PROBABLE LEAK AREAS
in
CONTAINMENT EPAs
for the
SARP STUDY

by

[illegible]
Sandia National Laboratories

October [illegible]

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P R E L I M I N A R Y

PURPOSE - The purpose of this study is to determine probable leak areas in containment electrical penetration assemblies (EPAs). This review will provide information which can be used in determining the impact of EPAs as a potential leak source in containment buildings. This study will attempt to focus on two problem areas; the potential for leakage under severe accident conditions and the potential for leakage with conditions of aging. The potential for leakage under operating conditions will be included in the Brookhaven National Laboratory (BNL) study.

BACKGROUND - Studies are currently underway to understand the functional failures of containments. [illegible] Containment Integrity [illegible] [illegible]

The [illegible] thorough investigation into the [illegible] integrity of [illegible] [illegible] analysis conducted on Mark I BWR [2] indicated [illegible] high temperatures in the drywell area, which is the location of the majority of electrical penetration assemblies. Because of the high temperatures, it was postulated in Reference 2 that the [illegible] structural failure would occur. Since other containments have similar electrical penetration assemblies, it was concluded that all containments would experience the same type of failure. The follow-in study [3] concluded that many electrical penetration assemblies have a low potential for leakage, because at least one set of EPA seals is exposed to a much lower temperature. These seals are outboard of the containment, which provides thermal lag during an accident progression. However, other types of penetrations with just inboard seals could have a high potential for leakage if they are sealed with organic materials.

PROBABLE LEAK AREAS UNDER OPERATING CONDITIONS - The main source of information concerning probable leak areas in EPAs can be derived from the LERs and Type B ILRTs. The LERs are an important documented source of information, but yet does not represent the entire history of experiences. The data listed in Nuclear Safety Information Center through February 1983 indicated 265 leak type of failures for all penetrations [4]. Out of 265, 18 are related to EPAs. Fifteen out of the 18 are leaks through only one of the double seals. The remaining three are probable through leaks. The word probable is applied to these three

cases. Because the complete details are not included in the NSIC listing. An estimate of several possible pre-existing leak areas can be derived. The three cases with probable through leaks occurred at Hatch 1 (1975), Fitzpatrick (1979), and Yankee Rowe (1981). The Hatch 1 incident was an initial leak rate of 50 cc/min through two coaxial cables. This problem was fixed by an application of epoxy sealant at both ends. The Fitzpatrick incident occurred during an outage, when new cables were pulled through a penetration [illegible] not sealed. [illegible] would have [illegible] the containment from [illegible]. The incident at Yankee Rowe involved five EPA flanges that were found loose. When the flanges were retightened the leaks were reduced to an [illegible]

[illegible], a brief introduction into the [illegible] and parameters [illegible]

[illegible]

[illegible]

[illegible] are defined as the pressure in Pascals, volume in cubic meters, and time in seconds.

which is the situation for the [illegible] under discussion. [illegible] flow is [illegible] types of flow, laminar and turbulent. [illegible] flow occurs at a condition where the upstream pressure is more than twice the downstream pressure [8,9]. The critical flow is then dependent on only the upstream pressure and temperature. The flow rate equation for air at [illegible] ambient temperature is [illegible].

$Q = 0.311\ pA$ (in cfs)   p = upstream pressure (psia)
A = leak area (in2)

or $Q = 8800\ pA$ (in scc/sec)

Applying this equation to the Hatch 1 leak of 50 cc/min (0.833 scc/sec), the calculated equivalent hole diameter is 0.0015 inches (2X10-6 in2). This is small compared to a hole that is needed for a leak rate of 0.1% of the containment volume per day, i.e., a 1 mm diamter hole (0.040 inches). The probable leak area in the Yankee Rowe incident is derived solely on the basis of flange dimensions. Assuming that the five flanges that leaked used a flange for a 12 inch diameter nozzle, then the O-ring groove is 17 inches in diameter and the total seal length is:

$L = \pi \times d \times 5 = 3.1416 \times 17 \times 5 = 267$ inches

If the gap between the loose flanges is assumed to be 1/2 mil (0.0005 inches), then the assumed probable leak area will equal 0.0267 in2.

The maximum allowable operating leak rate may vary from plant to plant. The maximum operating leak rate will depend on various parameters, which includes containment volume, number of EPAs, and permissible leaks in other types of penetrations. The [illegible] design and fabricate EPAs according to IEEE Standard [illegible]. The most recent issue of the standard [illegible] that the assembly can not have a leak rate greater than 10-2 cc/sec of dry nitrogen to qualify for shipment. The design leak rate after a [illegible] accident [illegible] can not exceed 10-2 cc/sec of dry [illegible]

[illegible] maximum EPA leak rates:

[illegible]

Plant Name	Manufacturer & Number of EPAs	Design Volume	Containment ILRT*	Expected EPA Leak Rates**
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Peach Bottom 2&3	Crouse-Hinds	0.3	99.3	(?)
Grand Gulf 1	Westinghouse(47)	0.3	99.3	0.47
Sequoyah 1 & 2	Westinghouse(47)	1.2	333	0.47

* ILRT - Integrated leak rate for containments. Assumed to be 0.1% of containment volume per day.

** This column is the number of EPAs(n) times the maximum allowable leak rate per day per assembly, which is 10-2 cc/sec of dry nitrogen at DBA pressures and temperatures.

PROBABLE LEAK AREAS UNDER SEVERE ACCIDENT CONDITIONS - The potential for leak paths through EPAs under severe accident conditions has been studied in Reference 2. Severe accidents as used in that study refers to temperatures, pressures, and time durations that exceed the design basis accident (DBA) conditions. The severe accident scenarios studied for EPA leakage are those in which both the fan coolers and sprays are not functioning. This type of severe accident leads to a continuous increase in pressure, which will eventually lead to a loss of structural integrity of the containment building. The ultimate capability of the containment building provides an upper bound to the [illegible] loading that EPAs can be subjected to.

[illegible] materials used in fabricating EPAs can degrade with [illegible] these materials most sensitive to temperatures [illegible] radiation aging, and other environments.

The probable leak paths in EPAs under severe accident conditions have only a very limited amount of experimental verification and is discussed in Reference 2. The only analytical efforts applied [illegible] the EPAs under severe accident conditions. The thermal analysis is important because it is used to calculate the response at the outboard end of an EPA to the inboard temperature and pressure profiles. If the assembly has sufficient length and mass the outboard temperature will lag considerably behind the inboard temperature. If at least one set of the EPA seals and/or sealants are at or below the design temperature, then the potential for leakage is expected to be low.

The temperatures and pressures have been calculated for a number of different severe accident progressions [2 & 3]. One very important trend was noted for short duration high temperature spikes and this was steam explosions and hydrogen burns do not impact EPAs. Another very important trend that was noted for PWRs, is that the long time temperature approaches a maximum of 350 F. This is significant, because it suggests an upper limit to the temperature exposure. The Mark III BWRs appear also to have this same temperature limit. However, for the Mark I (like Browns Ferry) and also Mark II BWRs the inboard temperature can exceed 800 F.

In order to illustrate the contribution of EPAs to the potential for leakage, several containment buildings will be discussed. Although it would be desirable to generate overall results on a generic basis, this is not possible because of differences in EPA designs that have been used in different containment buildings. For example:

ZION - The EPAs installed in Zion 1 & 2 are all of the early D. G. O'Brien design. These are canister type of EPAs and are welded to the containment nozzles. The containment nozzles are 12 inch diameter schedule 40 steel pipe, which are welded to the liner plate. The EPA canisters are fabricated with 10 inch schedule [illegible] steel pipe with lengths of [illegible] inches. The [illegible] at the outboard end. The canisters have internal ports so that pressure monitoring is conducted within the nozzle.

[illegible] containing 46 EPAs are for low voltage power, control, and instrumentation [illegible]. The [illegible] conductors use a ceramic insulation assembly which is brazed to the copper conductor [illegible]. The brazed connection is the primary seal for the [illegible] assemblies and are expected to have a long term temperature capability.

The LVP, LVC, and LVI assemblies all have similar type of [illegible]. [illegible] each conductor is provided with a glass-to-metal seal. These assemblies are in turn welded to a [illegible] inch thick header plate. All the conductors are additionally supported by potting material on each side of the header plate. One side of the plate has [illegible] inches of GE RTV 511 and ? 1/4 inches of Emerson and Cummings [illegible] potting compound. This potting provides secondary sealing. Since the primary seal is glass the aging effects will be minimal. Glass also has a temperature capability above the 330 F expected in a severe accident and therefore no through leakage is expected.

Since the primary seals for all the Zion EPAs are non-organic, they are expected to be affected very little by aging and will have a high temperature capability.

SURRY 1 & 2 - The Surry EPAs are designed to be mounted in a 8 inch diameter schedule 40 nozzle. The nozzles are 59.75 inches long and welded to a 1 inch thick insert plate. There are 91 nozzles in the containment building, 90 located in one region between elevation 15 and 25 and one nozzle located at elevation 55. (All the nozzles do not contain EPAs). Three different manufacturers have supplied EPAs to Surry; Amphenol (1971-72), D. G. O'Brien (1972-73), and Conax (1981-82). Amphenol has been the

major supplier with 64 EPAs, 32 to each containment. The Amphenol design consists of a double ended canister with connector sockets brazed into the header plates. The design has a hermetic seal in the header plate and at both ends of the assembly (i.e., a double ended seal). These assemblies are bolted to the flanges welded in each nozzle. Two O-rings of silicone rubber are used for sealing the flanges. The remainder of the assemblies are welded construction.

D. G. O'Brien supplied [illegible] EPAs, [illegible]. This design uses glass-to-metal seals in the modules and should have a good long term and high temperature capability. The assemblies are bolted to the nozzle flanges and use double O-rings as a [illegible] above the long term maximum temperature of [illegible] F expected in a [illegible] accident.

[illegible] voltage service to the reactor coolant pumps. These EPAs have an [illegible] configuration. They are bolted to [illegible] flanges and change from an [illegible] inch diameter to 12 inch diameter with [illegible] inch extension. [illegible] modules mounted in the 12 inch blind flange. These modules utilize a ceramic bushing insulation that is brazed to a coupling assembly. The coupling assembly uses O-rings to provide a seal to the header. These O-rings are an organic material (believed to be Viton). The seals are all outboard of the containment (i.e., single seal). In the event of any [illegible] accident condition in the containment, the [illegible] of the EPA, provides some mechanism for thermal lag and cooling.

PEACH BOTTOM 2 & 3 - No information regarding EPAs was supplied by the utility and therefore no estimates of capability are possible at this time. The only information located to date has been a reference in the FIRL data bank. The data bank information states that the vendor was Crouse-Hinds and their operation was taken over by Westinghouse in the early 70s.

GRAND GULF 1 is a Mark III BWR type of containment that has a reinforced concrete containment building with a 3/8 inch steel liner plate. The concrete wall is 42 inches thick and all the EPA nozzles are 48 inches long. The nozzles are welded to the steel liner plate, which has been thickened locally to 1/2 inches for the EPA nozzles. There are 47 Westinghouse EPAs in Grand Gulf 1. Three are 18 inches in diameter and 44 are 12 inches in diameter. Two of the 18 inch diameter EPAs supply medium voltage power (to the reactor coolant pumps) and contain three modules, each with a 1000 MCM conductor. The EPAs consist of a canister 51-1/4 inches long and three modules that incorporate a ceramic bushing which is brazed to an assembly that in turn is welded to

Appendix I

Containment Purge and Vent

Area for Zion 1 and 2

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

Upton, Long Island, New York 11973

Department of Nuclear Energy

7203

June 20, 1983

Mr. Goutam Bagchi
Equipment Qualification Branch
Division of Engineering
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Goutam:

As you requested, attached is Brookhaven National Laboratorys (BNLs) evaluation of the leakage area associated with containment supply and exhaust valves for Zion 1 and 2. If you have questions or if we may be of further assistance, please feel free to call.

Sincerely,

Bruce E. Miller
Engineering Analysis and
Human Factors Group

BEM/smm
Attached
cc: R. A. Bari (wo/att.)
R. E. Hall
W. J. Luckas, Jr.
J. H. Taylor
File

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CONTAINMENT PURGE AND VENT VALVE

LEAKAGE AREA FOR ZION 1 AND 2

Brookhaven National Laboratory

Upton, NY 11973

June 20, 1983

CONTAINMENT PURGE AND VENT VALVE
LEAKAGE AREA
FOR ZION 1 AND 2

Objective

Estimate the potential leakage area associated with the containment purge and vent valves installed at the Zion Nuclear Power Station, Units 1 and 2.

Discussion

The containment purge supply and exhaust air duct are each equipped with two (2) 42-inch isolation valves in series. One valve is inside containment and one valve is outside containment. These valves are manufactured by H. Pratt and are Model R1A valves.

The purchase specification for these valves stipulates a normal inside containment temperature of 65°F to 120°F and approximately a 50% relative humidity. After an incident the specification stipulates that a saturated steam air mixture will exist such that the "....valve design shall be based on 70 psia, 300°F which will decay to approximately 5 psia, 120°F in 24 hours and will remain at this condition one year thereafter."

During normal operation, the specification further states "...the neutron-proton (gamma) radiation exposure rate" is to be 10^{-1} rads/hour resulting in a total exposure of 4×10^4 rads based on a 40-year plant life. After an incident, the radiation exposure is specified to be 2×10^6 rads during the first three hours and a total exposure of 1×10^9 rads, with an average weighted value of 1.0 meV, based on a one year operating period for system decay. A dilute mixture of sodium hydroxide and boric acid is also specified (containment spray system).

The purchase specification calls for each valve to be hydrostatically tested at the vendor's plant for leakage at 300 psi with each valve seat to be hydrostatically tested to a pressure of 150 psid across the disc to prove it drop-tight.

Conversations with H. Pratt, the valve manufacturer, have revealed that the metal to metal clearance between the valve disc and body range from 1/16 to 1/8 inch. The seating surface or seal ring is Ethylene Propylene Terepolymer. Shaft bearing clearance is .015 inches when the bearing material is bronze. When calculating the area, it was assumed that the bearing is a corrosion resistant sleeve-type. The disc diameter is approximately 40.9 inches and the shaft diameter approximately 4.24 inches.

Potential leakage areas are between the shaft and bearing and the valve disc and body. The total area surrounding the shaft is .1008 square inches. Leakage past the shaft bearing is considered to be negligible, since total failure of the shaft seal, packing retainer ring, packing, lantern gland ring, and bonnet assembly must occur for there to be leakage through an area of .1008 square inches.

Disc and body clearance is 1/16 to 1/8 inch. With a 41-inch disc, total failure of the seal ring, assuming the valve closed, reveals an area around the disc of 4.0282 square inches or 8.0622 square inches, respectively.

When determining the disc area, it was assumed that the valve is closed, that there is a straight run of pipe upstream of the valve, and total failure of the valve seat ring occurs.

Results

When determining leakage rate for the purge and vent valves, the most conservative approach would be to assume total failure of the valves inside containment (valve failed open). Thus, with an area varying from 8.06 to 4.03 square inches per valve, the total leakage area for the two valves located outside containment would be:

1. Past the disc - 16.12 to 8.06 square inches
2. Past the shaft - .2 square inches
3. Total - 8.26 to 16.32 square inches.

Zions containment is designed for 62 psia; 2-1/2 times this pressure is 155 psia. The purchase specification calls for a disc hydrostatic test, to prove that it is drop-tight, at 150 psig, or approximately 165 psia. Thus, it is concluded that total disc failure at 2-1/2 times Pa, design pressure, is unlikely.

the header plate. The canisters are welded to the nozzle at the outboard end. The MVP EPAs are double ended and have a ceramic bushing at both the inboard and outboard end. The pressure is maintained and monitored in the interior of the canister.

There are forty four 12 inch diameter EPAs and all contain three standard Westinghouse modules. These modules are 5 inches in diameter and 12 inches long. The conductors pass through two glass-epoxy plates that are mounted in the midplane of the modules. These two plates have a small separation, [illegible] in the interior of the module can be pressure monitored. The remainder of the modules are filled with an epoxy sealant. The epoxy sealant also serves as potting material for [illegible] so that all three modules can be monitored simultaneously.

There is one additional EPA that is 18 inches in diameter and contains five modules as described above, instead of three. The design and fabrication is identical to the three module EPA and any conclusions regarding those EPAs would apply to this EPA.

[illegible] suppression pool will appreciably reduce the temperatures exposed to the EPAs, even though the drywell may experience high temperatures.

[illegible] that any temperature response of the outboard seals will lag the inboard environment.

The design and fabrication of the Westinghouse EPAs should have a substantial margin to survive the maximum severe accident temperature and pressure (~ 350 F and 55 psig). The ultimate pressure capability of the containment building has been estimated to be 55 psig, and therefore, provides a limiting pressure on the EPAs.

The limiting parts of the EPAs are most likely to be the O-rings, because they are fabricated from organic materials. These materials will creep with age (and temperature) and increase the probability of leakage with age. (Some of these same EPAs are stored in a warehouse, where pressure monitoring is maintained and some of the EPAs have experienced pressure reductions during

this period of storage. However, the cause of these leaks has not been identified or no estimate of the leak rate is available. The volume being monitored is small, approximately 228 cc, so that even at the permissible leak rate the pressure would drop in a few weeks, unless the pressure is maintained.)

SEQUOYAH 1 and 2 - The Sequoyah plants are a PWR containment with an ice condenser type of suppression system. This type of design typically has a large steel shell for the containment. The steel shell is approximately [illegible] building that functions primarily as a biological shield. The nozzles in the containment shell are typically short, in this case only 2 feet long. The primary vendor for the Sequoyah EPAs [illegible]

[illegible] The EPA temperature test specification was fifteen minutes at [illegible] F and 12 psig, then [illegible] F and [illegible] psig for ten days. The fifteen minutes at [illegible] F, because of thermal lag, [illegible]

The Sequoyah plants also have one EPA that is a Westinghouse modular design, but details are not available. In addition, the personnel locks contain a Conax module type of penetration seal.

In a severe accident, the containment atmosphere will tend to be in a saturated steam state. This means that the temperature and pressure are not independent and can be established by knowing either value. Since the Sequoyah containment shell has one of the lowest estimated ultimate pressure capacities (60 psig) the corresponding temperature will be limited too. At 75 psia saturated steam, the temperature is approximately 308 F. This is above the qualifying temperature and the EPAs with the epoxy primary sealants will have a limited useful lifetime and may result in a higher potential for leakage.

A brief discription of several containment buildings and their EPAs was presented above as background information. The next problem is to develop "probable leak areas" for EPAs under severe accident conditions. At this time only an estimate based on

engineering judgement can be provided, since the most realistic approach to this question is to measure leak rate in an appropriate experimental program.

The "probable leak areas" for EPAs which is based on a pressure criteria is not appropriate. The behavior we expect from the EPA sealants, gaskets, and O-rings is to be sensitive to temperature and time. In general, the EPA seals are separated far enough from the deformations in the containment wall, so that under a [illegible] accident, minimal changes are [illegible] to the EPA seals and hence do not change with pressure. In addition, O-rings are used extensively in header plates and a good O-ring design should [illegible]

[illegible]

[illegible] materials. The EPAs with glass-to-metal seals are assumed to have the lower values, while the organic seals will have the larger areas. To arrive at the total leak area, these values would be multiplied by the number of EPAs in each containment. [illegible]

TABLE II - [illegible]

Plant	Sealant/ Gasket & No. of EPAs	Limiting Temp. of Seal (°F)	Estimated Area Per EPA * Before (in2)	After (in2)
Zion 1 & 2	Glass/Welded (56 & 55)	300	10-7	10-7
Surry 1 & 2	Glass/Sil(22)	7	10-5	10-3
	Glass/Sil(11)	300/400	10-5	10-3
	Polysul/Vit(9)	340	10-5	10-3
Peachbottom	Epoxy(7)	250	10-5	10-3
Grand Gulf 1	Epoxy/Sil(47)	350	10-5	10-3
Sequoyah 1 & 2	Epoxy/Welded (47)	250	10-5	10-3

* Based on engineering judgement.

The estimates of "probable leak areas" in Table II can be used to estimate the total values under severe accidents. These results are tabulated in Table III and it assumes that all EPAs contribute equally to the flow.

TABLE III - PROBABLE LEAK AREAS FOR THE REFERENCE CONTAINMENTS

Plant	[illegible] (psig)	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Surry 1 & 2	[illegible]	.00015	.082	.164
Peach Bottom 2 & 3	[illegible]	-	-	-
Grand Gulf 1	15	.00015	.047	[illegible]
Sequoyah 1 & 2	12	.00015	.047	.094

(1) Low - Area based on assumed leak before an accident is initiated.
(2) Mid - Area based on assumed leak after an accident is initiated.
(3) High - Assumes that this area is twice the mid value.

The holes listed in Table III are quite small and their reponse to flow with particulates are expected to substantially different [8].

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