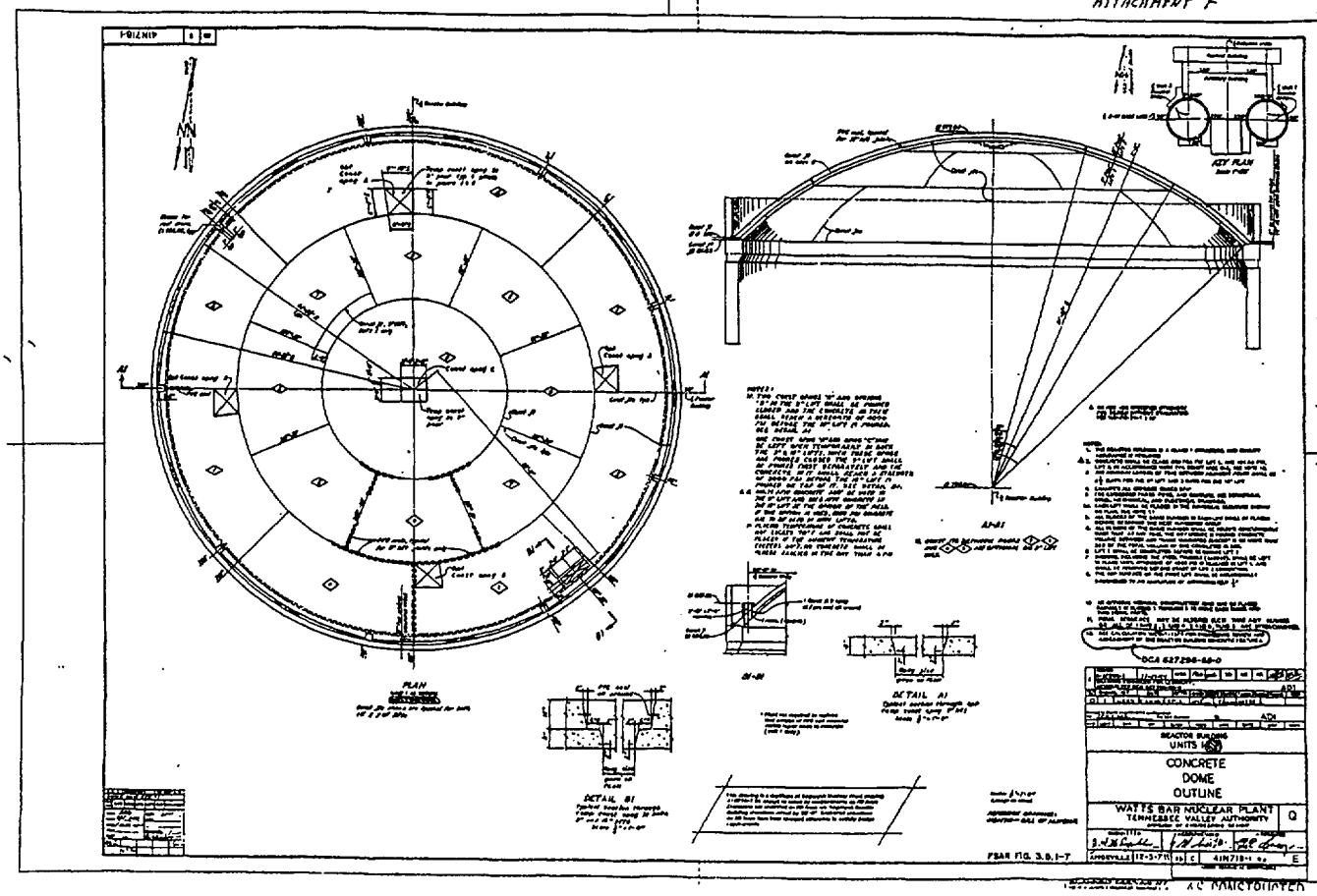
WM(B)-001
Rev. 0



WBN RPS 3-104, R0
RF ATTACHMENT A, PA76 & PA6

ATTACHMENT G

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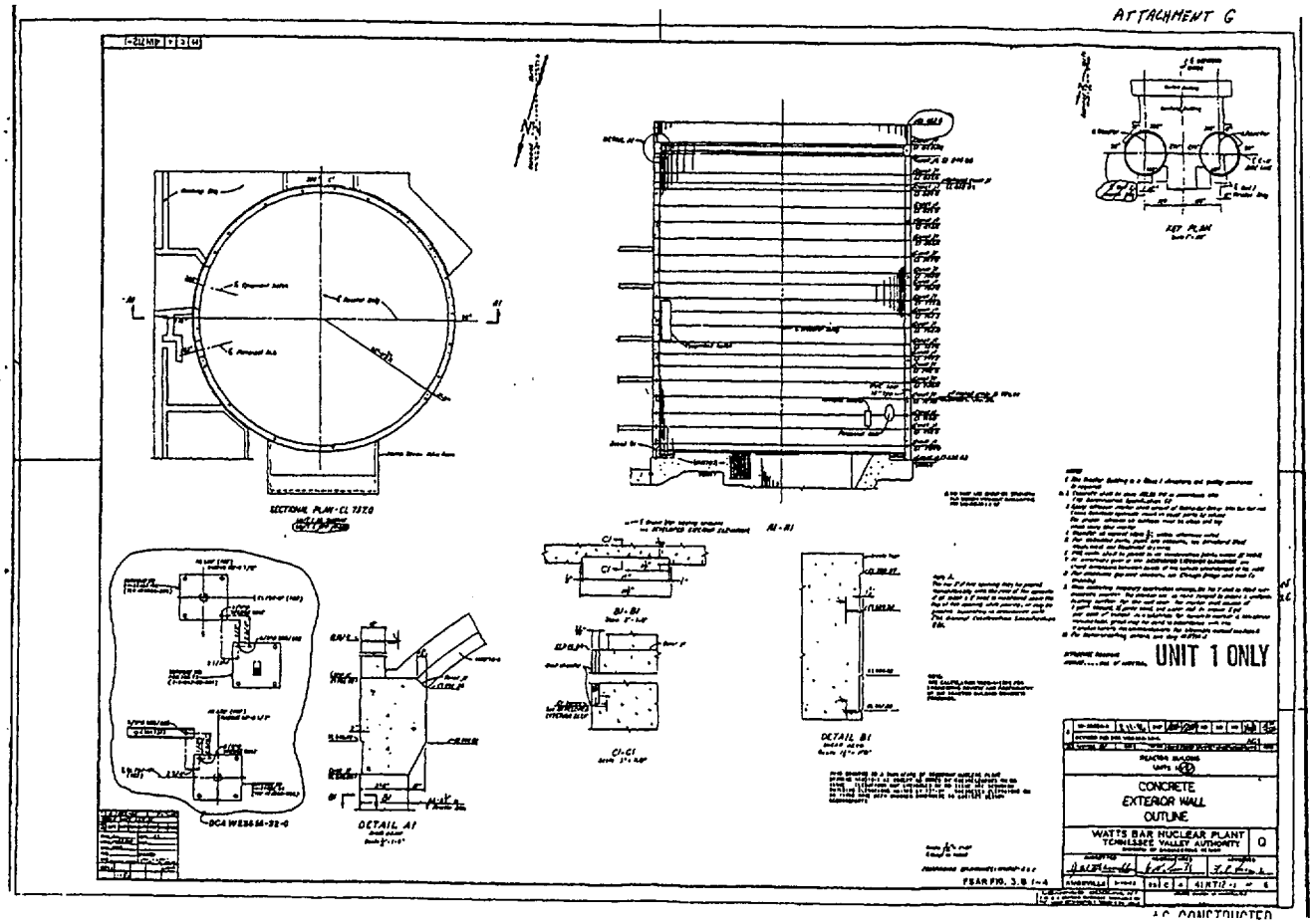
WH(B)-001
Rev. 0



ENCLOSURE 2

WATTS BAR NUCLEAR PLANT UNIT 1
STEAM GENERATOR ALTERNATE REPAIR CRITERIA
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
STEAM GENERATOR TESTING AND INSPECTION ISSUES

ENCLOSURE 2

WATTS BAR NUCLEAR PLANT UNIT 1
PROPOSED TECHNICAL SPECIFICATION CHANGE WBN-TS-99-014
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
STEAM GENERATOR TESTING AND INSPECTION ISSUES

TVA and NRC met to discuss two remaining issues associated with the inspection and testing of the steam generator tubes on July 17, 2000. The two concerns with the WBN program were the 1) inspection program for dented tube support plate intersections and 2) validity of the pressurization rate affect on burst testing for the voltage based repair criteria. As a result of these remaining concerns, TVA has revised the responses to Question 1 and 2 of Enclosure 5, in TVA's letter dated September 18, 2000. These responses, which supersede those in the September 18, 2000, letter, are provided in the Attachment to this enclosure.

As a result of the above referenced meeting, NRC had no further questions concerning the WBN inspection program for dented tube support plate intersections. TVA and NRC agreed upon the issues below as being the remaining concerns for the pressurization rate affect on tube burst testing. These issues as stated below were provided to TVA by an e-mail from the NRC WBN Project Manager on August 13, 2001.

NRC Concerns

1. We are concerned with specific aspects of the TVA study as follows:

   a) the representativeness of the trapezoidal shape part through wall flaws used for pressurization rate testing to the actual conditions of flaws in the ODSCC data base

   b) a lack of understanding of the configuration of threshold flaw profiles that would begin to demonstrate pressurization rate or foil reinforcement effects

2a). TVA indicated that to address the first concern they would provide additional information in the TVA report that would include actual profiles in the ODSCC database for flaws that have either a maximum depth exceeding 90% or an average depth exceeding about 60%.

2b). To assist the staff's review with respect to the second concern, TVA indicated they would provide the results of analyses that will give insights into the mechanistic causes under certain flaw profile conditions for the existence of pressurization rate or foil reinforcement effects.

ENCLOSURE 2

WATTS BAR NUCLEAR PLANT UNIT 1
PROPOSED TECHNICAL SPECIFICATION CHANGE WBN-TS-99-014
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
STEAM GENERATOR TESTING AND INSPECTION ISSUES

Response

TVA has included the above concerns in Section 3 of the Westinghouse Report SG-01-07-003, "Pressurization Rate and Foil Strengthening Effects on the Burst Strength of Axially Degraded Steam Generator Tubing," dated July 2001 which is provided in Enclosure 3. The testing in the report in Enclosure 3 was performed specifically for TVA to assist in resolving these issues. The Westinghouse report also provides the technical discussion of the appropriateness of the trapezoidal shape to bound ODSCC flaws in the database and insights into the causes under certain flaw conditions. In addition, as requested at the July 17, 2001, meeting, TVA has provided in Enclosure 4, the EPRI Report 1001441, "Steam Generator Tubing Burst Testing Review."

ENCLOSURE 2
ATTACHMENT

WATTS BAR NUCLEAR PLANT UNIT 1
PROPOSED TECHNICAL SPECIFICATION CHANGE WBN-TS-99-014
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
STEAM GENERATOR TESTING AND INSPECTION ISSUES

[REVISED RESPONSE TO QUESTION 1 AND 2 IN TVA'S LETTER DATED SEPTEMBER 18, 2000, ENCLOSURE 5]

QUESTION 1

Section 3.b.3 of Attachment 1 to GL 95-05, in Enclosure 1, Table 1, the licensee stated that "+Point (or equivalent) will be used for inspection of all dents >5 volts. Any indications found at such intersections with RPC [rotating pancake coil] should cause the tube to be repaired. If circumferential cracking or primary water stress corrosion cracking indications are detected, it may be necessary to expand the RPC sampling plan to include dents less than 5.0 volts." TVA has committed to perform RPC inspections of all intersections with dents greater than 2 volts. Based on experience with ODSCC at plants with dented support plate intersections, circumferential cracking has been observed in dents under 5 volts and at Sequoyah Unit 1, circumferential cracking has been observed in dents under 2 volts. For the staff to evaluate the Watts Bar dent inspection program in connection with this amendment, TVA will have to propose a program that will lead to inspection of dents for circumferential cracks in dents below 2 volts if their inspections indicate that circumferential cracking is occurring in dents above 2 volts. The proposed sampling and expansion program needs to be consistent with the inspection philosophy of the EPRI SG inspection guidelines.

RESPONSE 1

The hot leg dented tube support intersections with bobbin dent voltage greater than or equal to 2 volts will be inspected with a technique qualified to Appendix H of the EPRI Pressurized Water Reactor (PWR) Steam Generator Examination Guideline. The denting at WBN is mechanically induced, and is more correctly characterized as "dings." The majority are located near the edge of the support plate or just outside the support plate. The stresses are dramatically different than corrosion induced denting. The consequences of circumferential cracking at these dents are also different. No cracking has been identified in dented support plate intersections at WBN.

The inspection plan for WBN's Unit 1 Cycle 4 outage includes 100% of hot leg dented intersections greater than or equal to 2 volts. This inspection is driven by industry experience, and includes 159 intersections. If circumferential cracking is identified at WBN in a dented tube support plate intersection that is equal to

2 volts, the inspection plan expands to hot leg dented intersections greater than or equal to 1.0 volts.

QUESTION 2

In recent information provided by Entergy in connection with an operational assessment for ANO-2, data was presented that calls into question the validity of the burst correlation developed for the voltage-based repair criteria. This data demonstrates that rapid burst pressure testing for tubes with ODSCC flaws exhibits a strong testing rate effect, i.e., an apparent strength much higher than would be found from quasi-static testing. The burst data developed for the voltage-based repair criteria contains tubes tested under very rapid pressurization. Therefore, the burst correlation relied upon for the repair criteria may also exhibit this effect. Structural integrity is governed by a requirement to demonstrate a margin of 3 to the normal operating differential pressure. Normal operating pressure is a steady state condition. Therefore, the margin is based on the same condition, rather than a rapidly changing pressure condition. TVA needs to address the preceding explanation and demonstrate how the governing margins are satisfied by their proposed repair criteria.

RESPONSE 2

Industry testing and analysis of this issue indicates that there is no measurable pressurization rate effect on the burst pressure of degraded steam generator tubing for pressurization rates between 200 psi/sec and 2000 psi/sec. The testing and analysis has shown that the burst correlation developed for the voltage based repair criteria is not effected by pressurization ramp rate. The industry changed the screening criteria for In-Situ testing and recommended that In-Situ tests be performed at a rate not exceeding 200 psi/sec with 2 minute hold times. This information was presented to the NRC Staff on July 17, 2001, and is documented in the EPRI Report 1001441, "Steam Generator Tubing Burst Testing Review," in Enclosure 4 and the Westinghouse Report SG-01-07-003, "Pressurization Rate and Foil Strengthening Effects on the Burst Strength of Axially Degraded Steam Generator Tubing," in Enclosure 3. Questions which the NRC Staff raised during the meeting are documented in the report in Enclosure 3.

ENCLOSURE 3

WATTS BAR NUCLEAR PLANT UNIT 1
STEAM GENERATOR ALTERNATE REPAIR CRITERIA
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
WESTINGHOUSE REPORT SG-01-07-003

SG-01-07-003

Pressurization Rate & Foil Strengthening Effects on the Burst Strength of Axially Degraded Steam Generator Tubing

July 2001

Westinghouse Electric Company LLC
Nuclear Services Division
P. O. Box 158
Madison, PA 15663-0158

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Pressurization Rate & Foil Strengthening Effects on the Burst Strength of Axially Degraded Steam Generator Tubing

1.0 Introduction

A series of burst tests were performed for the Tennessee Valley Authority (TVA) to resolve questions arising from apparently anomalous burst test results described in EPRI Report 1001441, Reference 1 (Effect of Pressurization Rate on Degraded Steam Generator Tubing Burst Pressure). The tests were conducted by E-Mech Technology for Westinghouse with the results of the test and analysis program reported in Reference 2. The text of this report is essentially a reproduction of the text of that reference. Conventional fast rate tests, typified by pressurization rates of about 2000 psi/s, of steam generator tubing specimens with long, axial EDM slots having very deep sections led to measured burst pressures approximately 23% higher than observed in tests of nominally identical specimens tested at much slower rates of loading, Reference 1. This result was at variance with years of previous test data and the known effect of strain rate on the plastic flow properties of Alloy 600.

Small amounts of time dependent deformation are apparent in tensile tests of Alloy 600 between room temperature and typical steam generator operating temperatures. Alloy 600 does exhibit an increase in plastic flow strength as strain rates are increased, as evidenced by a very low strain rate sensitivity exponent, Reference 1. However, a 23% difference in burst pressure, after geometry variations were normalized, is difficult to reconcile with the small effects of time or rate dependent deformation observed in Alloy 600. Either a small amount of time dependent deformation, at the brink of instability, can dramatically influence the burst pressure of long cracks with very deep sections or the foil reinforced bladders used in the fast rate tests provided significant strengthening compared to the slow rate tests conducted without a bladder and foil sealing system. The potential for the presence of the reinforcing foil to influence the test results was identified in Reference 1.

The next section presents results of fast rate burst tests of the same tubing and electrical discharge machined (EDM) slot geometry described in , Reference 1, but without a bladder and foil sealing system. This allowed direct comparison with previous slow rate tests under otherwise identical test conditions. When it became apparent that the 0.006 inch thick brass reinforcing foil had artificially strengthened tubes with sections of remaining wall thickness on the order 0.002 inches, another series of tests were performed to identify the degradation geometries where foil strengthening effects were an issue.

This second series of tests focused on the validity of the bobbin voltage ARC burst test database. To minimize handling of pulled tube sections, conventional practice has been to insert a bladder and foil sealing system if it was suspected that fluid loss during testing would lead to test termination prior to reaching the burst pressure. Thus, some pulled tube specimens with deep crack locations were burst tested using a foil and bladder arrangement. If foil strengthening had occurred in these tests, then the bobbin voltage ARC burst test database would be confounded by artificial foil strengthening effects. A detailed statistical analysis of the database comparing results

conducted at fast and slow rates by different laboratories found no evidence of such strengthening, Reference 1. However a systematic test program was conducted as a conservative measure. Section 3 presents burst tests results of specimens with axial EDM slots of various depths with and without foil reinforcement. The EDM length is limited to 0.75 inches, the thickness of a drilled tube support plate in Westinghouse Model 51 and D SGs, and the test specimen profiles have a central deep section to encourage stable throughwall tearing prior to final burst.

2.0 Pressurization Rate Effects

The dotted line on Figure 2.1 illustrates the specified axial EDM slot profile, i.e., depth versus length, for the pressurization rate effect test specimens. This is the Type 14 profile described in Reference 1. The present test specimens were made from the same heat of Alloy 600 as used in earlier tests. The tubing OD is 0.75 inches with a wall thickness of 0.048 inches. The sum of yield and ultimate strengths at room temperature is 153.7 ksi. The EDM slot width was on the order of 0.005 inches, as in previous tests of Type 14 specimens.

Testing was performed using the system shown on Figure 2.2. Pressure was recorded as a function of time. Maximum pressures were reached in 2 to 4 seconds, leading to pressurization rates between 1000 to 2000 psi/sec. Figure 2.3 shows a typical pressure versus time plot. Since no bladder or foil was present, the onset of tearing through the wall thickness effectively ended the tests as the pump capacity was not sufficient to continue pressurization once a leaking through crack had developed. Continued pumping led to pressure spikes which could not be maintained as leakage occurred. These spike pressures were occasionally about 50 psi higher than the pressure at the onset of initial throughwall tearing and leakage. Continued pumping caused some degree of additional crack tearing shown by a decreasing pressure versus time history, see Figure 2.3.

After initial pressurization testing, throughwall tearing developed but the crack openings were minimal. Figure 2.4 shows the EDM slot appearance after leakage had developed to terminate initial pressurization. At this point plastic liners, or bladders, **without** foil reinforcement, were inserted and the specimens were retested. The typical appearance after re-pressurization is shown in Figure 2.5. Throughwall cracking has developed along the full length of the EDM slot and the fish mouth opening is substantial. The burst pressure of a representative tube with a 1.42 inch long, 100% throughwall axial slot is estimated to be about 1830 psi. The pressures needed to develop 1.42 inch long, 100% throughwall cracking in the Type 14 specimens is approximately 4000 psi. Obviously a burst appearance similar to that of Figure 2.5 signifies that the maximum pressure required to create this condition is the burst pressure. Crack extension into full thickness material is not a necessary condition to signify that the burst pressure has been reached, although it is a sufficient condition for steam generator tubing.

In four of the six tests the maximum pressure attained before a burst condition was identified occurred during the initial pressurization where the post test appearance was essentially identical to that of Figure 2.4. Bursting of tubes with axial partial depth slots or cracks is a two step process. Tearing through the wall thickness occurs first, followed by tearing down the axial length. Either of these steps may be limiting in terms of the pressure required. In Type 14 EDM profiles, tearing through the wall is the limiting step that essentially determines the burst pressure. In re-pressurization tests, only two of the six tests showed small pressure increases, 25 psi in one case and 134 psi in the other, compared to the initial pressurization results. The burst pressures reported in Table 2.1 are the maximum pressures attained up to the point where a burst condition was identified with certainty.

In order to account for degradation geometry variations from one specimen to another, crack depth profiles were measured via scanning electron microscope (SEM) fractography. The measured profiles are presented in Appendix A. Figure 2.1 shows that measured profiles were reasonably

consistent with the specified machine drawings. Using measured profiles, effective structural lengths and depths were determined using the procedure specified in the EPRI Flaw Handbook, Section 5.1.5, Reference 10. Burst pressures were then calculated using Equation 5-14 of this same section, i.e.,

$$P_B = 0.58(S_y + S_u)\frac{t}{R_i}\left[1.0 - \frac{L}{L+2t}h\right]. \tag{1}$$

where
P_B = the calculated burst pressure,
S_y = the yield strength of the material,
S_u = the ultimate strength of the material,
t = the thickness of the tube,
R_i = the inside radius of the tube,
L = the length of the slot or crack, and,
h = the relative depth of the slot or crack (depth divided by thickness).

Equation (1) should be used for EDM slotted specimens. Equation 5-11 of the Flaw Handbook, obtained from equation (1) by replacing the "1.0" constant by "1.104", is not appropriate because it includes ligament strengthening effects between adjacent and overlapping crack segments in pulled tubes which are not present in the Type 14 EDM profiles.

Any degradation geometry differences are normalized by examining ratios of measured to calculated burst pressures. Table 2.2 compares present results with the previous data.

Here it is seen that fast and slow rate tests without foil reinforcement provide the same burst pressure. The anomalous results in Reference 1 for fast rate tests are evidently due to a foil strengthening effect. Figure 2.6 and Figure 2.7 graphically illustrate that fast and slow rate tests of Type 14 specimens provide identical results if the test conditions are otherwise identical. Any pressurization rate effect is below detectable levels. Figure 2.6 compares the measured maximum pressure to the calculated maximum pressure using equation (1) above. Figure 2.7 compares the cumulative distribution function (CDF) of the results of each of the test groups. It is evident that the CDF of the results of tests performed at a slow rate with no foil is identical to the results from tests performed fast with no foil. Thus, the presence of a long EDM slot with very deep locations and a reinforcing foil led to high burst pressures measured for the Type 14 specimens. It is evident that the 0.006 inch thick reinforcing foil and the local remaining wall thickness of 0.002 inches led to strengthening effects more pronounced than had been experienced in the past for other axial crack or slot geometries. The next section describes a series of tests conducted to evaluate the foil strengthening effects.

Table 2.1 Measured Burst Pressures for Type 14 Specimens Fast Rate Tests Without Foil Reinforcement	
Specimen Identification	Burst Pressure (psig)
WAT-14-001	4074
WAT-14-002	4260
WAT-14-003	4113
WAT-14-004	4025
WAT-14-005	4683
WAT-14-006	3892

Table 2.2 Measured/Calculated Burst Ratios for Various Test Conditions of Type 14 Specimens		
Loading Condition	Mean	Standard Deviation
Fast w/ Foil	121.2%	9.1%
Slow w/o Foil	97.6%	4.2%
Fast w/o Foil	97.3%	4.2%

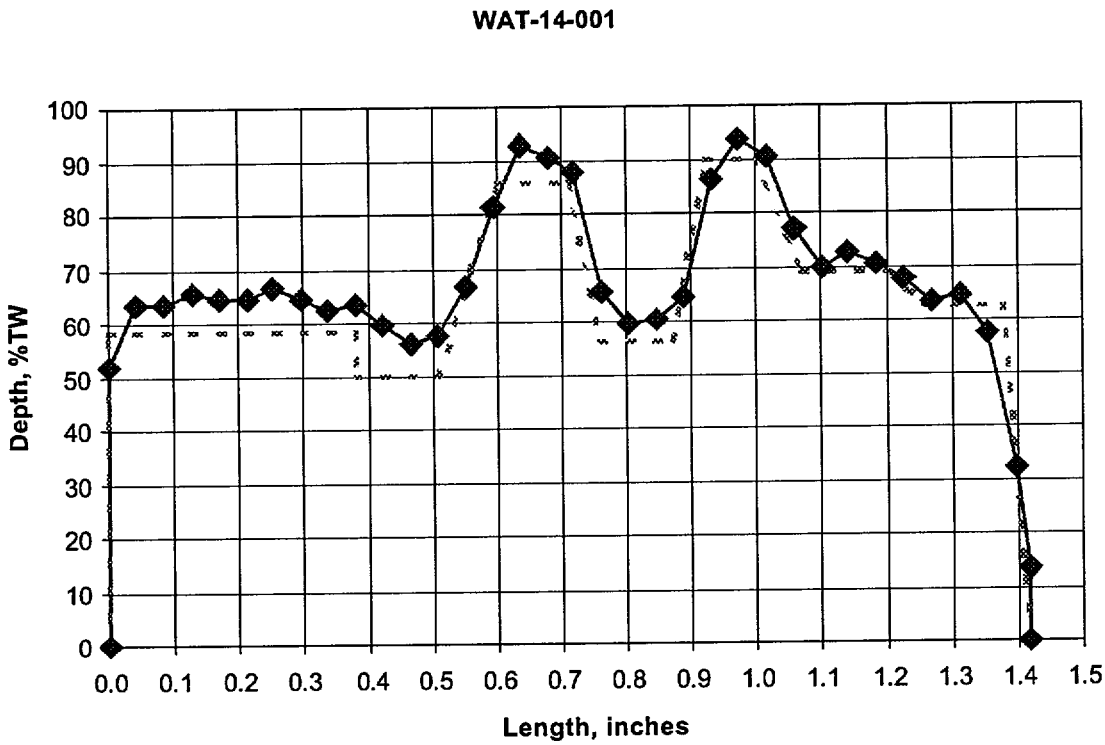
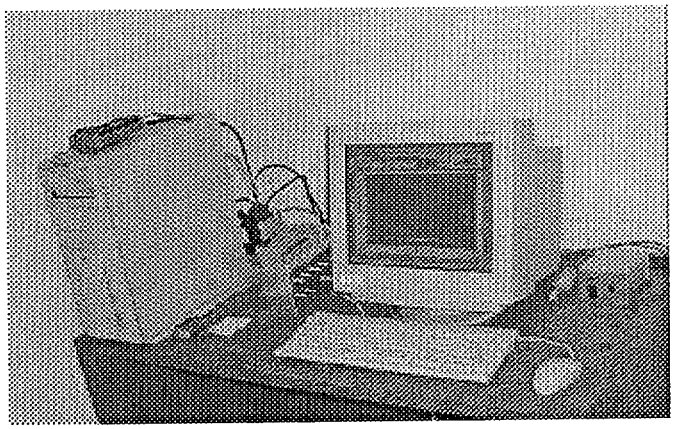
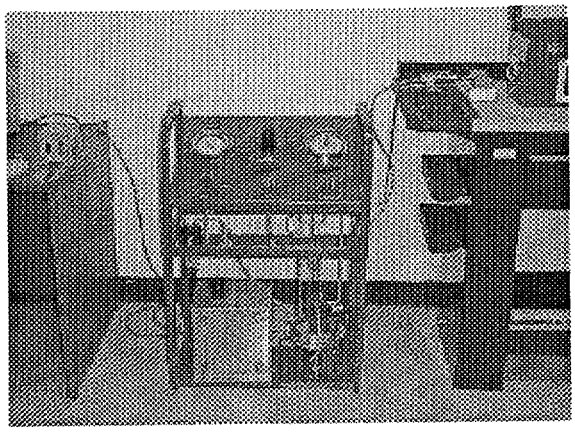


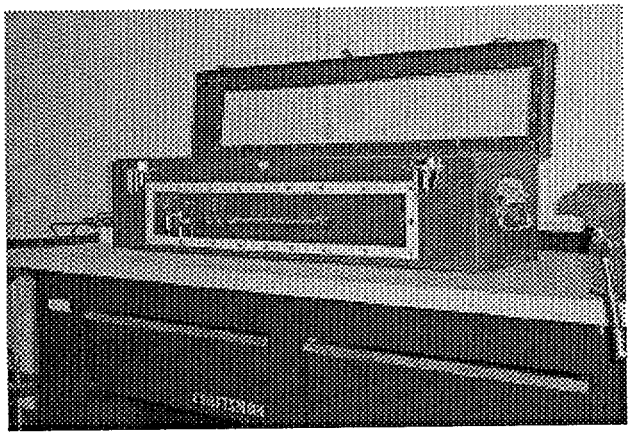
Figure 2.1: Type 14 EDM Axial Slot Specimen Depth Versus Length Profile, Dotted Line is Specified Drawing, Solid Line is Post Test Measured Profile



(a) Data Acquisition System



(b) Pumping System



(c) Test Chamber

Figure 2.2: Burst Test System Components

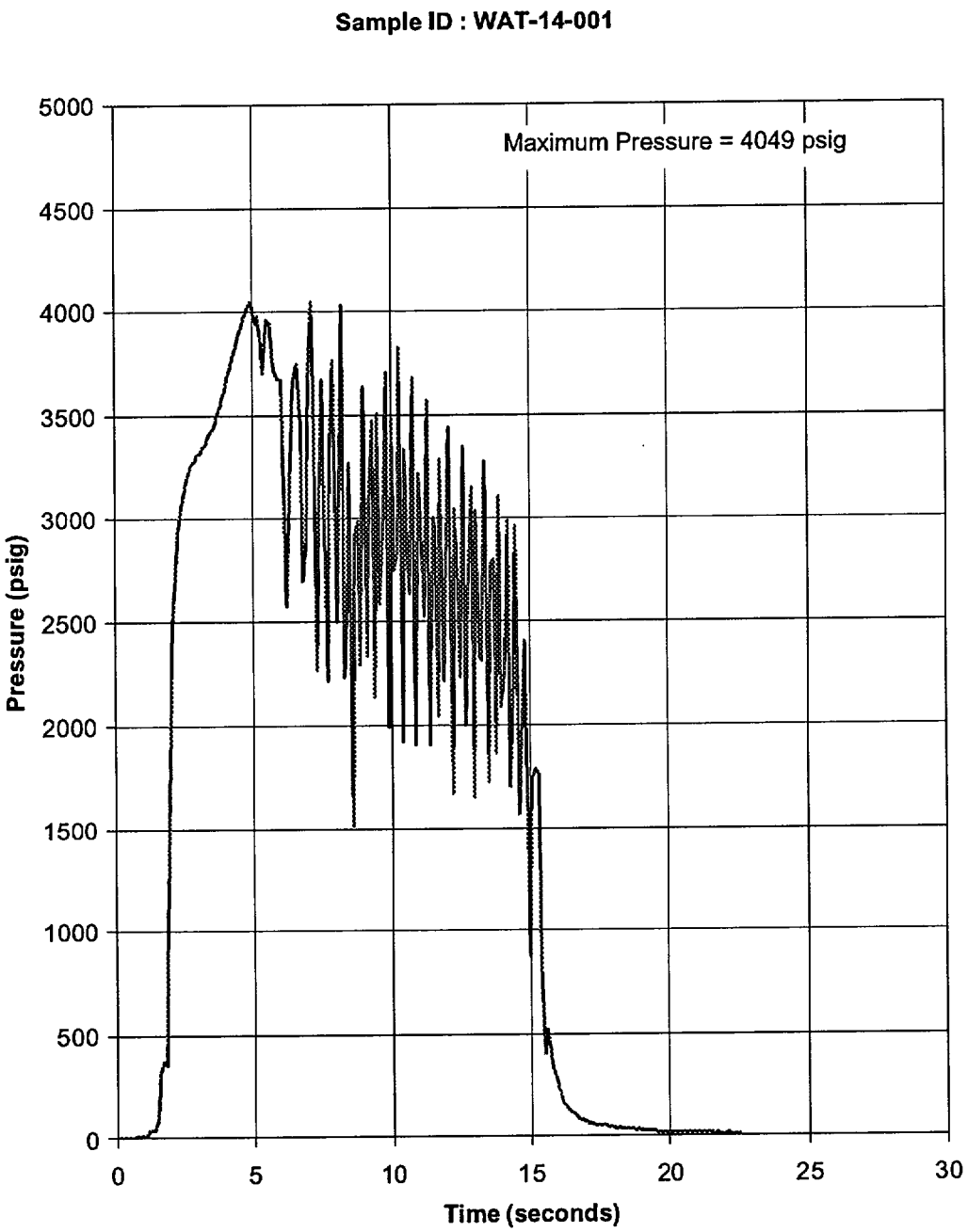


Figure 2.3: Initial Pressurization Curve for Specimen WAT-14-001

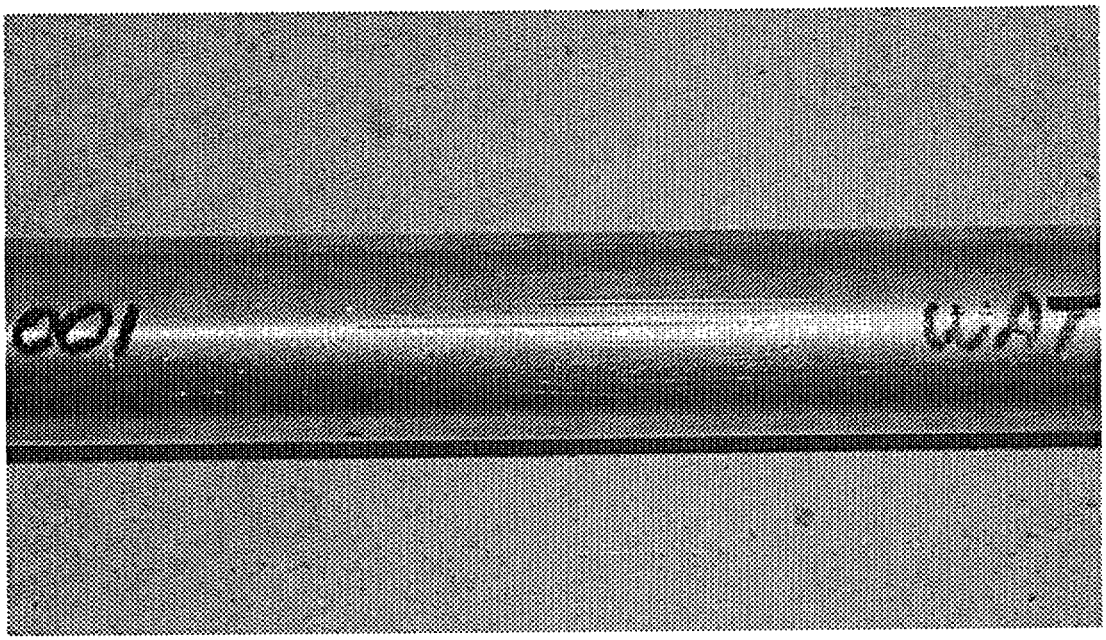


Figure 2.4: Post Test Appearance After Initial Pressurization to 4049 psi

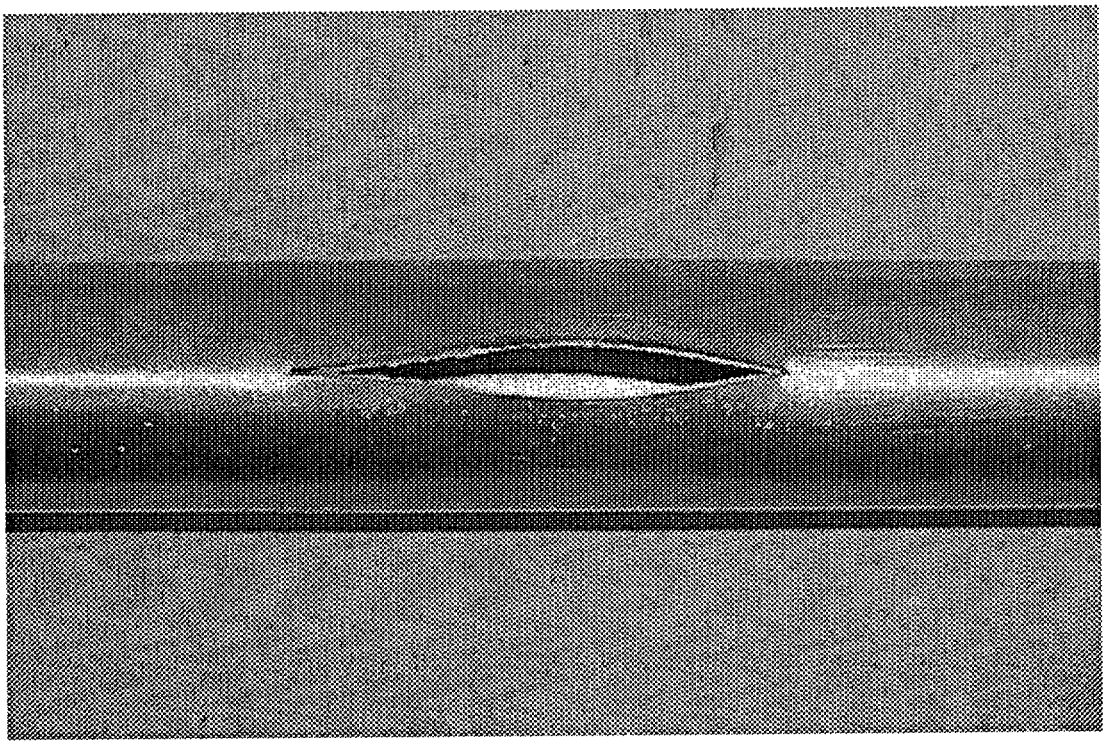


Figure 2.5: Post Test Appearance After Re-pressurization to 4074 psi

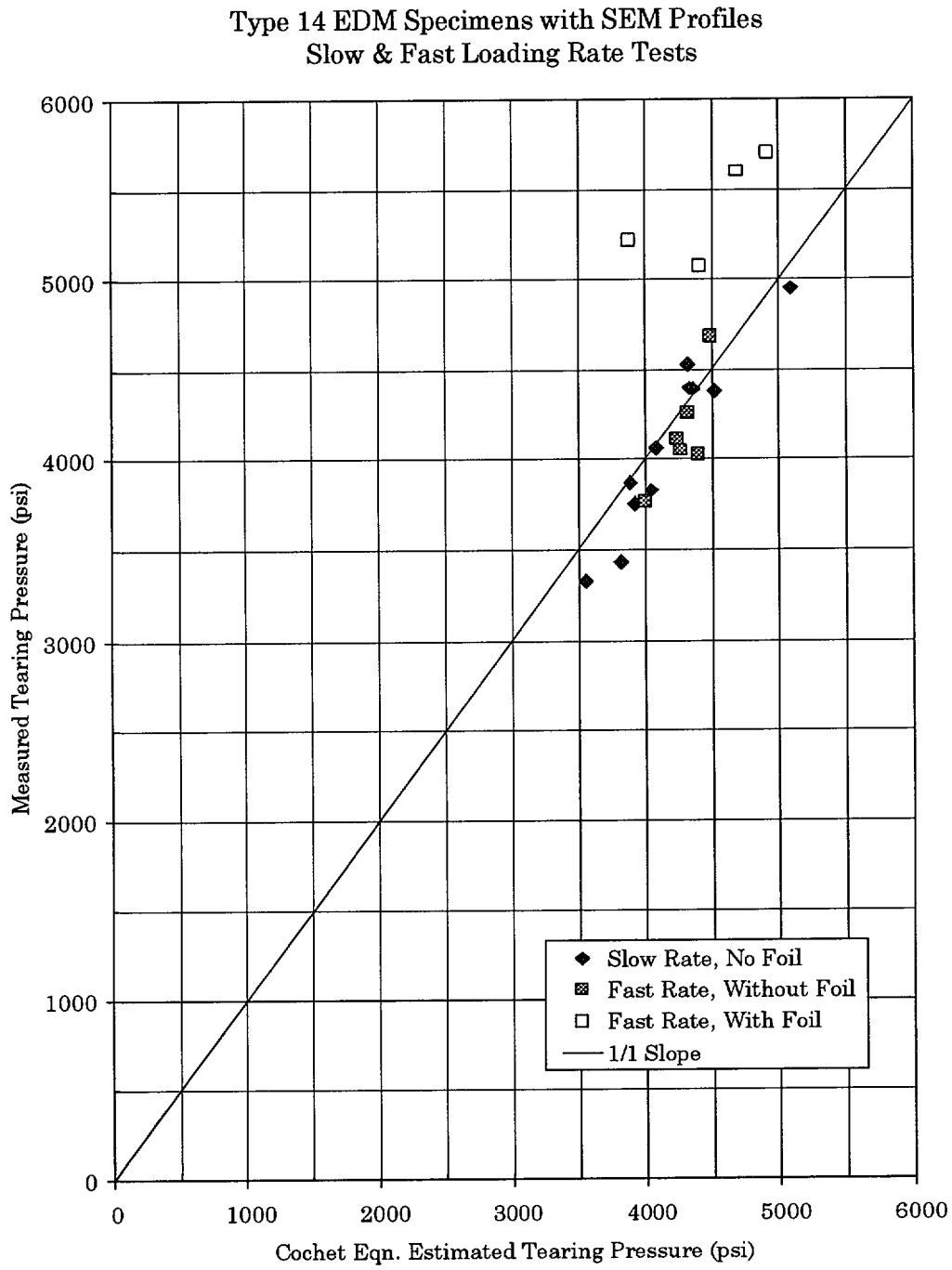


Figure 2.6: Comparison of Type 14 Burst Pressure Test Results as a Function of Test Conditions

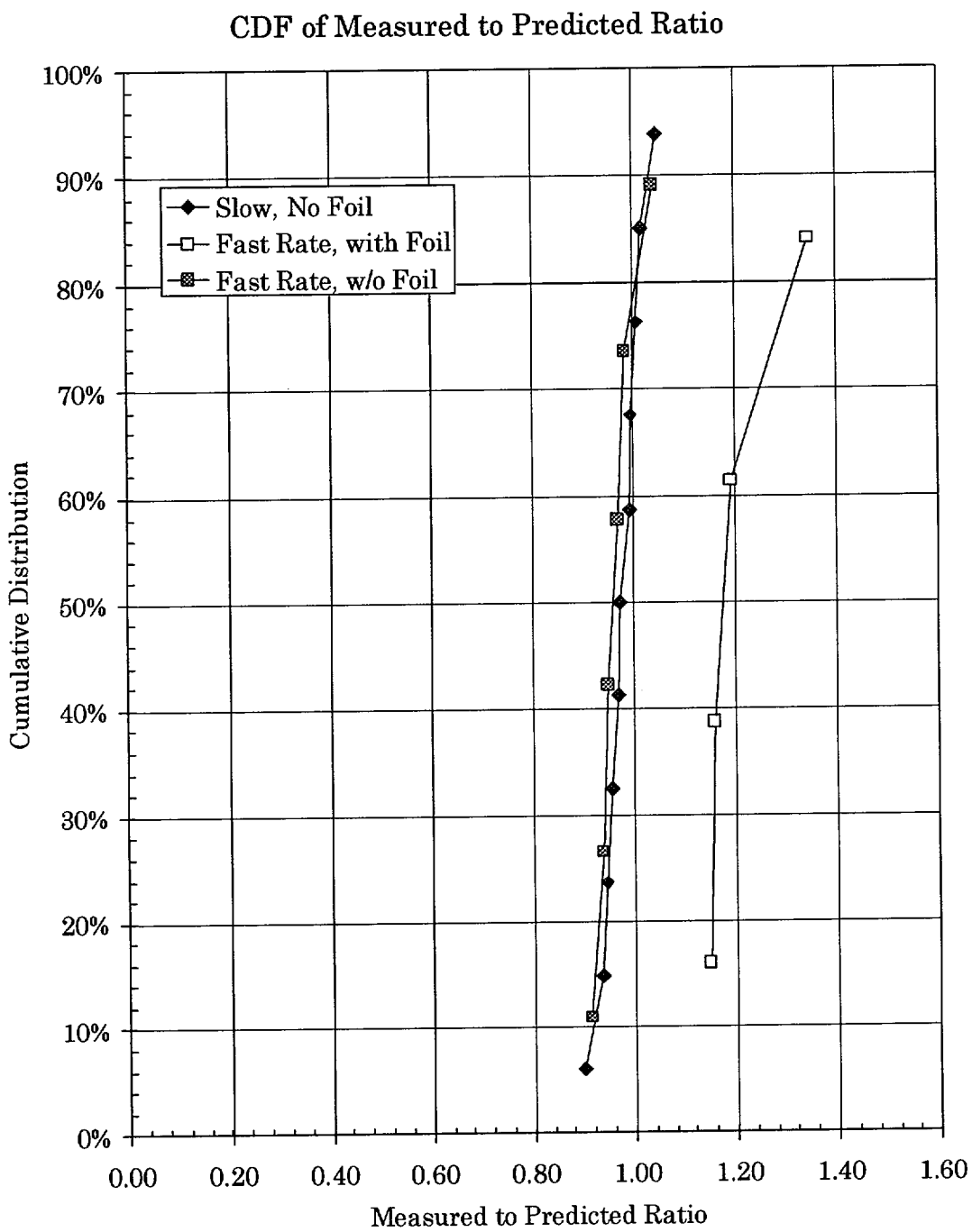


Figure 2.7: Comparison of Type 14 Burst Pressure Normalized Test Results as a Function of Test Conditions

3.0 Foil Strengthening Effects

If it is assumed that the anomalous fast rate test results of Reference 1 have been demonstrated to be due to a foil strengthening effect rate rather than a pressurization rate effect, the remaining question is to identify the degradation geometries where foil strengthening effects may have confounded previous burst test data. In particular, some pulled tube sections with deep cracks were tested with a bladder and foil insert in order to minimize handling. A bladder and foil insert eliminates the possibility of retesting due to leakage prematurely terminating a burst test. The primary focus of the systematic program test program described in this section is the validity of the bobbin voltage ARC burst test database. As noted earlier, a detailed statistical analysis of the database found no evidence of foil strengthening confounding the burst test data. In fact, the results of the analysis demonstrated that it was unlikely that there was any difference in the populations from which the data in the data sets were drawn. In order to check this finding, a systematic test program was conducted to obtain direct evidence regarding potential effect(s).

Destructive tests of SG tubes were conducted to examine the burst pressure as a function of axial EDM slot depth using both foil and bladder inserts and no inserts. The EDM slot length was held constant at 0.75 inches. This length approximates the maximum expected crack length for axial ODSCC/IGA degradation at drilled tube support plates. The EDM slot profile is illustrated in Figure 3.1. The central deep section encourages throughwall crack tearing, i.e., in the radial direction, and stable tearing in the axial direction prior to final bursting of the tube. Pre-test analyses showed that the selected combination of EDM slot lengths and depth profiles offered the highest probability of observing foil strengthening effects. The selected EDM profile captures all of the significant geometric features of interest and, as discussed later in this section, is representative of the deep crack profiles of concern in the Bobbin ARC burst test database.

The test material was mill annealed Alloy 600 tubing from heat NX9482. The tubing diameter is 0.75 inches with a wall thickness of 0.043 inch. The EDM slot widths were on the order of 6 to 8 mils. The certified mill test report (CMTR) of tensile properties indicated a sum of yield plus tensile strength equal to 153.1 ksi. Burst tests of unflawed sections of tubing led to an expected value of this sum of 155.8 ksi using the EPRI throughwall equation of Reference 3.

The burst test system of Figure 2.2 was used for the foil and no foil series of burst tests. Crack opening displacements were measured as a function of pressure for a limited number of specimens using the stereo microscope and video system shown on Figure 3.2. Both mid-length EDM slot openings and slot tip displacements were recorded, but not during the same tests.

The stereo microscope and video system was used to measure EDM slot profiles after burst testing. EDM slot lengths, both total and central deep section, were verified. Slot depths were measured at mid length and both slot tips. Typical slot depths were substantially less than nominal target values. The exceptions were the nominal 95% throughwall (TW) specimens, some of which exhibited very deep slots, approaching burn-through of the wall thickness. As in Section 2, EDM depth profiles were evaluated using Section 5.1.5 of the EPRI Flaw Handbook, Reference 10, to define effective structural depths and lengths. Burst pressure predictions were then calculated using equation (1) of this report. Since burst of a part-throughwall slotted tube is a two step process (radial tearing and axial extension) and the total slot length is 0.75 inches, no calculated

burst pressure can be lower than the 100% TW limit for a 0.75 inch long crack. This value is 2985 psi. The burst pressures of the nominal 95% TW and 100% TW EDM slots is controlled by the total length of 0.75 inches since tearing through the wall thickness is not the limiting step for these geometries.

Five (5) replicates were used for each of the foil and no foil burst test configurations at nominal maximum depths of 70, 80, 90, 95 and 100% TW. Actual maximum depths ranges from 55.9% to 100% TW. The large variation of actual depths compared to nominal depths made normalization of the results using the calculated burst pressures essential.

Two final test details need to be mentioned. The test duration time was on the order of 30 seconds, which means that the pressurization rates were on the order of 100 to 200 psi/sec. A typical pressure versus time curve is illustrated on Figure 3.3. The process for installing a foil reinforced bladder in a burst test specimen is illustrated on Figure 3.4. The foil used was brass with a specified thickness of 0.006 inches.

All tests led to tearing through the wall thickness. All tests with foil reinforced bladders led to tearing of full thickness material beyond the EDM slot tips. This led to post-test appearances typified by Figure 3.5. Tests with no bladder or foil at nominal depths of 80% TW and less also experienced post burst test appearances typified by Figure 3.5. At a nominal depth of 90% TW, which corresponded to an actual depth of about 85% TW, radial tearing of the central depth portion of the slot occurred and the tests then terminated due to loss of pressurizing fluid. Figure 3.6 illustrates a typical post-test appearance at this point. The length of 100% TW tearing is sufficient to demonstrate that retesting with a bladder will not demonstrate an increase in the pressure bearing capacity beyond the roughly 3300 psi already needed to create the throughwall tearing. This means that the burst pressure has been identified for this specimen. At nominal depths of 95% and 100% TW, testing with a foil reinforced bladder was required to reach the burst condition. Here, radial or throughwall tearing occurred at pressures well below the limiting burst pressure of 2985 psi for a 0.75 inch long, 100% TW EDM slot.

The burst pressures, the maximum pressure bearing capacity of the degraded test section, of the specimens are summarized in Table 3.1. A burst condition could not be demonstrated, i.e., achieved, for some of the specimens without the use of a foil reinforced bladder, this is denoted by the term "NB", no burst, in the table.

It is difficult to evaluate foil strengthening effects from Table 3.1. A graphical presentation is needed. Figure 3.7 shows a plot of measured versus calculated burst pressures. From this plot there is little if any systematic difference between the foil and the no foil burst data. In an alternative presentation, Figure 3.8 shows a plot of the measured to calculated burst pressure ratios as a function of maximum crack depth. Again there is scant evidence of foil strengthening but it could be argued there is about a 5% strengthening effect of the foil reinforcement at a maximum slot depth of about 90% TW. Slightly larger depths led to throughwall tearing and then a final burst pressure controlled by that of a 0.75 inch 100% TW slot. Just when a noticeable foil strengthening effect might be most obvious, none was evident.

The ANL equation of Reference 4 for ligament tearing is

$$P_T = \frac{P_0}{m_p} \text{ where } P_0 = 0.598(S_y + S_u)\frac{t}{R_m}. \tag{2}$$

Here, P_0 is the estimated burst pressure of a non-degraded tube. Relative to equation (1), R_m in equation (2) is the mean radius of the tube. Owing to the slight change in constant to 0.598, the respective terms of both equations (1) and (2) give essentially the same result. The m_p in equation (2) was originally derived as a stress intensity multiplying factor to account for the curvature of the tube. In that sense, it then becomes a burst pressure reduction factor relative to the non-degraded burst pressure. Reference 4 gives the expressions for calculating the value of m_p as,

$$m_p = \frac{1-\alpha h}{1-h}, \text{ where, } \alpha = 1 + 0.852h^2\left(1 - \frac{1}{m}\right). \tag{3}$$

It should be noted that Reference 4 uses constant values of 0.595 and 0.9 in equations (2) and (3) respectively. The constants presented here give essentially the same results, but were derived from a separate evaluation of the original data. Now, the value of m is given by,

$$m = 0.614 + 0.386e^{-1.125\lambda} + 0.433\lambda \text{ where } \lambda = \frac{L}{\sqrt{R_m t}}. \tag{4}$$

The non-dimension term, λ, is usually referred to as the normalized crack length. In addition, the constants in equation (4) have been adjusted for a value of Poisson's ratio of 0.3, see Reference 5. Using the ANL equation for normalization of geometry differences does not lessen the degree of scatter. At very large depths both the Cochet and ANL equations are a bit optimistic in terms of calculated pressures. This is expected for EDM slots. It does not occur in pulled tubes where ligament strengthening effects of adjacent and overlapping crack segments occur. The evaluation of foil strengthening effects is not obscured by the choice of a normalizing equation to compensate for geometry differences. If the normalizing equation is inaccurate, the effect will be systematic. Here one is simply looking for a different behavior between foil and no foil burst tests.

Another significant observation from Figure 3.8 is that a crack which tears to a length of 0.75 inches and is completely throughwall does not have the same burst pressure as a crack which is initially 100% TW and 0.75 inches long. This is because the near tip plastic strain field about a tearing crack is different from the near tip plastic strain field of a stationary crack. The end result is that the crack tip opening displacement (CTOD) needed for the onset of crack tearing is larger than the CTOD needed to continue tearing. This is illustrated in Figure 3.9. From the present tests, the burst pressure of a 100% TW crack torn to a length of 0.75 inches is about 10% less than that of a 100% TW crack that is initially 0.75 inches long. With the current EDM profiles, the tearing portion of the crack front is only 50% TW when it reaches the maximum extent of the machined slot (because the depth at the ends of the EDM slots is initially about 50% TW). Hence, an even larger burst pressure reduction could be expected if tearing occupied the full wall thickness. While this has significant implications for the prediction of the axial extent of crack tearing as a function

of pressure, it must be noted that this observation relevant for leak rate considerations rather than for burst pressure calculations.

The basic conclusion of the foil strengthening test program is that foil strengthening effects do not confound the bobbin voltage ARC database. Present test data and previous statistical analyses of the database confirm this point. Foil strengthening effects may be an issue for very long cracks with short deep crack sections, similar to the Type 14 EDM profile, as discussed below. Any foil strengthening effects for crack geometries relevant to the Bobbin Voltage ARC database are essentially within the scatter of burst test data. Two final questions need to be addressed in support of the above basic conclusion. These are:

(1) Are other 0.75 inch long profiles more prone to foil strengthening effects than the selected test profile?, and,

(2) Why would a foil strengthening effect be present for the 1.42 inch long Type 14 EDM profile and not in the 0.75 inch long profiles?.

The selected test profiles are representative of the deep crack profiles of interest in the Bobbin Voltage ARC burst test database. The profiles of interest are those with relatively low burst pressures and consequently high bobbin voltages. It is here where the foil strengthening effects, if they exist, would be expected to be most significant.

ODSCC destructive examination depth profiles in the ARC database were reviewed to verify the assumption that they could be adequately simulated by the trapezoid profile configuration for the current series of burst tests. Twenty (20) profiles from the review are included in this documentation. The review was limited to very deep (> 90% maximum depth), part-throughwall and throughwall profiles of significant length, including the longest indications in the database. Table 3.2 provides a summary of the 20 profiles and plots of each profile are shown in Appendix B.

The figures in Appendix B include the following profile features:

- Long indications > 0.65": Figures B-4, B-13, B-14, B-15, B-16, B-17, and B-18. The total length for the indication in Figure B-8 is long but includes a shallow tail about 0.1" long.
- Bathtub shape indications (near uniform, deep depths): Figures B-13 and B-19; only found in model boiler specimens.
- Double hump (two deeper sections separated by a shallower section) indications: Figures B-1, B-12 and B-18.

The pulled tube specimens all tend toward a trapezoidal crack shape although the deepest section may be closer to one end of the flaw (Figures 3 and 9, for example). Table 3.2 identifies the length for which the indication is > 85% deep or the length spanning 85% depth for the double hump specimens. A depth of 85% is used as a summary indication characteristic to represent a depth typical of ligament tearing depths for indications near burst margin requirements. The longest

pulled tube indications, such as found in Plant L and shown in Figures B-16 to B-18, have short deep segments of the indications. As the throughwall length increases, the length above 85% would of course increase as shown for the indication in Figure B-3. Except for long throughwall indications, the length above 85% for the pulled tubes is typically 0.2 to 0.3 inch for indications with maximum depths > 90%. In contrast, the ANO-2 type 14 indication has a length of about 0.6 inch averaging about 85% depth and an overall length of about 1.3" > 60% deep to support longer ligament tearing lengths.

Figure B-12 is a near uniform throughwall indication with a short length between the throughwall segments to form a double hump specimen that would burst at a pressure comparable to that of a bathtub flaw. The model boiler specimen profiles of Figures B-13 and B-19 represent bathtub shaped indications. The specimen profile on Figure B-19 is near throughwall over most of the indication length. The specimen profile on Figure B-13 has a long throughwall segment with the remaining length near throughwall. For the bathtub indication shape, the lengths outside the deep shape are short such that ligament tearing would not open a longer flaw and the burst pressures would tend to approach the burst pressures of a throughwall indication of comparable length.

It is concluded that the ARC database indications may predominantly be simulated by trapezoidal shapes such as used in the burst test program of this report. A central deep section is included with depths from 55% TW to 100 %TW. The deep section length is 0.25 inches. This is a good match to the profiles of interest in the database. Furthermore, calculations for various lengths of the central deep section show that a length of this order is required to simulate the condition where crack tearing begins at less than the burst pressure of a 100 % TW crack of length 0.75 inches. Here, foil strengthening could elevate the burst pressure past the limiting 0.75 inch throughwall burst pressure. This situation would be easily noticeable. Figure 3.10 shows a plot of calculated burst pressures versus maximum depth for central section lengths of 0.25, 0.125 and 0.0 inches with a constant total length of 0.75 inches and a sidewall depth of 50% TW. The horizontal line is the burst pressure for a 100% TW EDM slot over the total 0.75 inch length. The selected test profiles span the test conditions of most interest.

An analysis of foil strengthening effects was performed assuming that the foil acts as a friction patch providing a closure force across the EDM slot. With a plastic collapse mode of failure, the effect of the friction will be to elevate the burst pressure by a ratio that is independent of crack length and depth, i.e., the percentage increase in burst pressure will be constant regardless of the degradation geometry. The rationale for this conclusion is that the coefficient of friction between the foil and the tube should be constant, as would the foil width, and typical testing procedures require that the foil length be scaled with the slot length. From this viewpoint it may be concluded that any systematic set of degradation geometry variations should be sufficient to identify a foil strengthening effect.

For very deep cracks, the remaining ligament cannot deform to a large extent before tearing. If the strength of the ligament is not sufficient to limit the opening it must tolerate before a complete plastic collapse condition is attained, then early ligament failure will occur. This can trigger a final burst. The slot or crack opening that a ligament can tolerate scales with its size. Figure 3.11 shows a plot of pressure versus slot opening for a partial depth EDM slot with a total length of 0.75

inches and a minimum remaining ligament of about 0.019 inches (45% TW). This ligament could open no more than 0.014 inches before tearing. Smaller ligaments will tear at much smaller openings. The opening forced upon a ligament is controlled by the crack length and ligament size. The ligament material provides a closure force opposing the crack or slot opening. Thus, larger ligaments can both tolerate larger openings and act to limit the opening that is applied. For example, the elastic opening at the center of a 100% TW crack in a flat plate varies proportional to the crack length. For a given applied stress, the remaining ligament of a long crack is forced to strain more than that of a short crack. The ligament in a short crack is, in effect, helped by the unflawed adjacent material experiencing relatively little deformation.

The strengthening effect of a ligament does not increase as the opening increases. The ligament is fully plastic at very small openings. The only question is whether or not the contribution of ligament strengthening will continue as deformation elsewhere in the degraded region continues to develop. For a given ligament size (thickness), early ligament tearing is more prone to develop in a long crack than in a short crack. Thus, closure forces provided by a foil, the friction patch, can delay ligament failure leading to an increase in overall strengthening. The tendency for large openings in long cracks compared to short cracks makes the restriction of opening a more substantial factor for long cracks. The flat plate example above illustrates this increased tendency for opening. Bulging experienced by cracks or slots in shells greatly exacerbates this tendency for opening as a function of crack length by about an additional factor of 2 for the 1.42 inch long Type 14 slot relative to that for a 0.75 inch long slot. When the factor of limited ligament opening prior to failure is considered (an elastic-plastic fracture mechanics viewpoint), larger foil strengthening effects are expected for long very deep partial depth EDM slots or cracks then for shorter cracks with the same ligament size.

The observation of a possible very mild foil strengthening effect in 0.75 inch long slots and an implied much larger effect in the Type 14 EDM profile specimens is consistent with a slot length difference of nearly a factor of 2. This discussion plus earlier observations support the basic conclusion that foil strengthening effects do not confound the bobbin voltage ARC database.

Table 3.1: Summary of "Foil" and "No Foil" Burst Test Results

No Foil						Foil				
Nominal Max. Depth (% TW)	Specimen Number	Measured Max. Depth (% TW)	Measured Burst Pressure (psi)	Calculated Burst Pressure (psi)	Meas./Calc. Ratio	Specimen Number	Measured Max. Depth (% TW)	Measured Burst Pressure (psi)	Calculated Burst Pressure (psi)	Meas./Calc. Ratio
70	1	60.8	6374	5946	1.072	6	63.4	5813	5653	1.028
70	2	59.9	5833	6047	0.965	7	61.4	5981	5884	1.016
70	3	60.5	6266	5972	1.049	8	57.6	6044	6190	0.976
70	4	64	6113	5631	1.086	9	61.4	6310	5866	1.076
70	5	59.9	6197	6032	1.027	10	55.9	6497	6392	1.016
80	1	71.5	5032	5013	1.004	6	75.2	4855	4647	1.045
80	2	67.1	5479	5376	1.019	7	69.7	4536	5092	0.891
80	3	66.9	5273	5390	0.978	8	74.4	4600	4720	0.975
80	4	68.6	4668	5197	0.898	9	75.5	4899	4649	1.054
80	5	73.2	4850	5195	0.934	10	74.1	4855	4738	1.025
90	1	86.5	3327	3638	0.915	6	86.2	3577	3660	0.977
90	2	84.4	3337	3796	0.879	7	86.4	3617	3663	0.987
90	3	85.6	3499	3638	0.962	8	83	3980	3969	1.003
90	4	80.4	3415	4040	0.845	9	82.1	3936	4050	0.972
90	5	80.4	4270	4152	1.028	10	80.7	3740	4185	0.894
95	1	>95	NB	2985	NA	6	>95	2673	2985	0.895
95	2	>95	NB	2985	NA	7	86.6	3587	3536	1.014
95	3	87.2	3317	3485	0.952	8	>95	2801	2985	0.938
95	4	>95	NB	2985	NA	9	87.1	3607	3494	1.032
95	5	>95	NB	2985	NA	10	>95	2737	2985	0.917
100	1	100	NB	2985	NA	6	100	2609	2985	0.874
100	2	100	NB	2985	NA	7	100	2776	2985	0.930
100	3	100	NB	2985	NA	8	100	2762	2985	0.925
100	4	100	NB	2985	NA	9	100	2678	2985	0.897
100	5	100	NB	2985	NA	10	100	2722	2985	0.912
						1R	100	2766	2985	0.927
						2R	100	NB	2985	NA
						3R	100	2683	2985	0.899
						4R	100	2668	2985	0.894
						5R	100	2698	2985	0.904

"XR" = retested with foil
"NB" = No Burst
"NA" = Not Available

Table 3.2: ODSCC ARC Database Destructive Exam Data Examples - Pulled Tube and Model Boiler Data									
Figure	Year	Plant	Row	Col	TSP	Length (inch)	Max. Depth (%)	Avg. Depth (%)	Profile Description
1	1993	R-1	9	76	2	0.400	91	66.7	Double hump over about 0.25" for >85% peak depths, trapezoidal shape
2	1995	AA-1	16	42	3	0.330	97	74.4	Trapezoidal shape, 85% over about 0.2"
3	1995	AA-1	42	44	3	0.520	98	74.1	Trapezoidal shape, 85% over about 0.3"
4	1992	MAR	26	34	3	0.669	100	85.2	Long, trapezoidal shape, 85% over about 0.47" (TW 0.24")
5	1993	R-1	9	91	2	0.462	100	80.2	Trapezoidal shape, 85% over about 0.27" (TW 0.09")
6	1995	AA-1	27	43	3	0.590	100	75.0	Trapezoidal shape, 85% over about 0.27" (TW 0.1")
7	1995	AA-1	42	44	5	0.530	99	57.5	Trapezoidal shape, 85% over about 0.2"
8	1995	AA-1	41	65	5	0.686	100	63.0	Trapezoidal shape, 85% over about 0.3 (TW 0.27"), shallow 0.1" tail"
9	1995	AB-1	3	107	3	0.590	100	68.2	Trapezoidal shape, 85% over about 0.25" (TW 0.13")
10	1995	AB-1	20	7	3	0.602	100	72.0	Trapezoidal shape, 85% over about 0.28" (TW 0.24")
11	1998	AC-1	18	100	3	0.637	100	69.3	Trapezoidal shape, 85% over about 0.2" (TW 0.05")
12		3/4 MB	600-1			0.500	100	88.4	Double hump over about 0.45" (TW 0.31") for >85% peak depths
13		3/4 MB	601-6			0.740	100	90.1	Long, bathtub flaw shape, 85% over about 0.6", TW about 0.37"
14		3/4 MB	601-4			0.660	100	63.7	Long, 2 axials separated by ligament, one 85% (TW 0.25") over about 0.26"
15	1995	A-1	28	35	1	0.696	96	63.0	Long, trapezoidal shape, 85% over about 0.2"
16		L	8	69	1	0.855	98	59.5	Longest Indication, trapezoidal shape, 85% over about 0.1"
17		L	8	66	1	0.750	96	54.4	Long, trapezoidal shape, 85% over about 0.05"
18		L	12	70	1	0.783	97	59.9	Long, double hump, trapezoidal shape, about 0.26" for >85% peak depths
19		7/8 MB	607-3			0.490	98	89.9	Bathtub flaw shape, 85% over about 0.41"
20		7/8 MB	543-4			0.520	98	79.9	Trapezoidal shape, 85% over about 0.31"

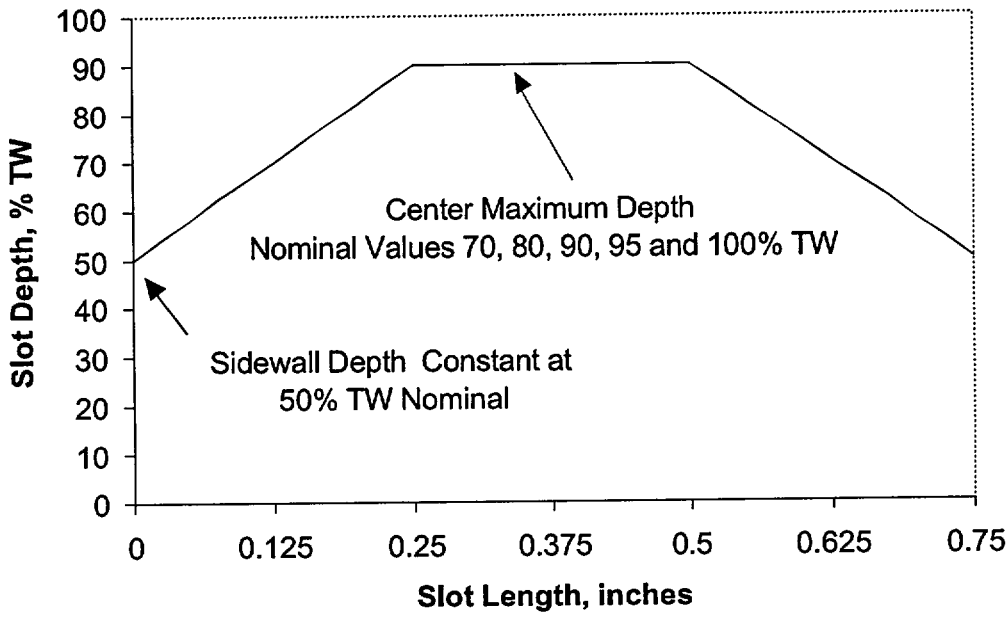
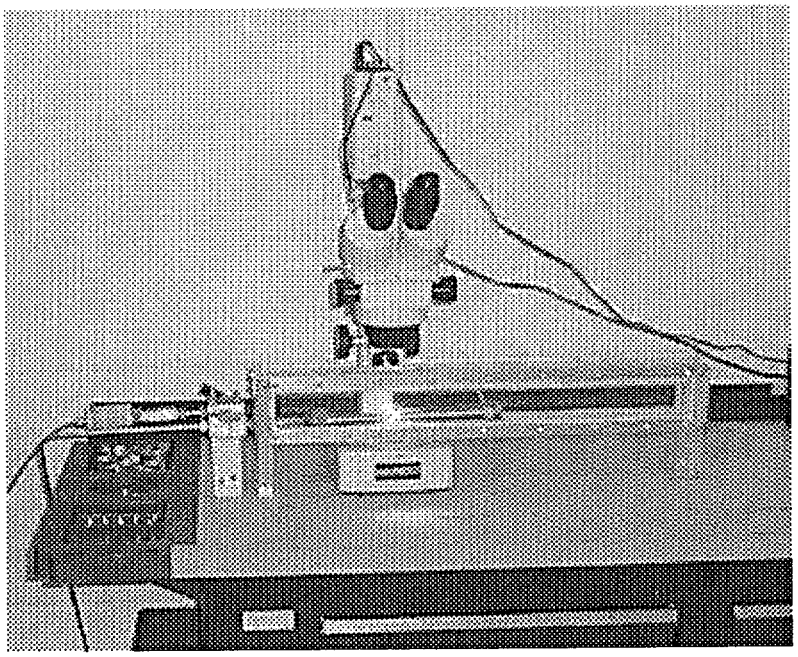
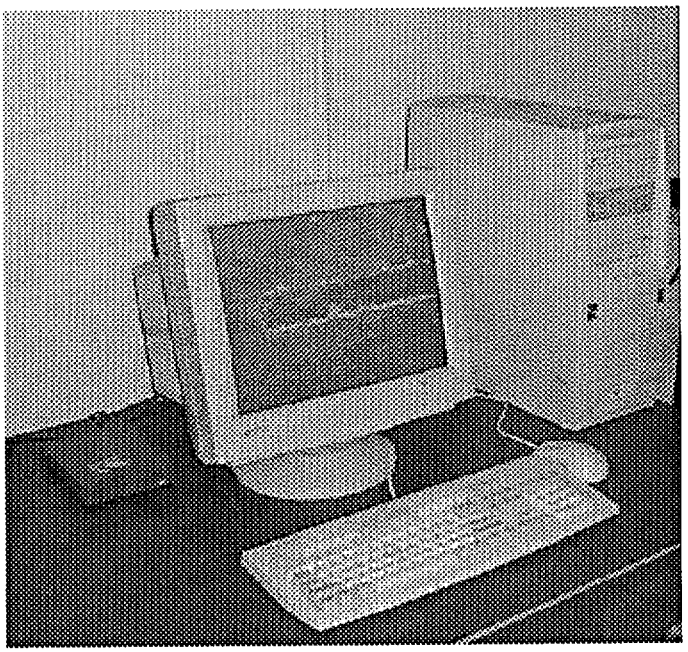


Figure 3.1: Schematic of EDM Slot Depth Profile



(a)



(b)

Figure 3.2: Stereo Microscope and Video Capture System

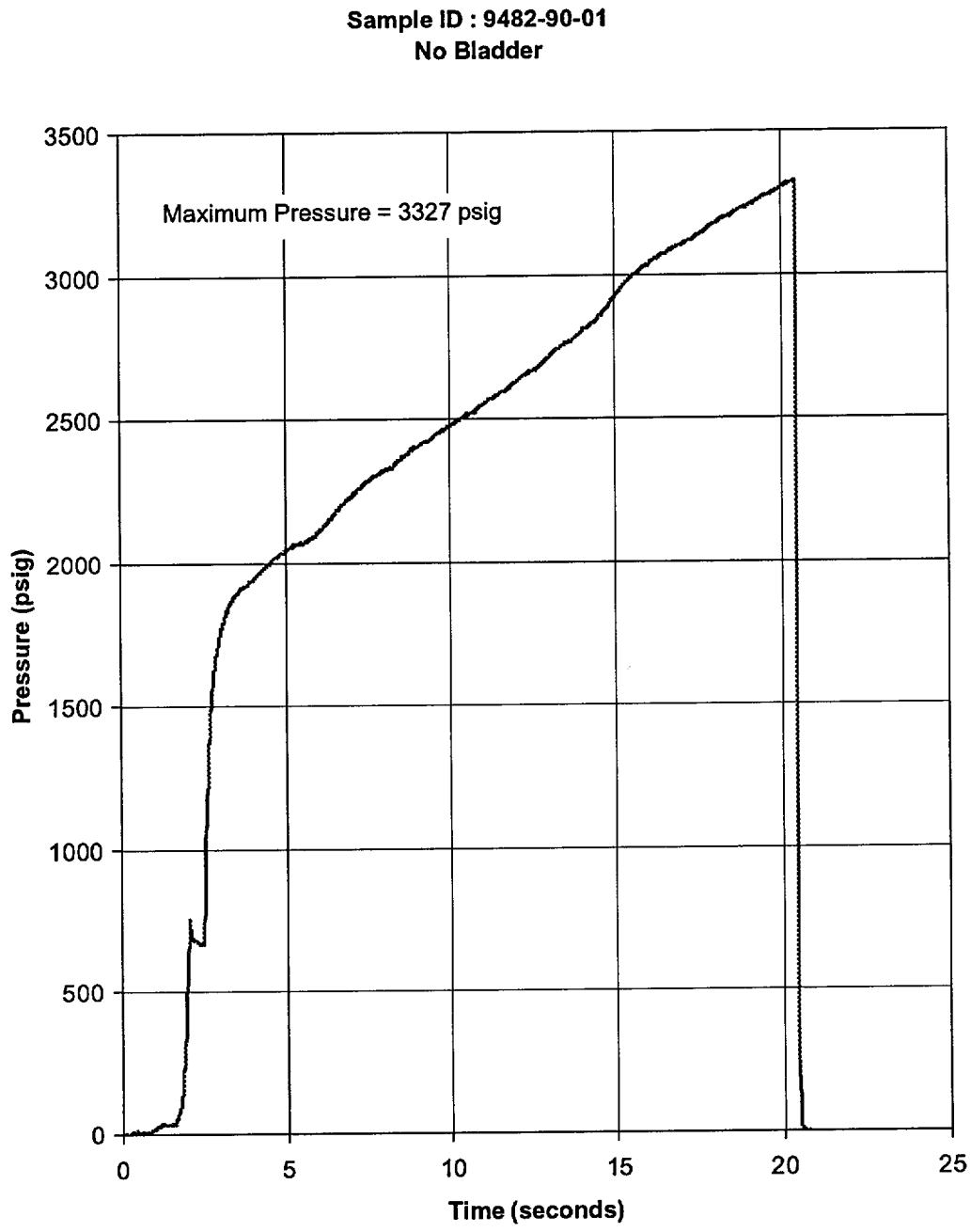


Figure 3.3: Typical Pressure Versus time Curve

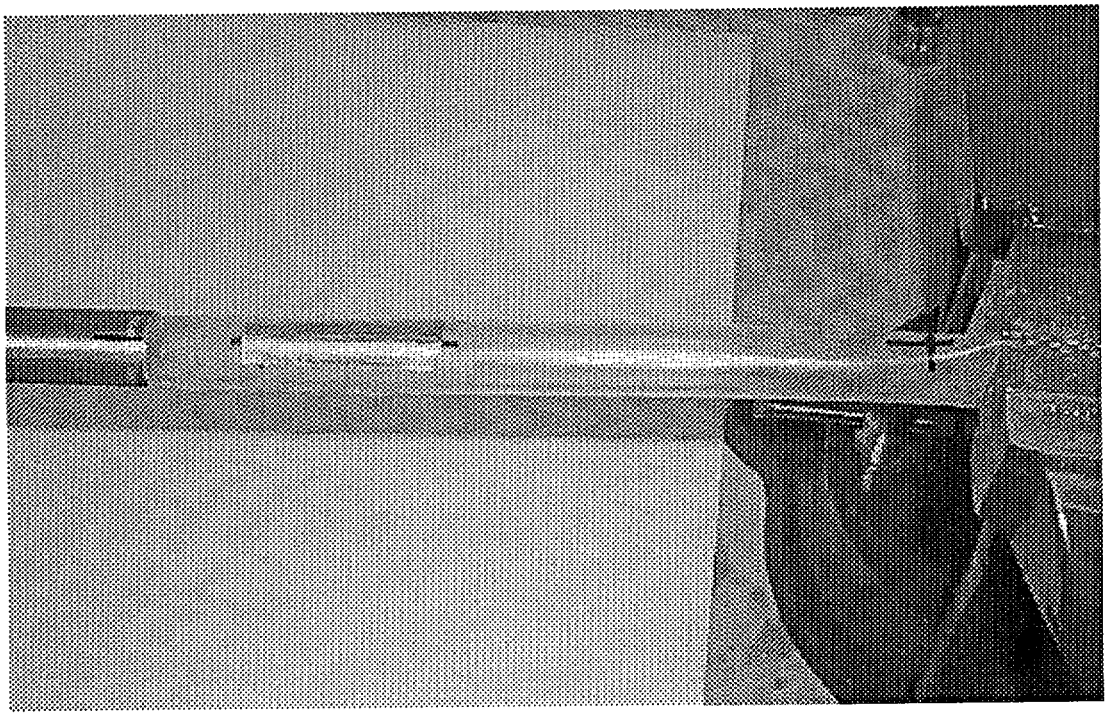


Figure 3.4: Bladder and Reinforcing Foil Installation

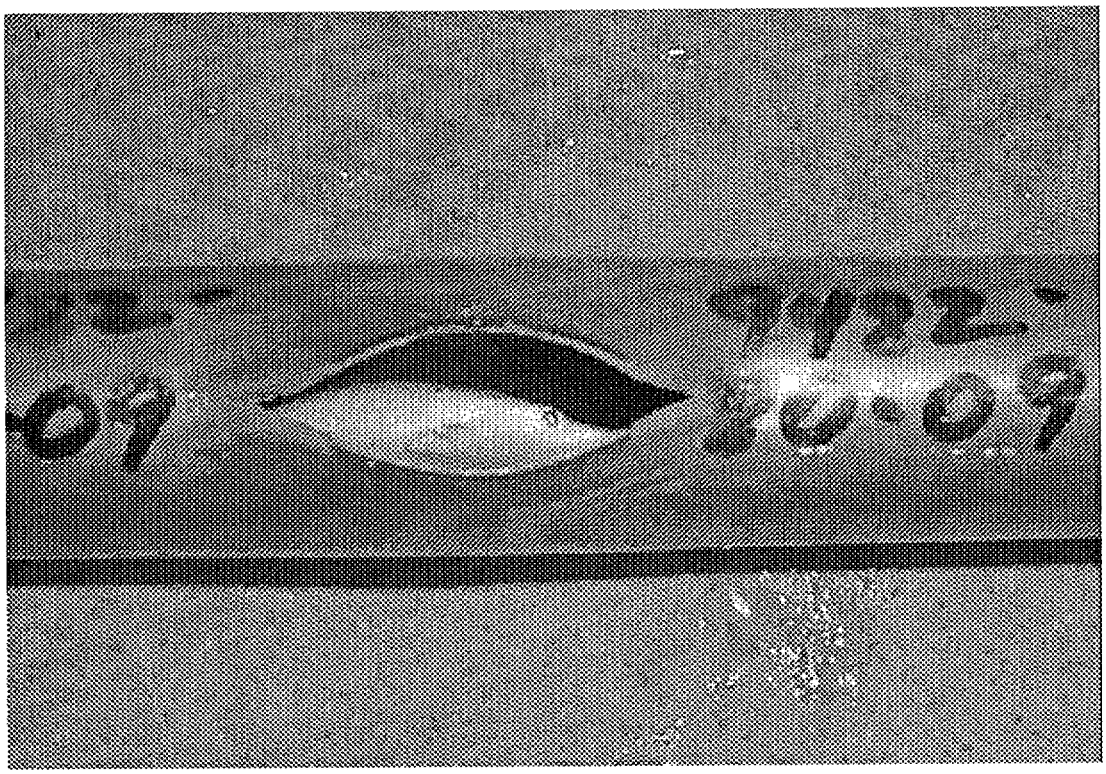


Figure 3.5: Post Test Appearance Illustrative of Tearing
Beyond the EDM Slot Tips

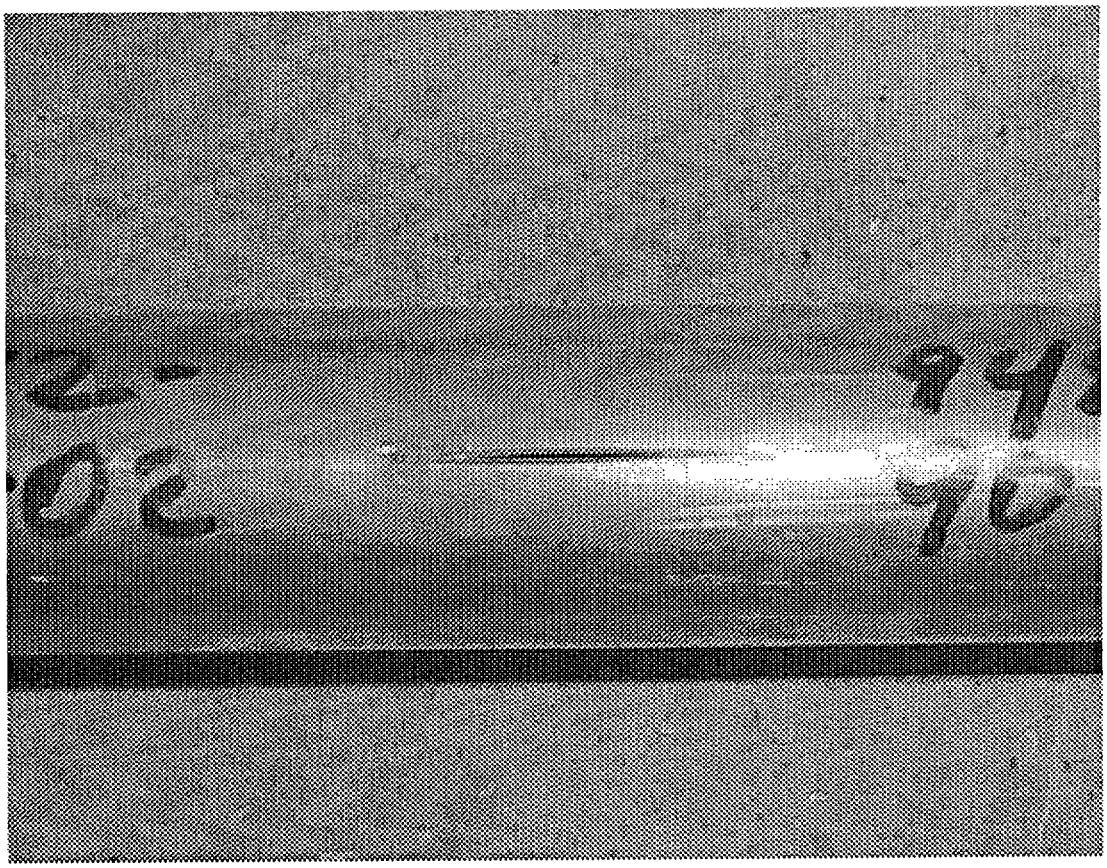


Figure 3.6: Post Test Appearance of Partial Tearing.
The Combination of Specimen Appearance, Analysis and Maximum Test Pressure Demonstrated That the Burst Pressure Has Been Attained.

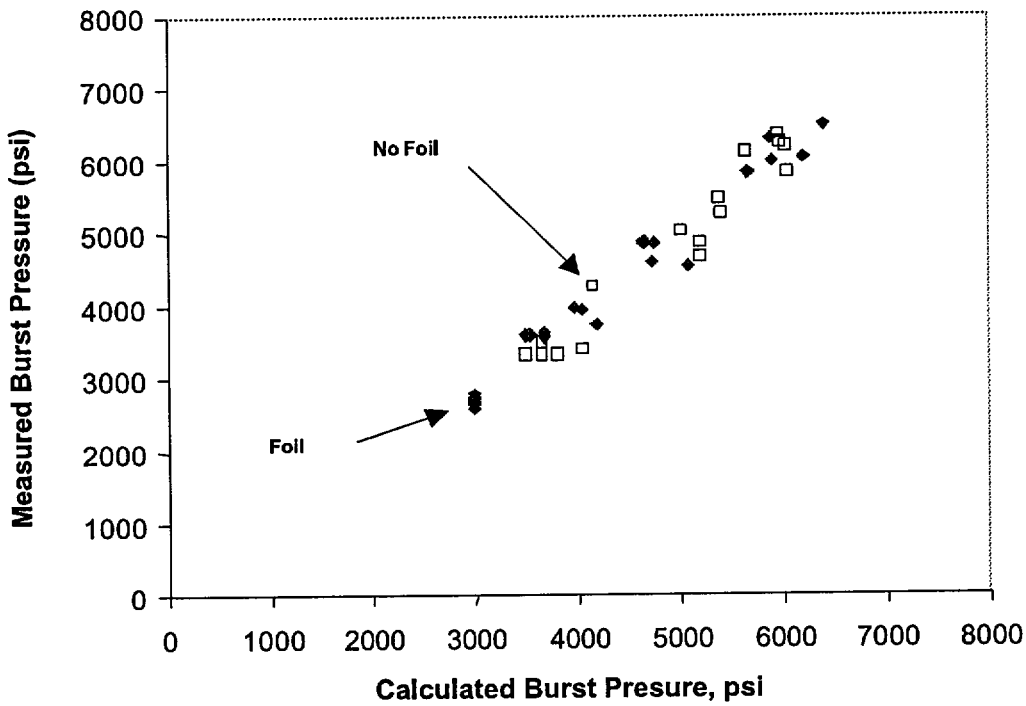


Figure 3.7: Measured Versus Calculated Burst Pressures Showing No Evidence of Foil Strengthening

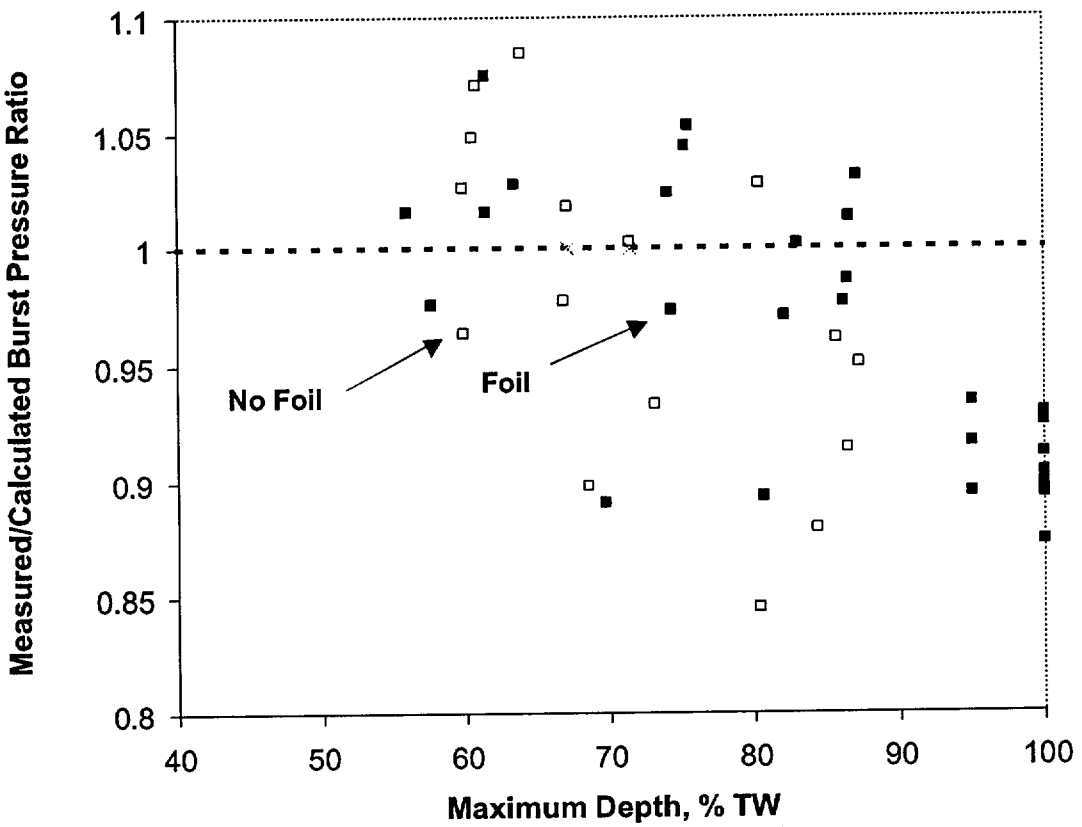


Figure 3.8: Measured/Calculated Burst Pressure Ratio Versus Maximum Depth

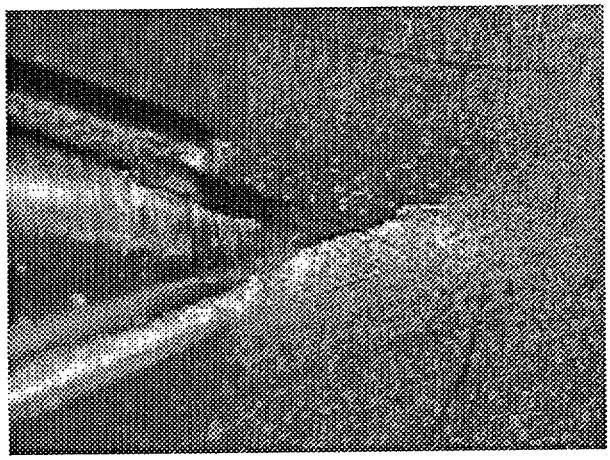


Figure 3.9: Appearance of the Crack Tip After Axial Crack Tip Tearing Has Developed (The brass foil liner is apparent in the picture.)

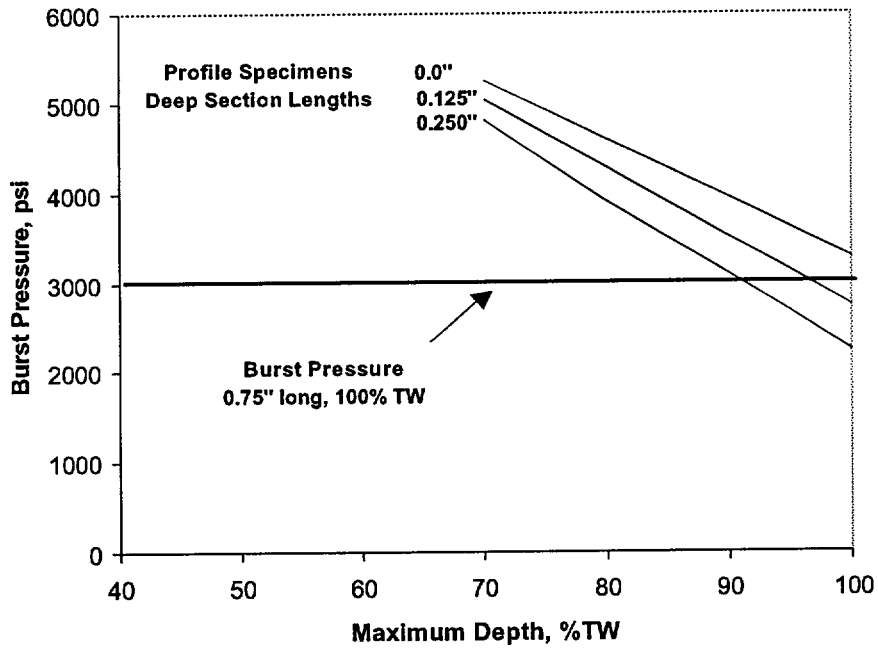


Figure 3.10: Calculated Burst Pressure for Various Lengths of Central Deep Section, 0.75 Inch Total EDM lot Length, 50% TW Sidewall Depth

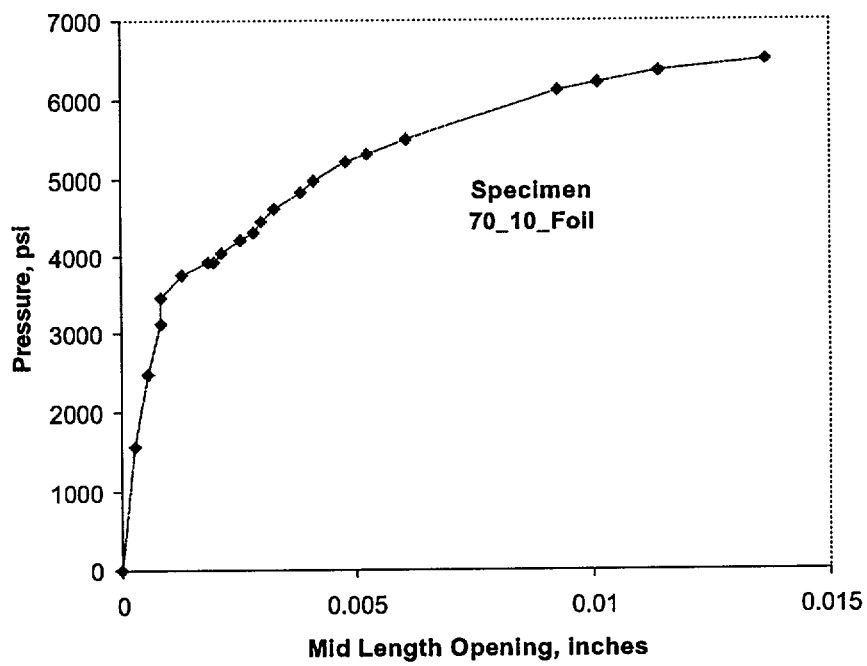


Figure 3.11: Pressure versus Slot Opening at Mid Length

4.0 Summary & Conclusions

A series of degraded SG tube burst tests were performed to resolve questions arising from the test results discussed in Reference 1. As described in this report, conventional fast rate tests of steam generator tubing specimens with long, axial EDM slots having very deep sections led to measured burst pressures approximately 23% higher than observed in tests of nominally identical specimens tested at much slower rates of loading. This result was at variance with years of previous test data and the known effect of strain rate on the plastic flow properties of Alloy 600. The results from the tests described herein demonstrated that the foil reinforced bladders used in those fast rate tests provided significant strengthening compared to the slow rate tests conducted without a bladder and foil sealing system. A plausible technical argument based on the principles of solid and fracture mechanics has also been presented to explain the observed results.

Given the observation of an instance of substantial foil strengthening beyond expectations, another series of tests were performed to identify the degradation geometries where foil strengthening effects were an issue. This second series of tests focused on the validity of the bobbin voltage ARC burst test database. Historically, some pulled tube specimens with deep crack locations were burst tested using a foil and bladder arrangement. A detailed statistical analysis of the database for those tests found no evidence of a strengthening effect. Recognizing the indirect nature of those results, a systematic test program was developed and conducted which provided direct verification of that conclusion.

The results from the various testing programs lead to the following conclusions:

1. There was no pressurization rate effect present in the results for the Type 14 specimens as discussed in Reference 1. Thus, there is no effect of pressurization rate on the measured burst pressure in the conventional testing range of 20 to 2000 psi/sec. (The strengthening effect observed in the results for the Type 14 specimens was likely due to the presence of the reinforcing foil for the bladder liner used during the tests.)
2. The use of a foil reinforced bladder liner for specimens made to simulate degradation with a length of 0.75" has no significant effect on the burst pressure of the specimens.
3. Foil strengthening effects have not confounded the bobbin voltage ARC database. It is noted that the potential for foil to influence the results for very long cracks with short deep sections, similar to the 1.4" long Type 14 EDM profile, was not a subject of investigation for this program. A hypothesis has been developed to explain the rationale for increased foil strengthening effects at longer crack lengths.

In conclusion, the ODSCC ARC database is satisfactory for the purpose for which it was intended without additional consideration of the influence of extraneous factors on the reported results.

5.0 References

1. Report 1001441, "Effect of Pressurization Rate on Degraded Steam Generator Tubing Burst Pressure," EPRI, Palo Alto, CA, April 2001.
2. EMECH-07XX-SR-1, "Comments on Pressurization Rate and Foil Strengthening Effects on the Burst Strength of Axially Degraded Steam Generator Tubing," Begley, J. A., et al., E-Mech Technology, Inc., Pittsburgh, PA, July 2001.
3. TR-105505 (Proprietary), "Burst Pressure Correlation for Steam Generator Tubes With Throughwall Axial Cracks," EPRI, Palo Alto, CA, October 1997.
4. NUREG/CR-6575, "Failure Behavior of Internally Pressurized Flawed and Unflawed Steam Generator Tubing at High Temperatures — Experiments and Comparison With Model Predictions," United States Nuclear Regulatory Commission, Rockville, MD, March 1998.
5. TR-105505, "Burst Pressure Correlation for Steam Generator Tubes with Throughwall Axial Cracks," EPRI, Palo Alto, CA, October 1997.
6. NEI 97-06, "Steam Generator Program Guidelines", Nuclear Energy Institute, Washington, DC, December 1977.
7. TR-107621-R1, "Steam Generator Integrity Assessment Guidelines: Revision 1", EPRI, Palo Alto, CA, March 2000.
8. TR-107620-R1, "Steam Generator In Situ Pressure Test Guidelines", EPRI, Palo Alto, CA, June 1999.
9. "Performance Demonstration Data Base, Appendix A, Technique Specification Sheets", EPRI, Palo Alto, CA, January, 1999.
10. Report 1001191, "Steam Generator Degradation Specific Management Flaw Handbook," EPRI, Palo Alto, CA: 2001.
11. EMECH-0714-1, Rev. 1, "Condition Monitoring and Operational Assessment of Steam Generator Tubing at Diablo Canyon Unit 1, 1R9," Begley, J. A., et al., E-Mech Technology Inc., Pittsburgh, PA, February 1999.
12. AES98033350-1-1, "An Operational Assessment of Steam Generator Tube Degradation at Crystal River Unit 3," Begley, J. A., et al., Aptech Engineering Services, Inc., Sunnyvale CA, April, 1998.

Appendix A

Measured Type 14 EDM Profiles

Figure A-1

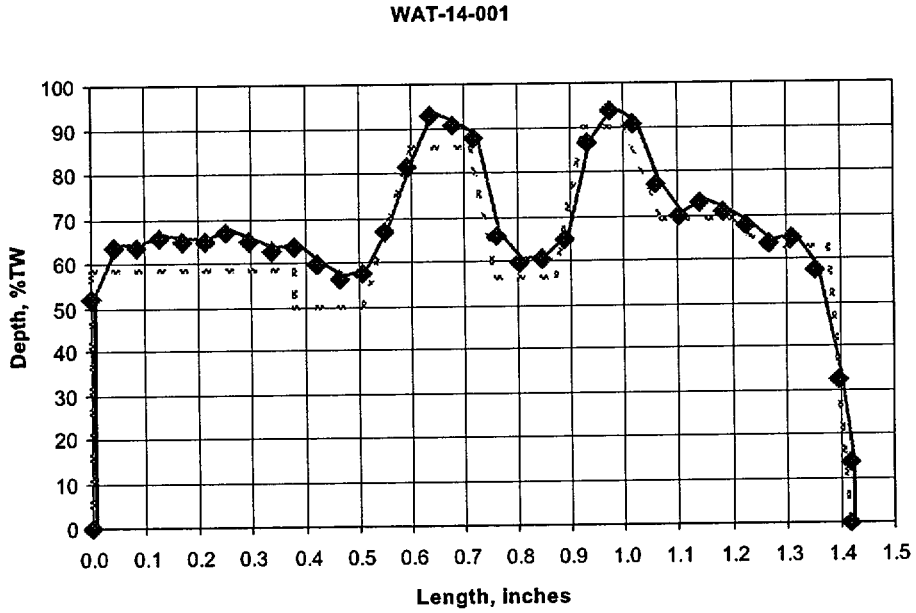


Figure A-2

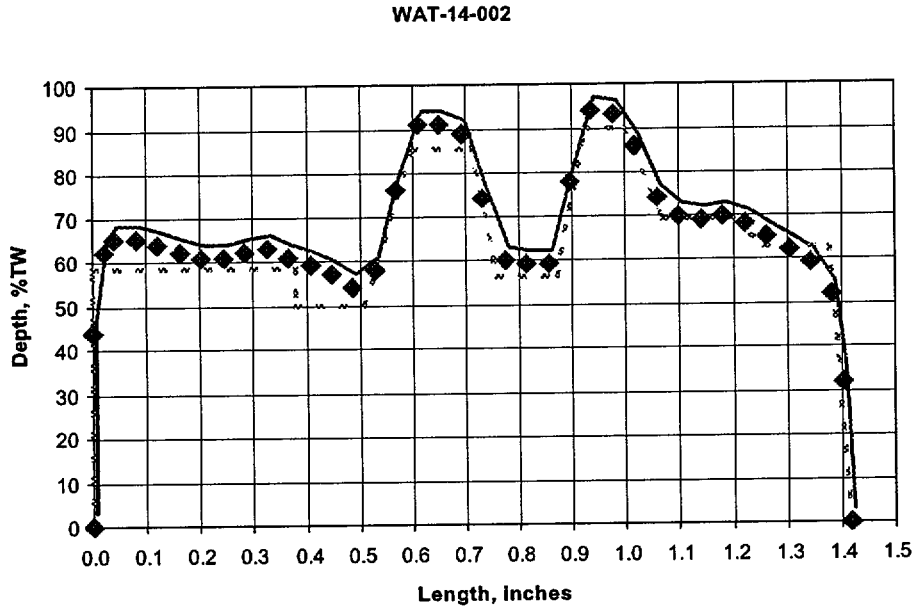
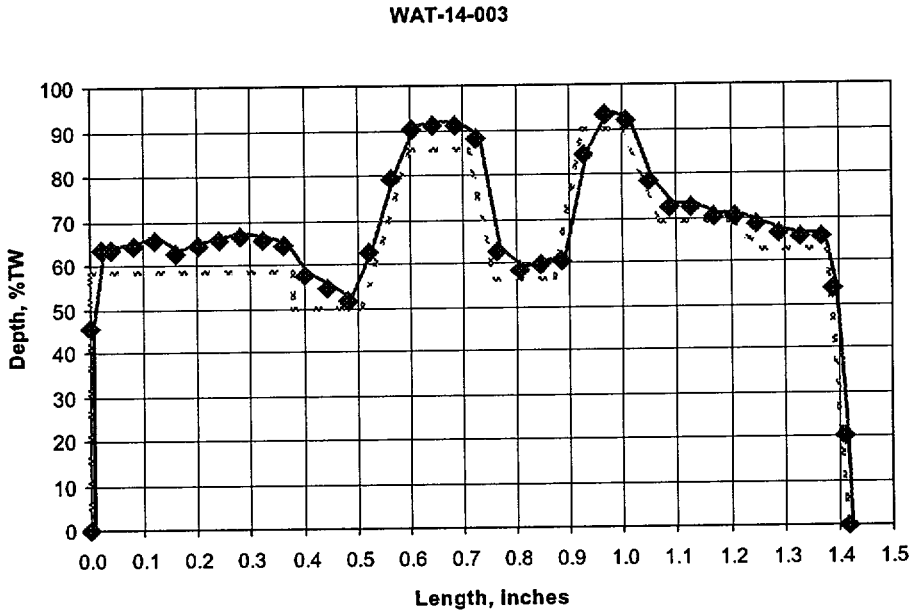


Figure A-3



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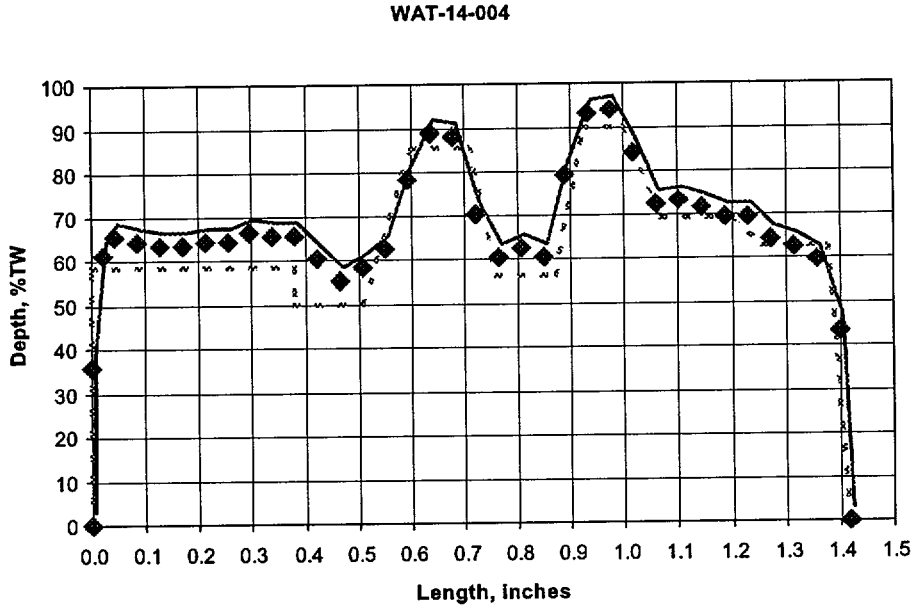
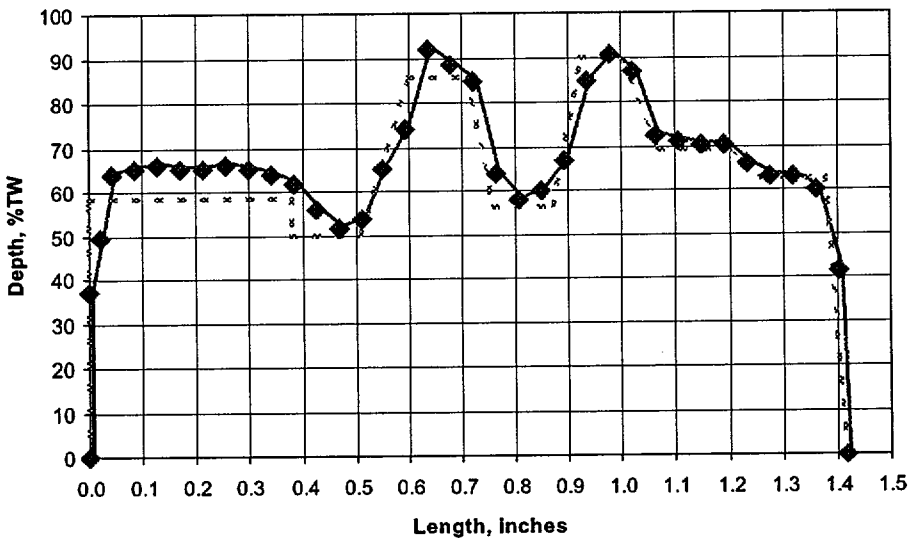


Figure A-5



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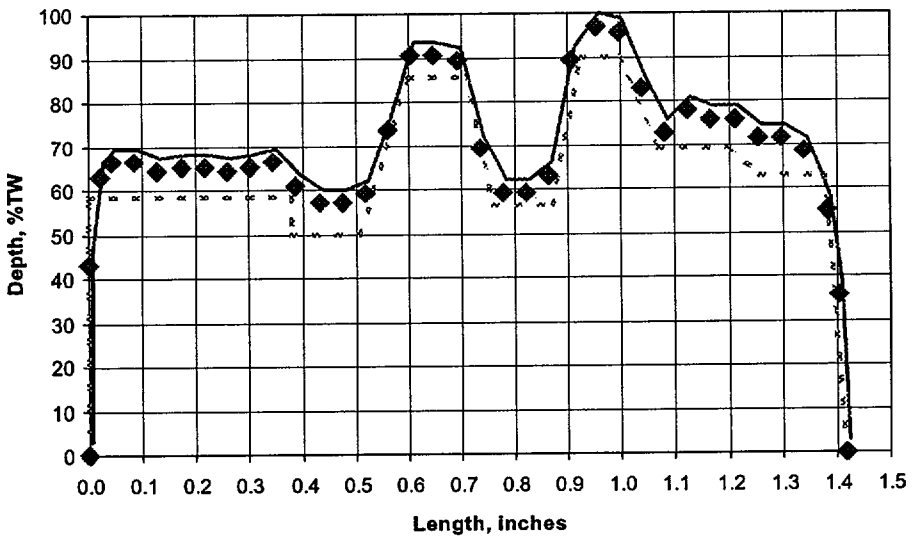


Appendix B

Selected Crack Depth Profiles
Bobbin Voltage ARC Database

Figure B-1

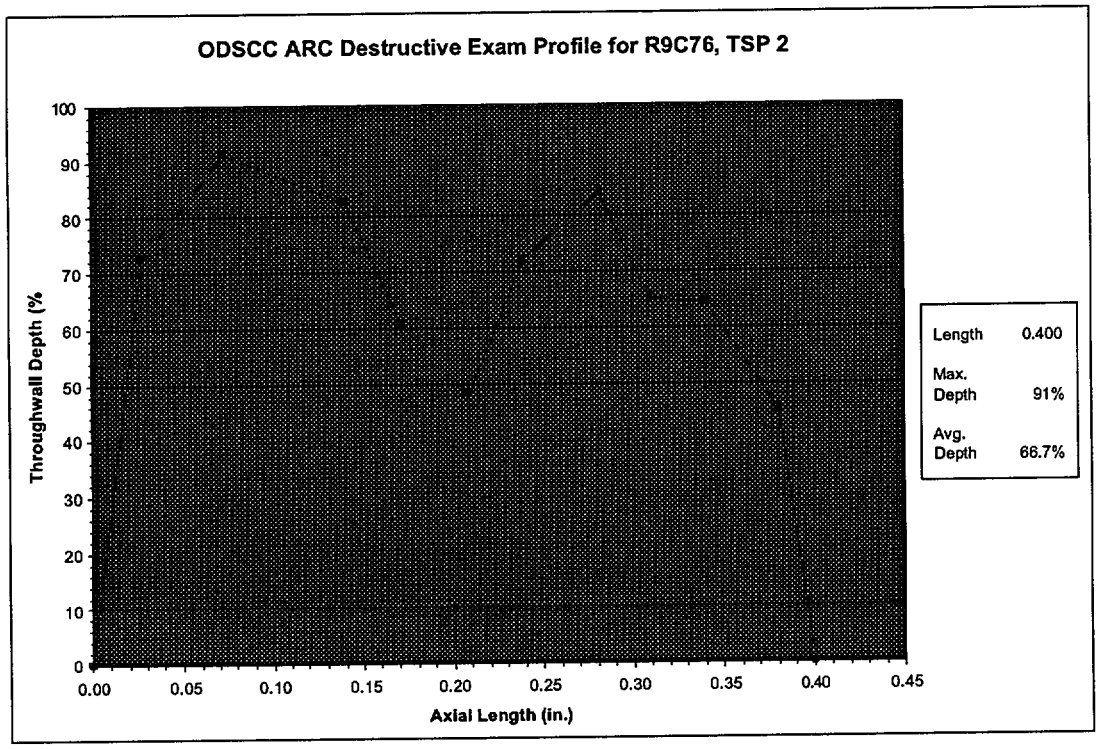
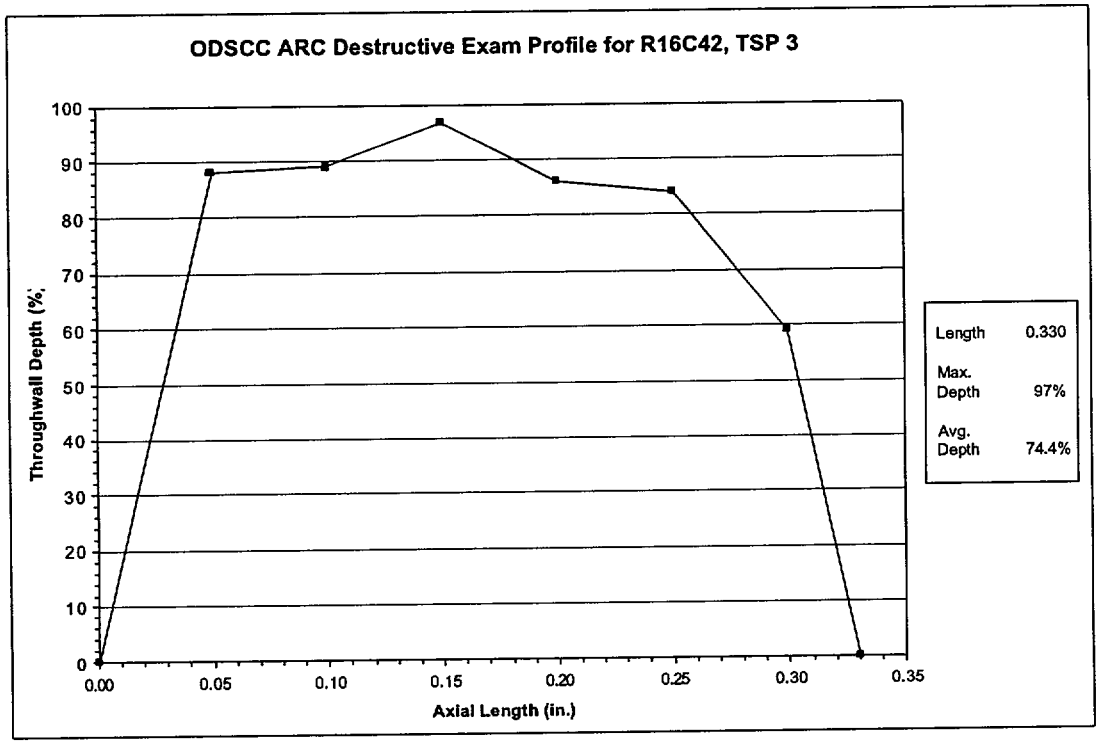


Figure B-2



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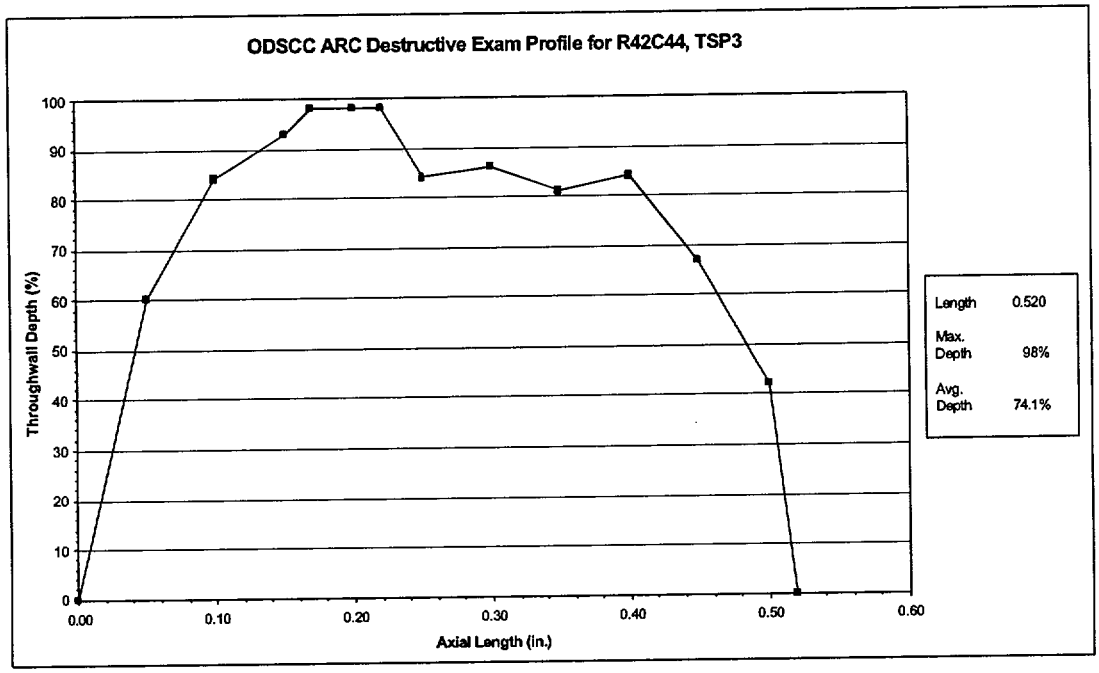

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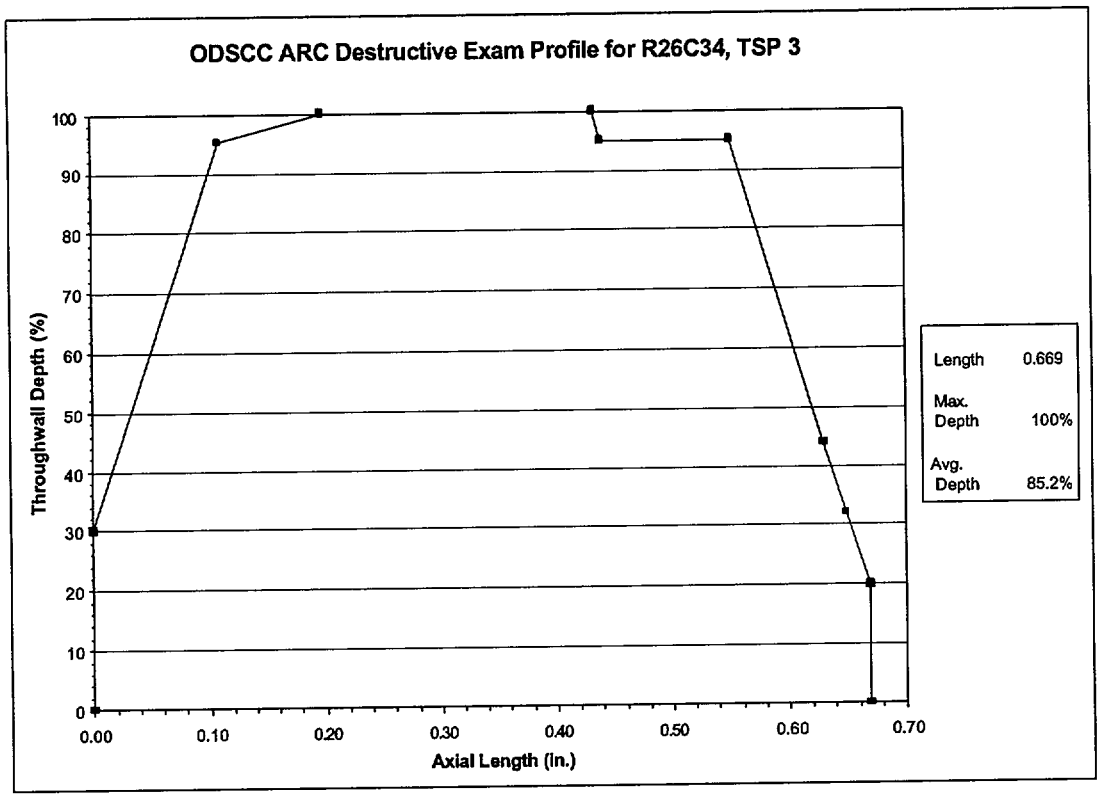

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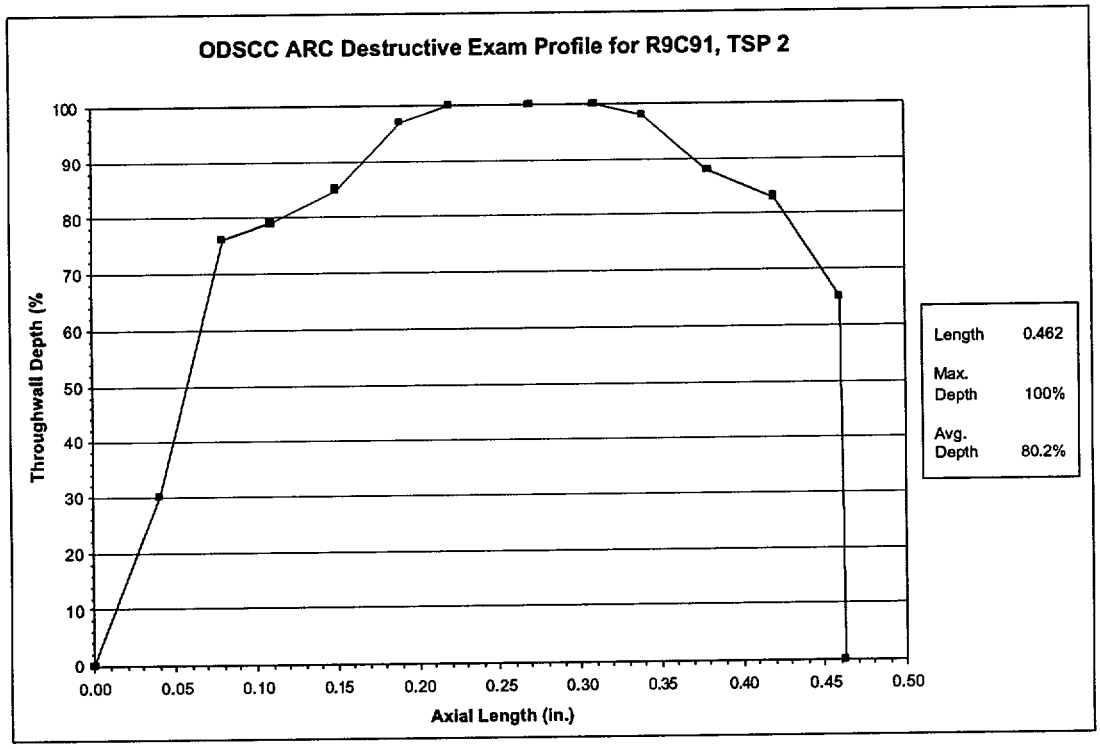

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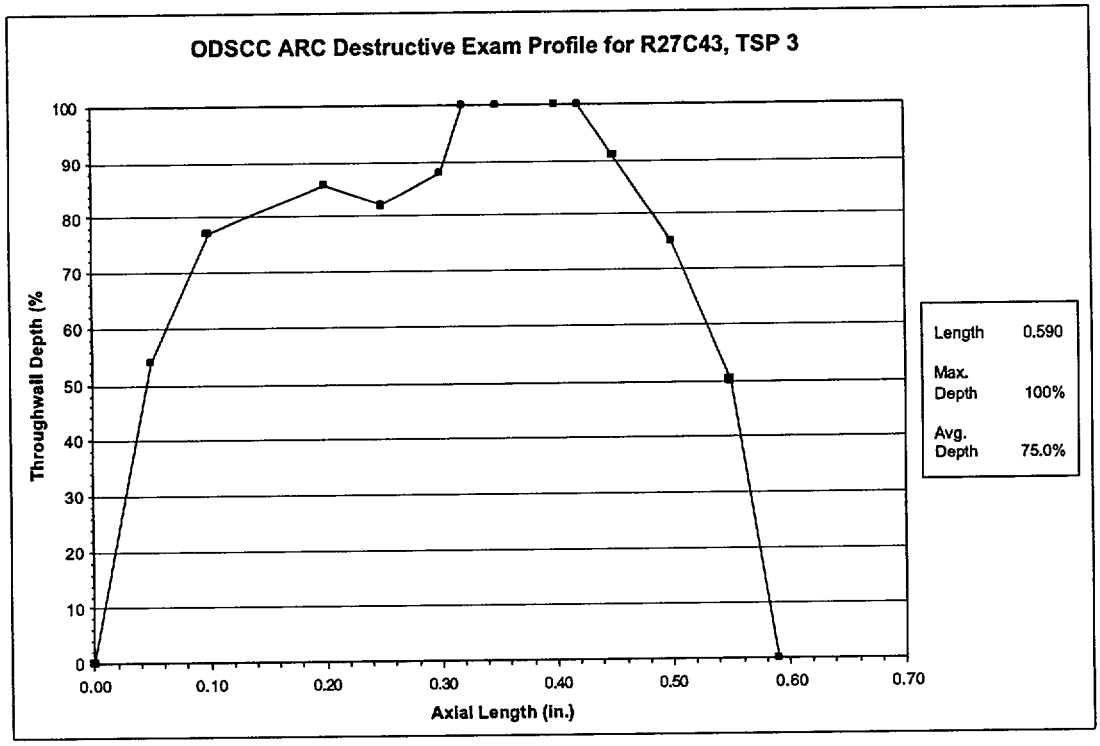

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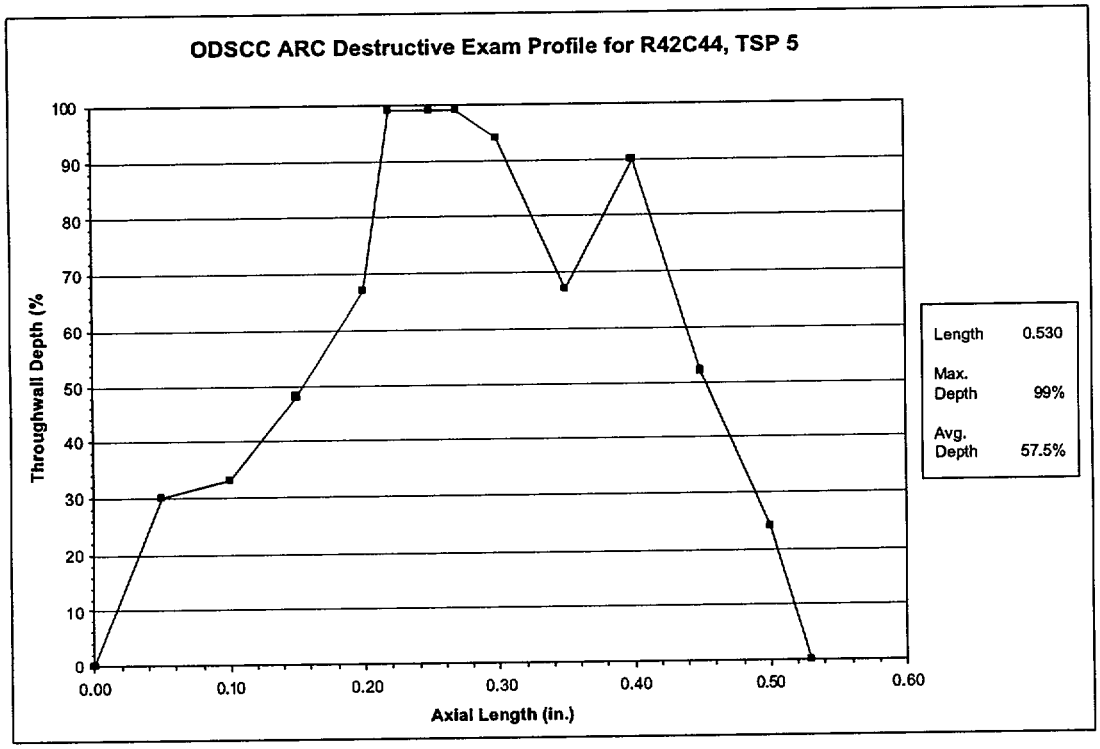

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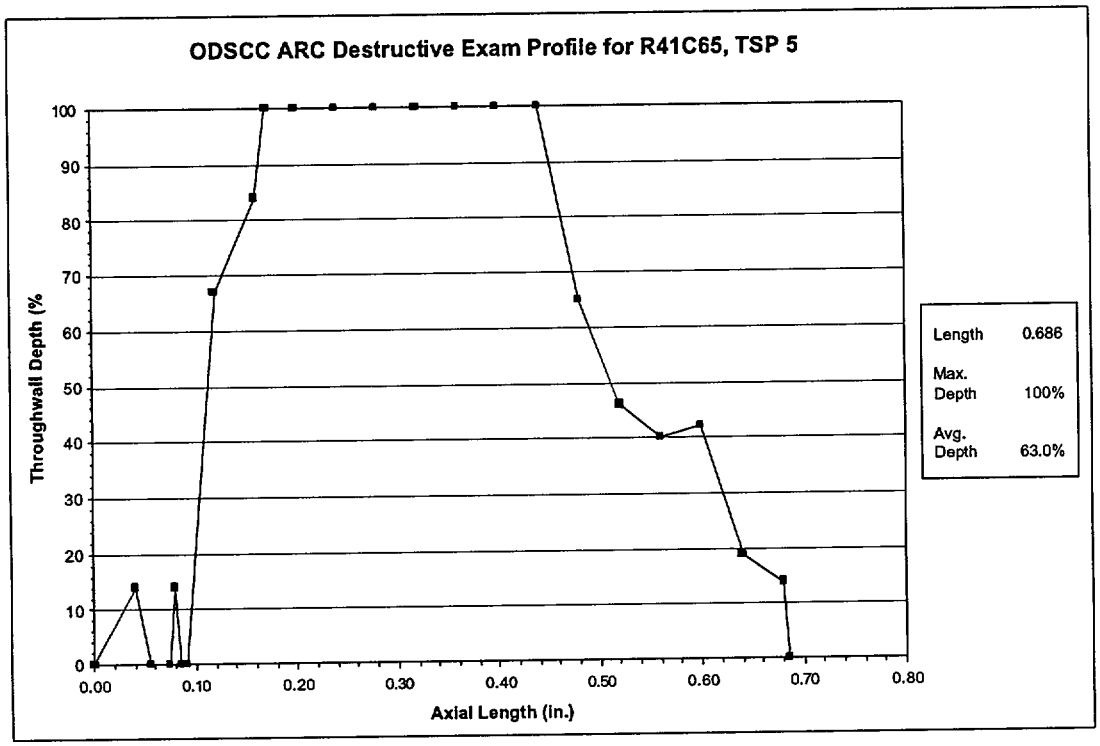

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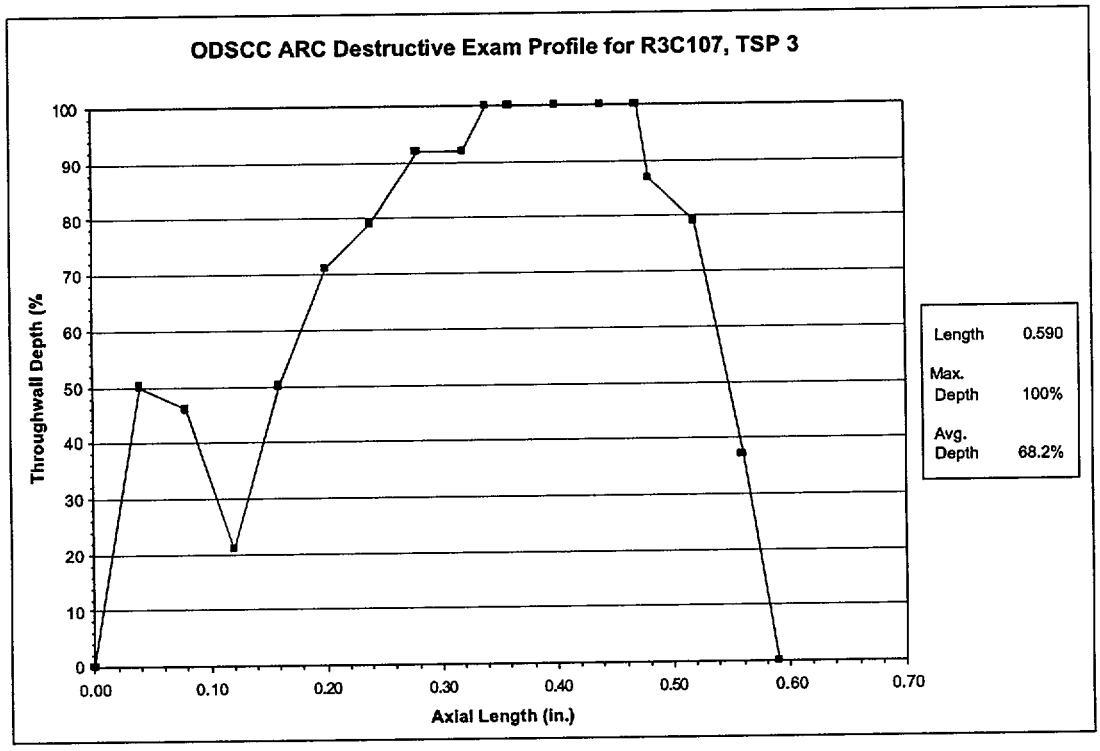

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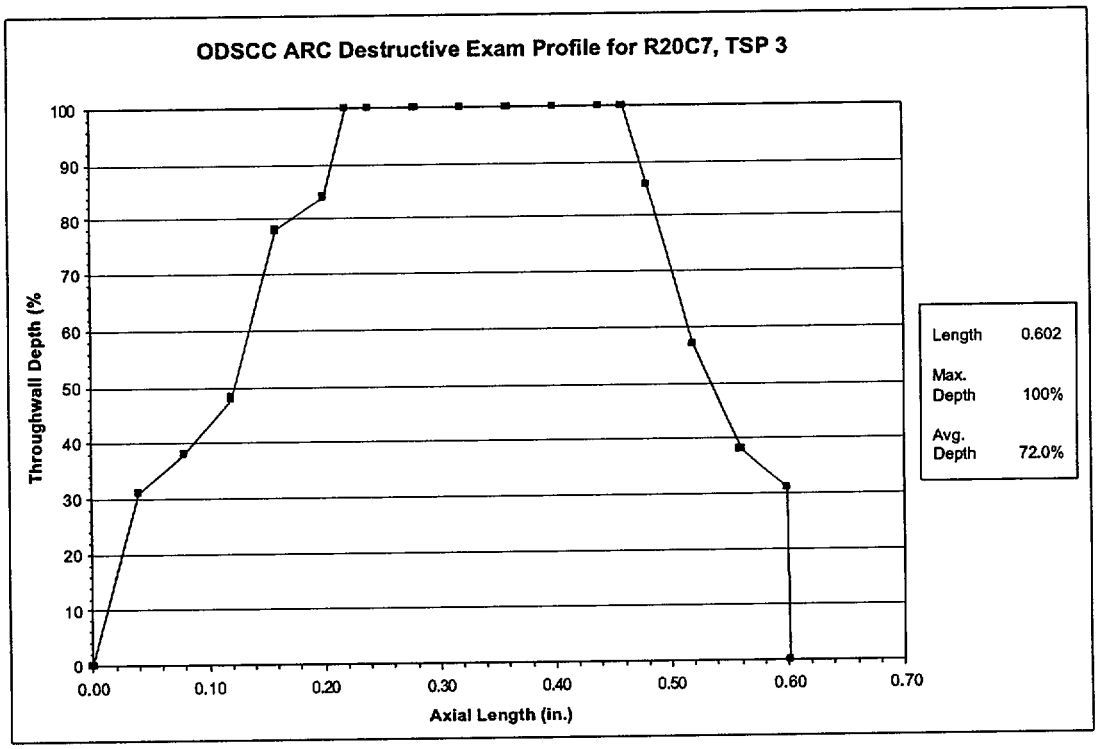

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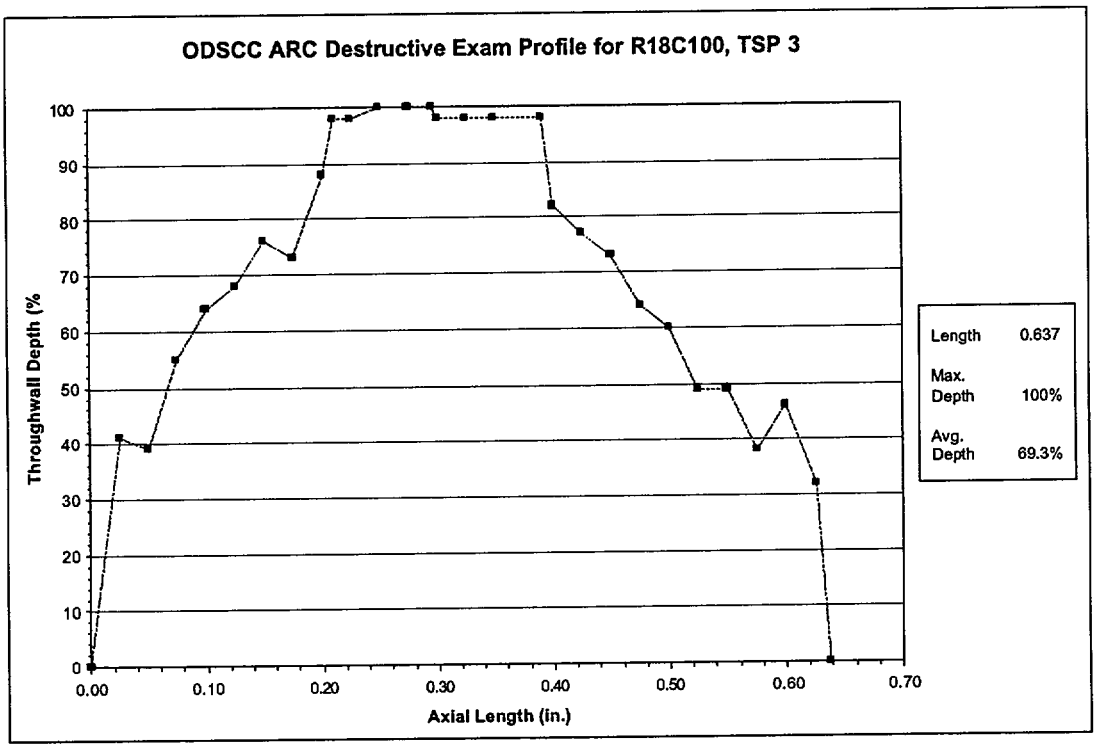

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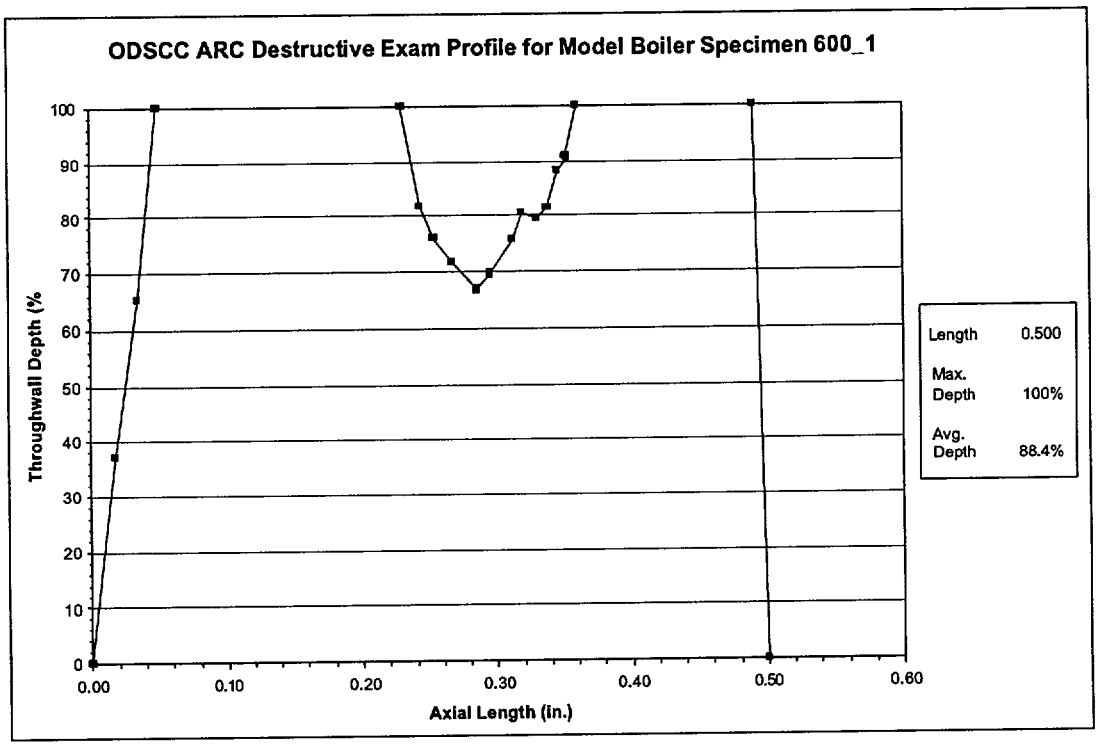

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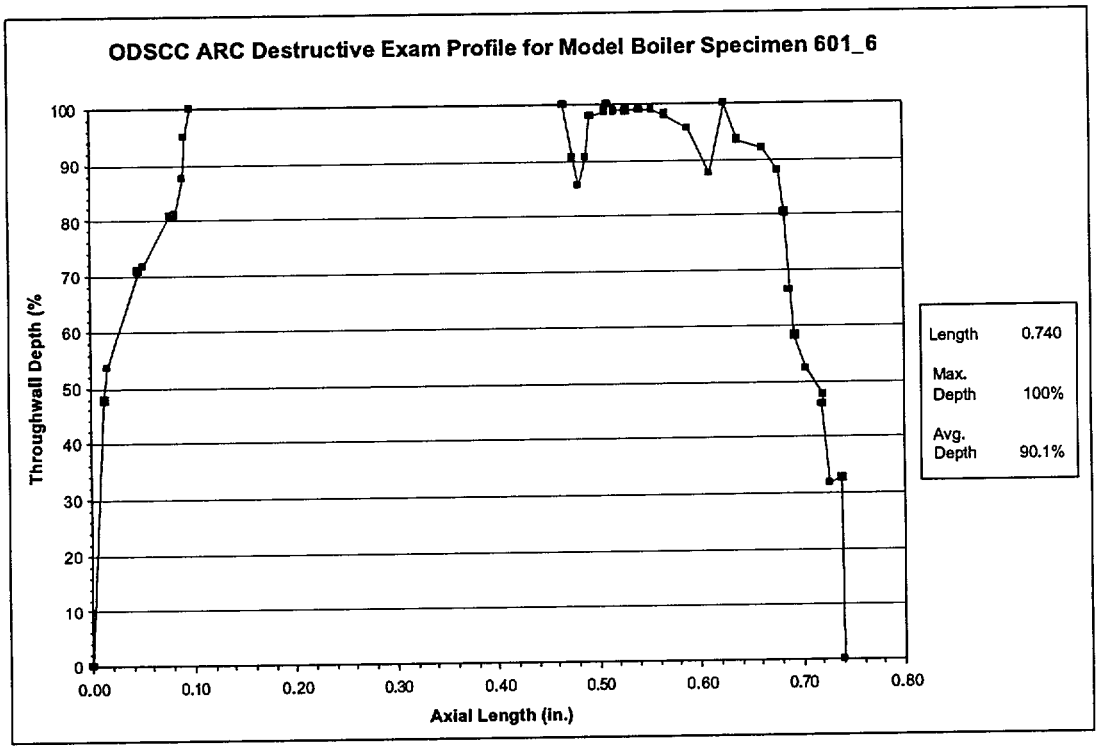

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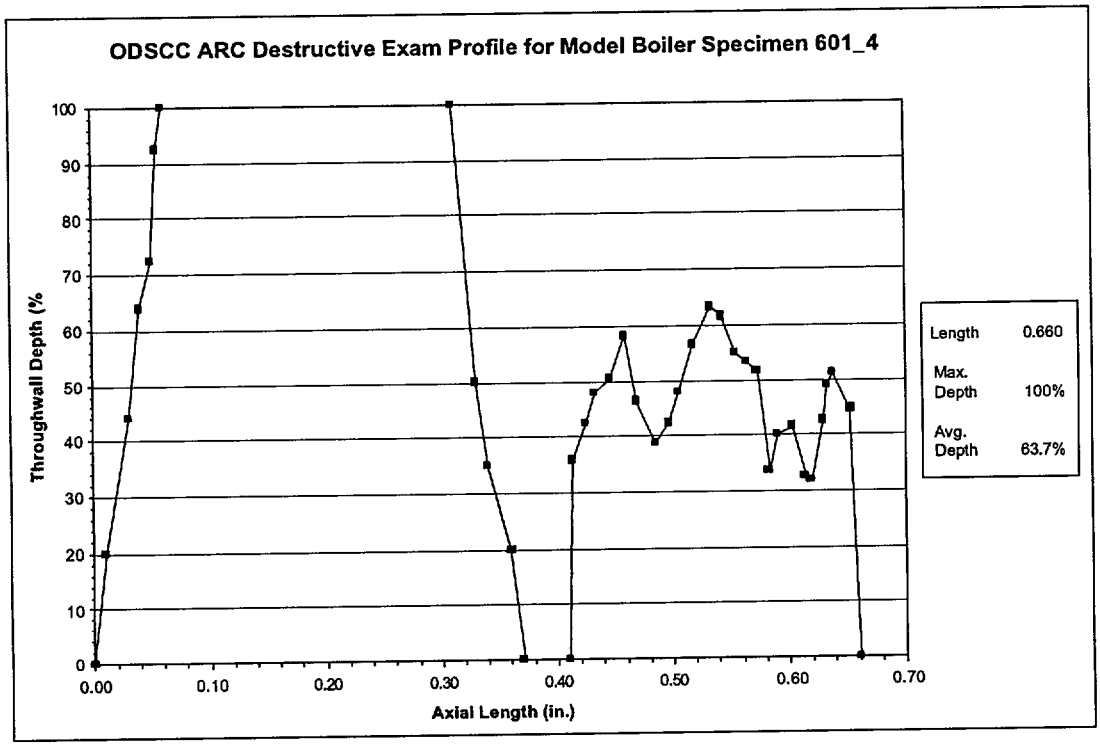

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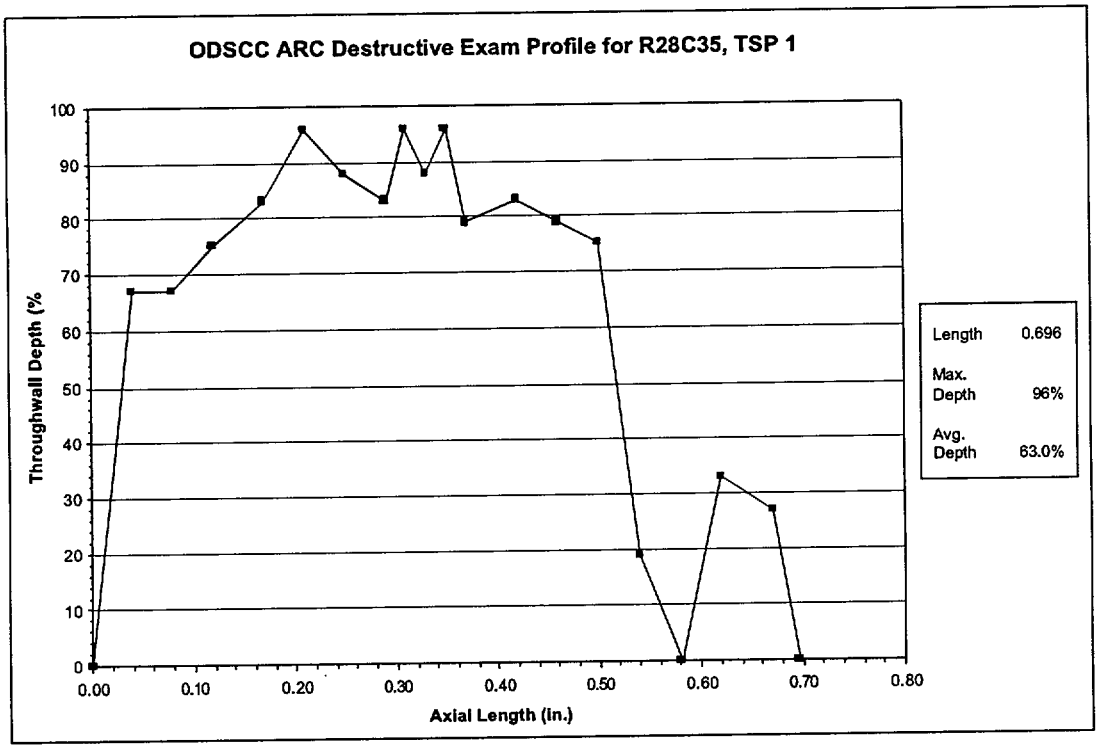

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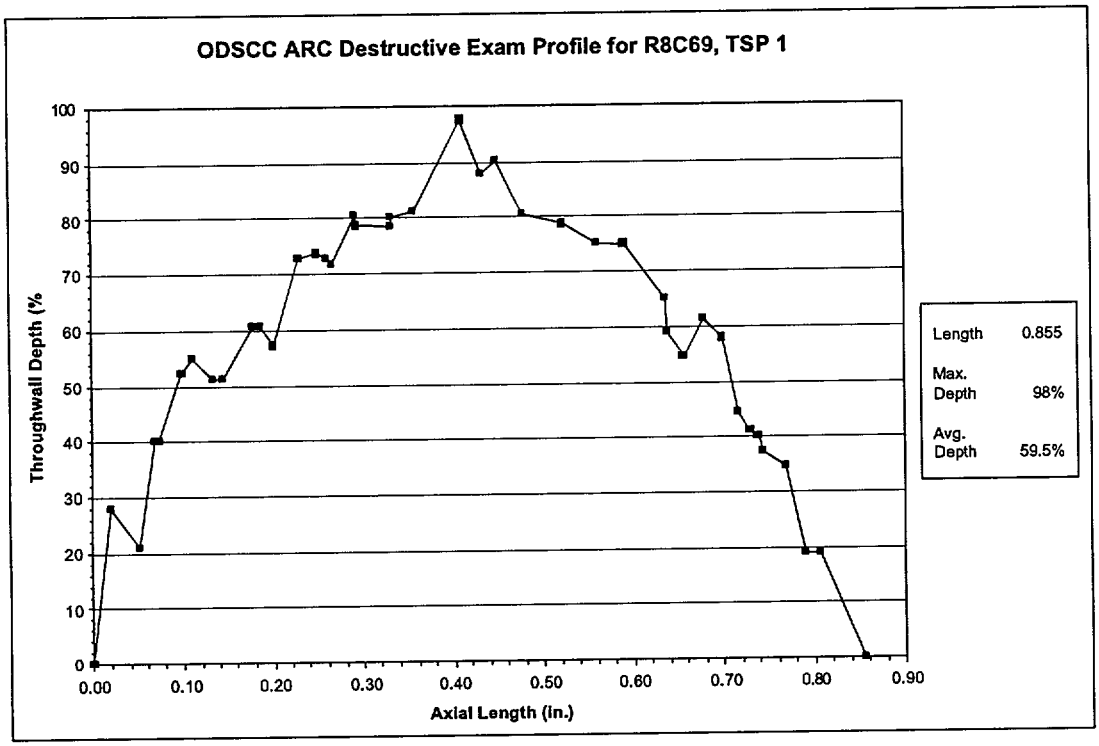

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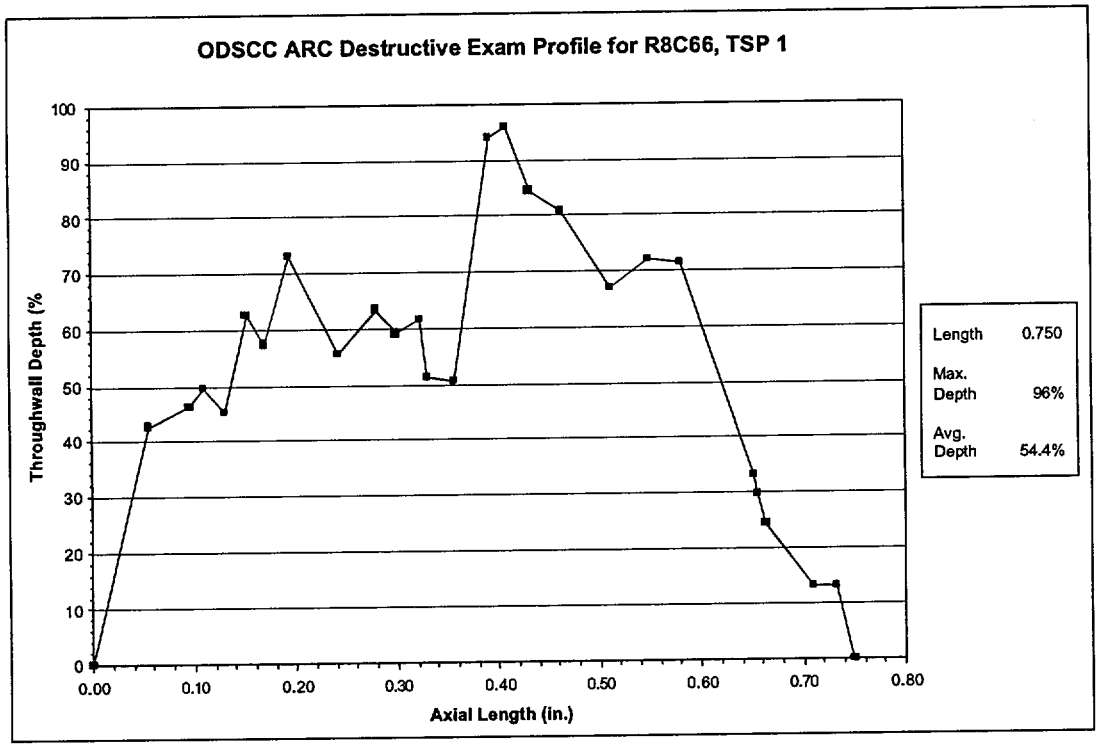

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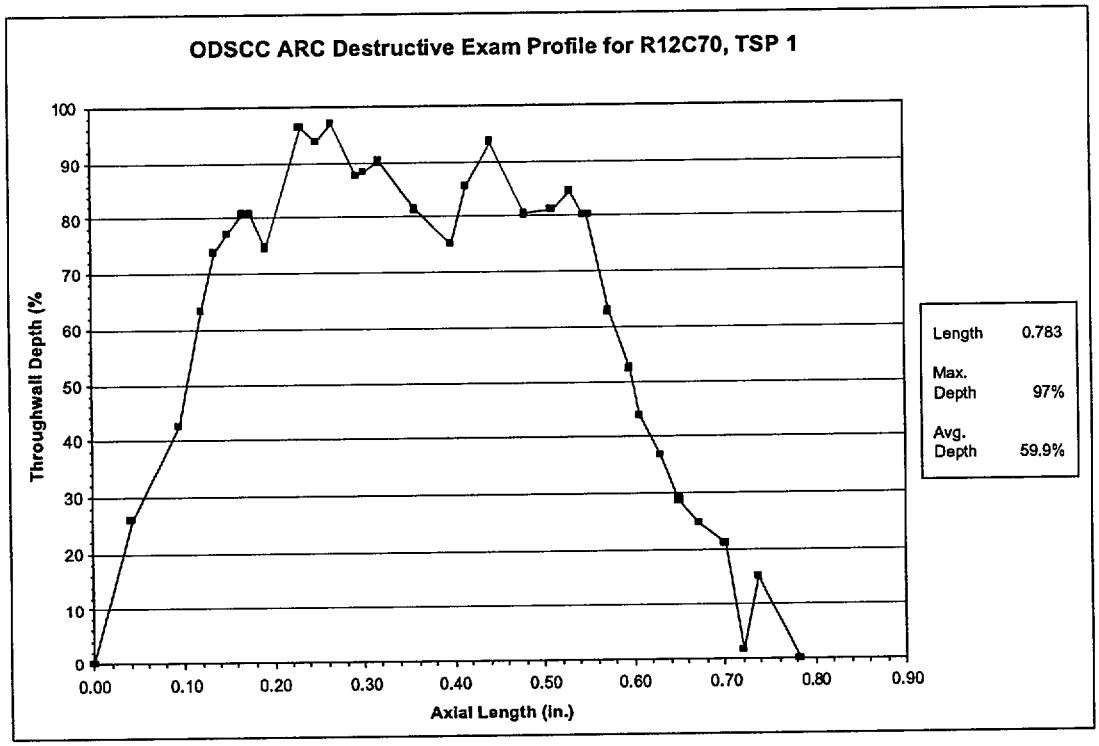

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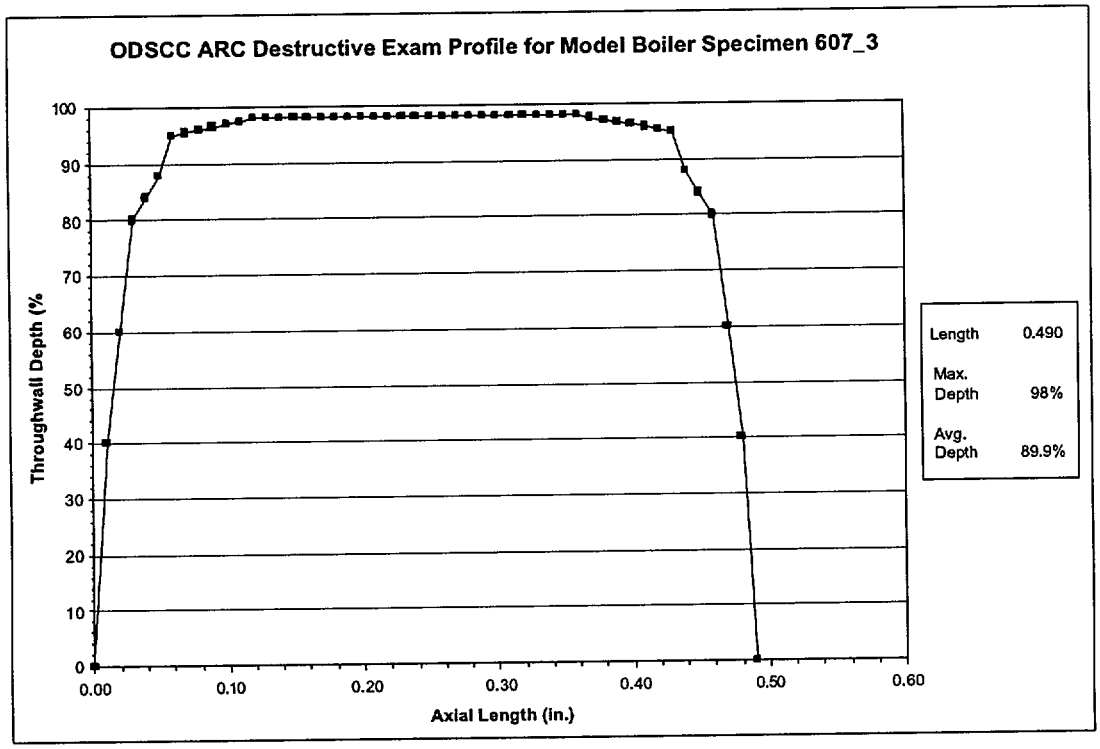
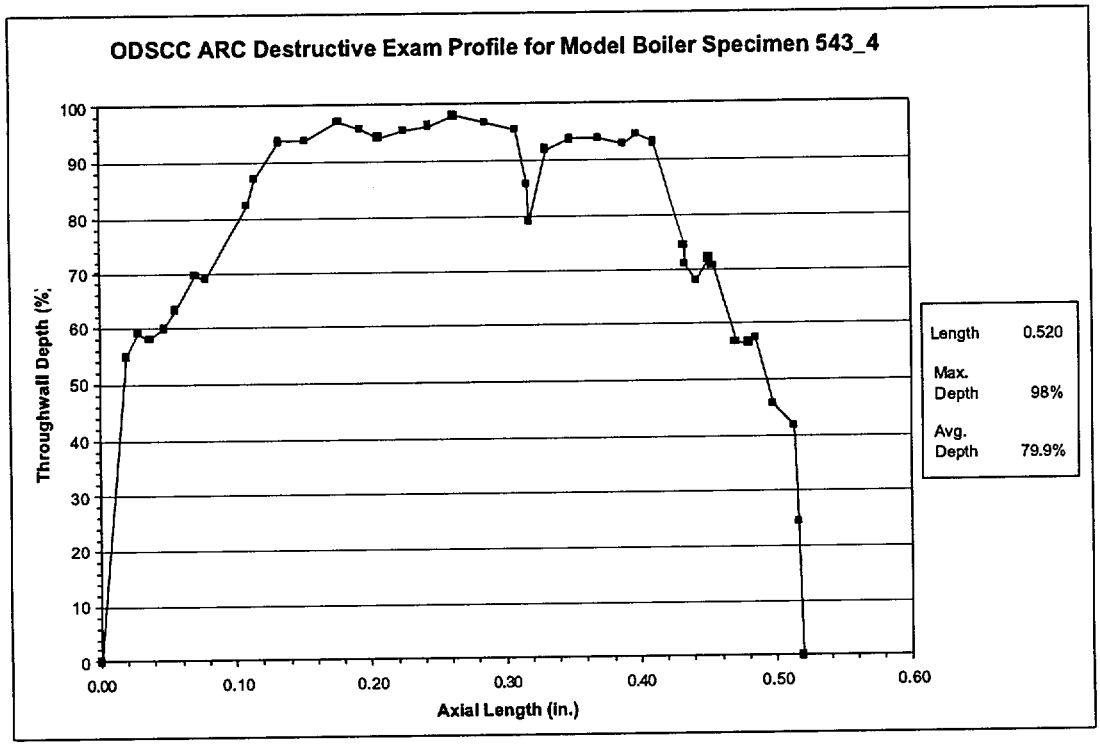
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