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INDIANA MICHIGAN POWER

June 28, 2002

AEP:NRC:2606
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Docket Nos: 50-315
50-316

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Mail Stop O-P1-17
Washington, DC 20555-0001

Donald C. Cook Nuclear Plant Units 1 and 2
GENERIC LETTER 96-06
ASSURANCE OF EQUIPMENT OPERABILITY AND CONTAINMENT INTEGRITY DURING DESIGN-BASIS ACCIDENT CONDITIONS
REQUEST FOR ADDITIONAL INFORMATION
(TAC NOS. M96801 and M96802)

References:

1. Generic Letter 96-06, "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," dated September 30, 1996

2. Letter from A. C. Bakken III, Indiana Michigan Power Company, to Nuclear Regulatory Commission Document Control Desk, "NRC Generic Letter (GL) 96-06, Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions (TAC Nos. M96801 and M96802)," submittal C0800-10, dated August 15, 2000

3. Letter from M. W. Rencheck, Indiana Michigan Power Company, to U. S. Nuclear Regulatory Commission Document Control Desk, "NRC Generic Letter (GL) 96-06, Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions Response to Request for Additional Information (TAC Nos. M96801 and M96802)," submittal C0801-05, dated August 31, 2001

A072

4. Letter from John F. Stang, Nuclear Regulatory Commission, to A. Christopher Bakken III, Indiana Michigan Power Company, "Donald C. Cook Nuclear Plant, Units 1 and 2 – Request for Additional Information, 'Responses to Generic Letter (GL) 96-06 Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions,' (TAC NOS. M96801 and M96802)," dated May 10, 2002

In Reference 1, the Nuclear Regulatory Commission (NRC) requested licensees to determine if piping inside of containment could be subjected to either two-phase flow or waterhammer following a design-basis accident. Indiana Michigan Power Company (I&M) responded in Reference 2, stating that there was a potential for a waterhammer to occur in the non-essential service water (NESW) piping to the containment upper ventilation coolers following a loss-of-offsite power. An evaluation of potential waterhammer events led to the conclusion that the piping would remain intact. In Reference 3, I&M responded to an NRC request for additional information. This response included information regarding both the potential for waterhammer in the NESW piping and thermal overpressurization of isolated piping inside containment. In Reference 4, the NRC requested additional information regarding the waterhammer analysis.

The attachment to this letter responds to the NRC's request for additional information in Reference 4.

This letter contains no new commitments. Should you have any questions, please contact Mr. Gordon P. Arent, Manager of Regulatory Affairs, at (616) 697-5553.

Sincerely,

J. E. Pollock
Site Vice President

RV/bjb

Attachment

c: K. D. Curry, w/o attachment
J. E. Dyer
MDEQ – DW & RPD, w/o attachment
NRC Resident Inspector
R. Whale, w/o attachment

AFFIRMATION

I, Joseph E. Pollock, being duly sworn, state that I am Site Vice President of Indiana Michigan Power Company (I&M), that I am authorized to sign and file this request with the Nuclear Regulatory Commission on behalf of I&M, and that the statements made and the matters set forth herein pertaining to I&M are true and correct to the best of my knowledge, information, and belief.

Indiana Michigan Power Company

J. E. Pollock
Site Vice President

SWORN TO AND SUBSCRIBED BEFORE ME

THIS 28 DAY OF June, 2002

Notary Public

My Commission Expires 5/26/05

JENNIFER L [illegible]OSKY
Notary Public, Berrien County, Michigan
My Commission Expires May 26, 2005

ATTACHMENT TO AEP:NRC:2606

RESPONSE TO GENERIC LETTER 96-06 REQUEST FOR ADDITIONAL INFORMATION

Generic Letter (GL) 96-06 requested licensees to determine if piping systems inside of the reactor containment building were susceptible to either two-phase flow or waterhammer during design-basis accidents. In a letter dated August 15, 2000, Indiana Michigan Power Company (I&M) noted that the non-essential service water (NESW) system piping supplying the upper containment ventilation coolers was susceptible to waterhammer following a loss-of-offsite power (LOOP). An evaluation of potential waterhammer events led to the conclusion that the piping would remain intact. In a letter dated August 31, 2001, I&M responded to a Nuclear Regulatory Commission (NRC) request for additional information. The response included information regarding both the potential for waterhammer in the NESW piping and thermal overpressurization of isolated piping inside containment. In a letter dated May 10, 2002, the NRC requested additional information regarding the waterhammer analysis. The following responds to the NRC's request for additional information.

NRC Request 1

Provide a simplified diagram of the fan cooler system showing the piping areas, elevations, and flow velocities at the time before the calculated waterhammer occurs. This will allow the NRC staff to perform its own calculation using the Joukowski equation.

I&M Response

The non-essential service water (NESW) system at the Donald C. Cook Nuclear Plant is a once-through cooling system that takes suction from the plant forebay (directly supplied by Lake Michigan), pumps the water through heat exchangers that cool plant components, and returns the water back to the lake. Figure 1 is a simplified schematic of the NESW system as modeled for the transient analysis associated with a loss of offsite power.

The primary heat loads on the NESW system inside containment that are not isolated following a LOOP are the containment ventilation units (four lower and four upper), and two instrument room ventilation units.

The elevation of the lower containment ventilation units is 45 feet above Lake Michigan mean low water level and the elevation of the upper containment ventilation units is 120 feet above Lake Michigan mean low water level. Consequently, the water will start to drain from the system when power to the pumps is lost, starting with the higher elevations at the upper containment ventilation units. At the time just before power is restored, the upper ventilation units and their piping are mostly voided while the lower ventilation units are still full of water although there are some voids in the higher regions of the piping attached to the lower unit. There is also some voiding in the higher regions of the main piping that runs around the outside of the containment, particularly at the high points in the loop seals in the piping. When power is restored and the pumps are restarted, the upper portion of the main supply line outside of containment refills. When this line refills, a mild waterhammer of less than 200 pounds per square inch (psi) is calculated to occur. Since a portion of the supply lines to the ventilation units is still voided at this time, this initial pressure pulse does not propagate into the containment. Once the main supply line is filled with water, the piping to the ventilation units begins to fill.

The shut-off head of the NESW pumps is about 200 feet of flowing fluid. When the high points in the system have voids, the head capacity from the pump must overcome the combination of the elevation head and the resistance losses to refill the piping. Since the flow paths to the upper coolers are in parallel with the flow paths to the lower ventilation units and the elevation head to the upper coolers is substantially higher than that for the lower ventilation units, the flow will preferentially pass through the lower ventilation units. Only when the flow in the return piping from containment to the forebay is sufficiently high to maintain enough pressure to support the water column in the discharge line from the upper ventilation units can the void at the top of the discharge line be filled. There is little difference between the supply and discharge flows as the containment ventilation units fill. As a result, the collapse of the final void in the NESW system occurs very slowly as the water level in the discharge piping rises slowly.

Figure 2 is a sketch of the piping in the region of the upper ventilation units. It should be noted that the inlet pipe enters the coils from the bottom and the discharge pipe leaves the coils at a higher elevation so the final void collapse takes place in the discharge piping just downstream of the ventilation unit .

Figure 3 provides the calculated flow rates in the supply piping (to containment) and the return piping (from containment) as a result of the loss-of-coolant plus LOOP transient. When the pumps trip, the supply flow drops rapidly whereas the return flow decays more slowly as it is supplied by the inventory of water in the piping. Check valves prevent the flow from initially draining back through the pump; however, as the water level in the system decreases and the pressure drops due to loss of elevation head, some forward flow through the supply line is established because of a pressure differential between the supply and discharge lines. After the pumps restart, both the supply flow and the return flow are re-established and the piping to the upper ventilation units refills as the return flow becomes large enough to support the water column in the upper ventilation unit discharge lines. At the time the final void collapses, the flow rate in the supply and discharge lines are almost equal.

Figure 4 shows the mass flow rates in the piping where the collapse of the final void occurs. Initially, the inlet and outlet flow rates are equal. When the pumps trip, the inlet flow drops rapidly resulting in voiding at the higher elevation. When the pumps are restarted, the inlet flow rises rapidly to refill the system. When the water level spills over the top to the outlet piping, it falls through the void to the elevation where a water level exists that can be sustained by pressure drop in the discharge lines. A typical waterhammer occurs when the inlet flow fills a void and the outlet flow remains stagnant. However, the outlet flow in the vertical pipe in the discharge line from the ventilation unit has to fill from below in order to completely fill the piping. This can only occur if there is sufficient flow in the outlet line to generate enough friction pressure drop to sustain the increased elevation head as the pipe fills. Consequently, when the outlet pipe has filled, almost the full flow condition in the outlet line has already been established and the velocity of the water in the discharge line is almost equal to the velocity in the supply line. Figure 5 is a schematic that shows the flow conditions that exist at the upper cooler just prior to the time that the final void is filled.

Pipe diameters, flow areas, mass flow rates, flow velocities, and pressures for each segment just prior to collapse of the final void are provided in Table 1. These parameters indicate that the differential velocity across the void is very small just prior to final collapse as was indicated in the above discussion.

NRC Request 2

Provide the margin of safety of the calculated loads and stresses in the piping system from a postulated waterhammer event to the maximum allowable loads and stresses.

I&M Response

Since the NESW piping at Cook is non-safety related, the acceptance criteria for the piping analysis is based on assuring that the piping does not catastrophically fail due to the hydraulic load. Some amount of yielding is allowed and brittle failure will not occur because the piping and support materials are ductile. The acceptance criteria from Section III, Appendix F, of the ASME Boiler & Pressure Vessel Code were used.

Appendix F limits general primary membrane stress intensity for piping to $0.7S_u$ (calculated on an elastic basis). For A-106 Gr. B, S_u = 60 thousand pounds per square inch (ksi), so the stress limit is 42 ksi. This analysis calculates only the bending stresses resulting from the dynamic load (gravity and other loads are not considered). Since the gravity stresses are expected to be very low (less than 15 ksi), the pipe stresses are judged to be acceptable as long as the bending stress is less than 25 ksi.

As discussed in the response to Question 1, the waterhammer loads associated with collapse of the final void in the piping were small. In fact, the largest calculated waterhammer response occurred when the main supply pipe outside of containment fills.

Although the analysis showed this pressure pulse did not readily propagate into the coolers due to voids in the inlet lines, a conservative analysis was performed assuming the inlet lines to the ventilation units were filled with water. The forces associated with the corresponding hydraulic transient pressures were applied to the inlet piping for the upper ventilation units in a transient piping analysis to represent a worst case analysis for the pipe stress. Two cases were analyzed; one with all supports modeled with a typical stiffness and the other where all supports, other than anchors and nozzles, were ignored. The peak calculated pipe stress obtained from these analyses was 10.1 ksi.

The maximum calculated pipe bending stresses are all very low. The maximum stress anywhere in the model for either analysis case is only 10.1 ksi. This is much less than the assumed allowable stress, so the piping would not fail during the postulated event, even if the pipe supports were not present. Since the acceptance limit is 25 ksi (which is reduced for other concurrent loads), the margin is 14.9 ksi.

NRC Request 3

Provide an evaluation showing whether the discharge flow orifice will drain and therefore be a potential waterhammer site.

I&M Response

When the NESW pumps shut down due to a LOOP, the piping will start to drain and voids will form at the high points as the pressure drops to the vapor pressure, which will be less than one psi. Since the outlet pressure for the piping is at atmospheric pressure, the water column that can be maintained in the piping will be about 30 feet of elevation.

The flow orifice in the main discharge pipe is located at an elevation of 588 feet, 11 inches above sea level. The mean low water level for Lake Michigan is 577 feet above sea level. Since the orifice is less than 12 feet above the lake water level, the water in the discharge line would not be expected to drain below the level of the orifice unless there was significant leakage of air into the piping system. Since the pumps restart after 28 seconds, there would be little time for a large amount of air to leak into the pipe and the orifice would be expected to remain submerged during the transient. The analysis indicates that this is the case.

In addition to the flow orifice in the main discharge line, there is a similarly located orifice in the main supply line that also remains submerged throughout the transient. There are also orifices in the supply and discharge lines for each cooler. Due to the mechanism of filling the piping that was discussed previously, there is no indication that these orifices generate significant pressure transients as the piping refills.

NRC Request 4

Provide information concerning operator experience in restarting the fan cooler system in a voided condition.

I&M Response

The majority of experience related to filling the containment ventilation units involves restoration for maintenance activities. Each unit has a procedure for filling and venting the containment ventilation units when required, which results in a controlled refill of the system. There is no documented operating experience that a waterhammer has occurred when this procedure was being followed.

In January 2000, air entrainment in the Unit 1 NESW pump resulted in a loss of NESW flow to both units. Both units were defueled at the time of this event. No information has been found on the status of the upper containment ventilation coolers at that time, i.e. it is unknown if the coolers were in operation or being supplied by the NESW system. When NESW was restored, no waterhammer conditions were identified.

During preoperational testing, the Unit 2 NESW system experienced a pressure transient during an emergency power system test. This event resulted in the failure of an improperly installed expansion joint in the turbine building and was identified in Unit 2 License Condition 2.C(1) as a waterhammer. This license condition required an evaluation of the event be performed prior to Operational Mode 4 with the evaluation to specifically address the potential for flooding of safety related equipment if the water hammer had resulted in a break elsewhere. The evaluation indicated that any of the four expansion joints in the NESW system would fail prior to piping being overstressed and the evaluation addressed flooding in those locations, which were outside of containment. The evaluation also indicated that the actual event did not result in any other visible damage. The NRC was informed of the I&M evaluation in a January 27, 1978, letter and the item was resolved in NRC Inspection Report Number 50-315/78-02; 50-316/78-02, dated February 28, 1978.

NRC Request 5

Provide a comparison of predictions by the SYSFLO code with predictions of the Joukowski equation for waterhammer pressure pulse.

I&M Response

A simple sample analysis using the SYSFLO computer program was conducted to determine the pressure response of two water columns impacting at a void. A simple straight horizontal pipe with a void at the center and increased pressure at the ends was used for the analysis. Pressure boundaries at the ends of the pipe cause the flow to accelerate towards the void and the water columns impact against each other as the void disappears to generate the waterhammer. The schematic in Figure 6 shows the conditions in the pipe prior to the void collapse.

Figure 7 shows the calculated flow velocities of the two sample converging water columns and Figure 8 shows the calculated pressure at the midpoint of the pipe. Table 2 provides numeric values for the sample pipe geometry and the flow conditions just prior to the collapse of the void. The table also includes an approximate value for the pressure rise that would be expected from the Joukowski condition. The speed of sound used in the Joukowski equation was obtained from the equation for the speed of sound at the fluid conditions utilizing computerized steam tables.

$$C = \left(\frac{\partial P}{\partial \rho}\right)_S$$

C = speed of sound
P = pressure
ρ = density
S = entropy

The results for pressure increase from the Joukowski equation (1076 psi) and the SYSFLO code (1110 psi) compare favorably. The SYSFLO results include pressure oscillations at impact that are a result of the lumped parameter approach associated with finite flow connectors and that tend to overpredict the initial pressure peak. The magnitude of these oscillations depends on the detail of the model, with more conservative results associated with less detailed nodalization.

TABLE 1

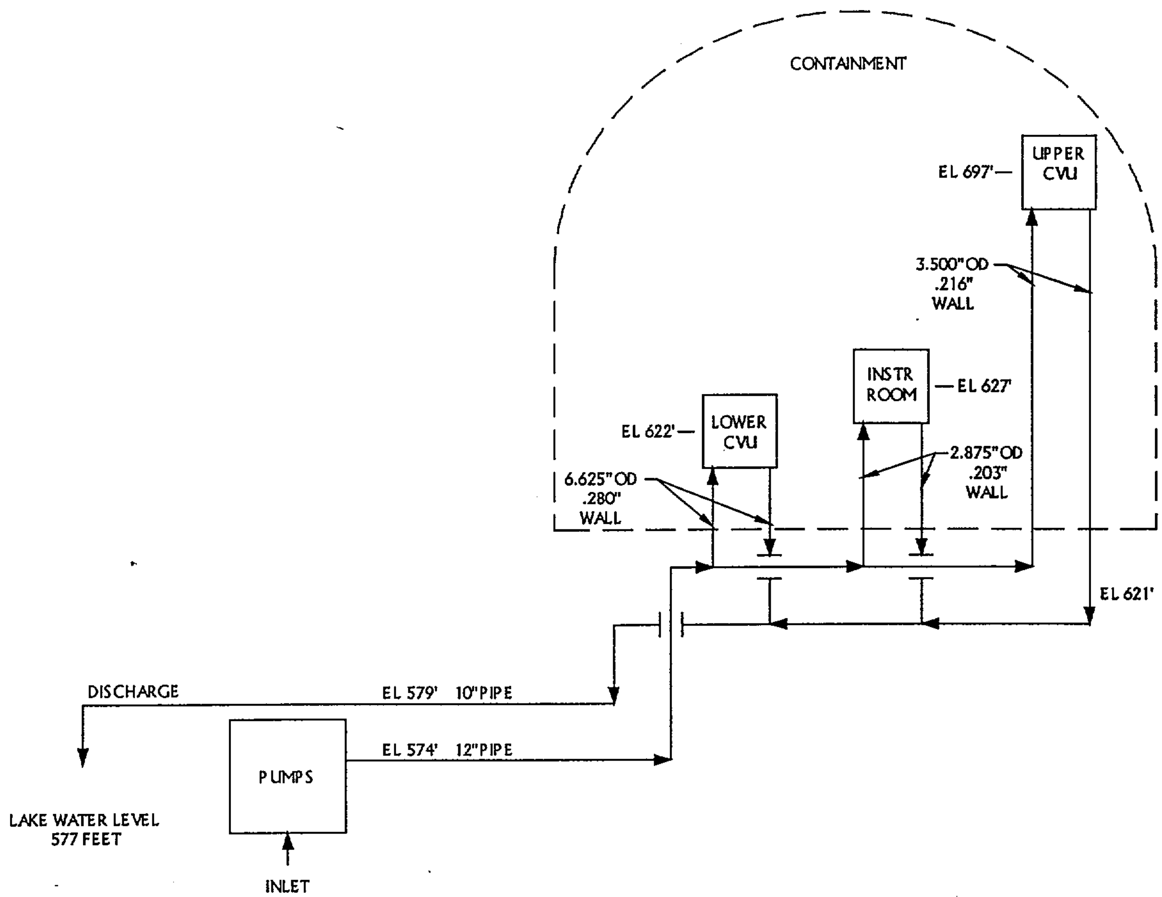
Parameters in Region of Final Void Collapse near Outlet of Upper Containment Ventilation Unit

Parameter	Value	Comment
Pipe Sizes (Figure 2)	Discharge piping 3.5 inch (") outside diameter (OD) with 0.216" wall thickness.	One pipe in model represents two ventilation units. Thus the flow area is 0.10268 square feet (sq. ft).
	Piping between discharge and coils is 1.9" OD with 0.2" wall thickness. Highest point in piping is in the discharge.	One path in model represents two paths in a ventilation unit. For two ventilation units there will be four paths in all with a flow area of 0.04909 sq. ft.
	The vertical headers for the serpentines are 2.125" OD with a 0.25"wall thickness.	One path in model represents two paths in a ventilation unit. For two ventilation units there will be four paths in all with a total flow area of 0.0576 sq. ft.
	Tubes are 0.625" OD with .035" wall thickness.	There are 22 tubes per bank and two banks per ventilation unit. Thus the modeled serpentine tube for the upper ventilation unit represents 88 serpentines in the plant with a total flow area of 0.14784 sq. ft.
Flow area at point of collapse	1.767 square inches/pipe.	Four parallel paths modeled as one with total area of 0.04909 sq. ft.
Pressure before collapse of void	Approximately 1 pound per square inch (psi).	Saturation pressure of water at about 100 degrees Fahrenheit.
Density of liquid	62.4 lbs/cubic foot (cu ft).	
Upstream velocity just prior to collapse of void	15 feet per second (ft/sec).	Note: Upstream and downstream velocities are in the same direction.
Downstream velocity just prior to collapse of void	12 ft/sec.	The difference in incoming velocities is 3 ft/sec. The velocity difference across the wave front will be 1.5 ft/sec. After the columns collide, the velocity will be 13.5 ft/sec.

TABLE 2

Parameters in Sample Pipe Problem to Test Waterhammer Results

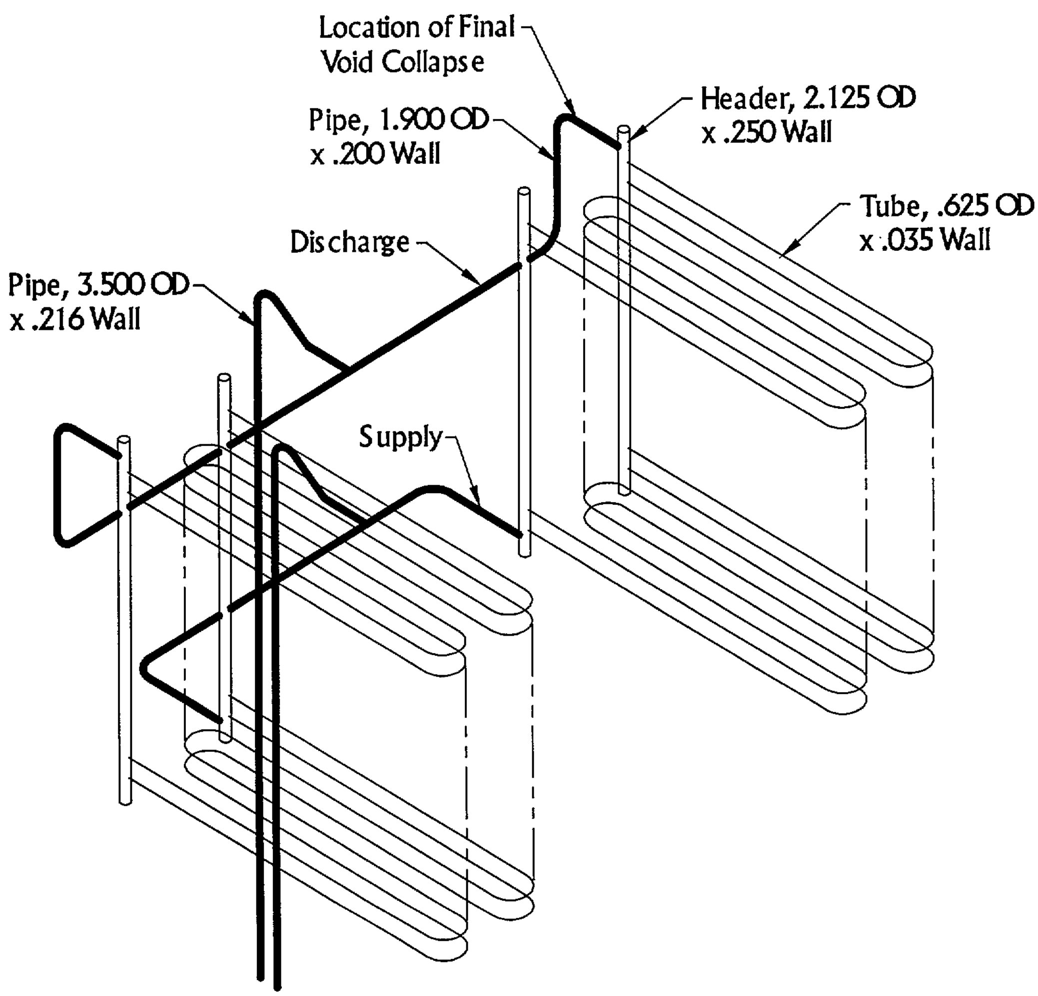
Parameter	Value	Comment
Pipe geometry	1 foot inside diameter (ID). 250 feet long.	
Boundary conditions	Void at center with increased pressure at both boundaries.	Ran to steady state conditions by imposing void as boundary condition.
Density of water	62.4 lbs/cu ft.	
Calculated velocity just before impact	20 ft/sec and –20 ft/sec.	After impact, both velocities are zero.
Calculated pressure increase	About 1110 psi.	
Speed of sound used	~ 4000 ft/sec.	SYSFLO does not require speed of sound. This was used for Joukowski equation.
Joukowski calculated maximum pressure	1076 psi.	The difference between the incoming velocities is 40 ft/sec. The velocity difference across the wave front will be 20 ft/sec. After the columns collide, the water velocity will be zero.



CVU – Containment Ventilation Unit
INSTR ROOM – Instrument Room

Figure 1

Schematic of NESW Model



Discharge piping nominal elevation – 698 feet 11 inches
Supply piping nominal elevation – 696 feet 0 inches

FIGURE 2

Detail of Piping Configuration for Upper Containment Ventilation Unit

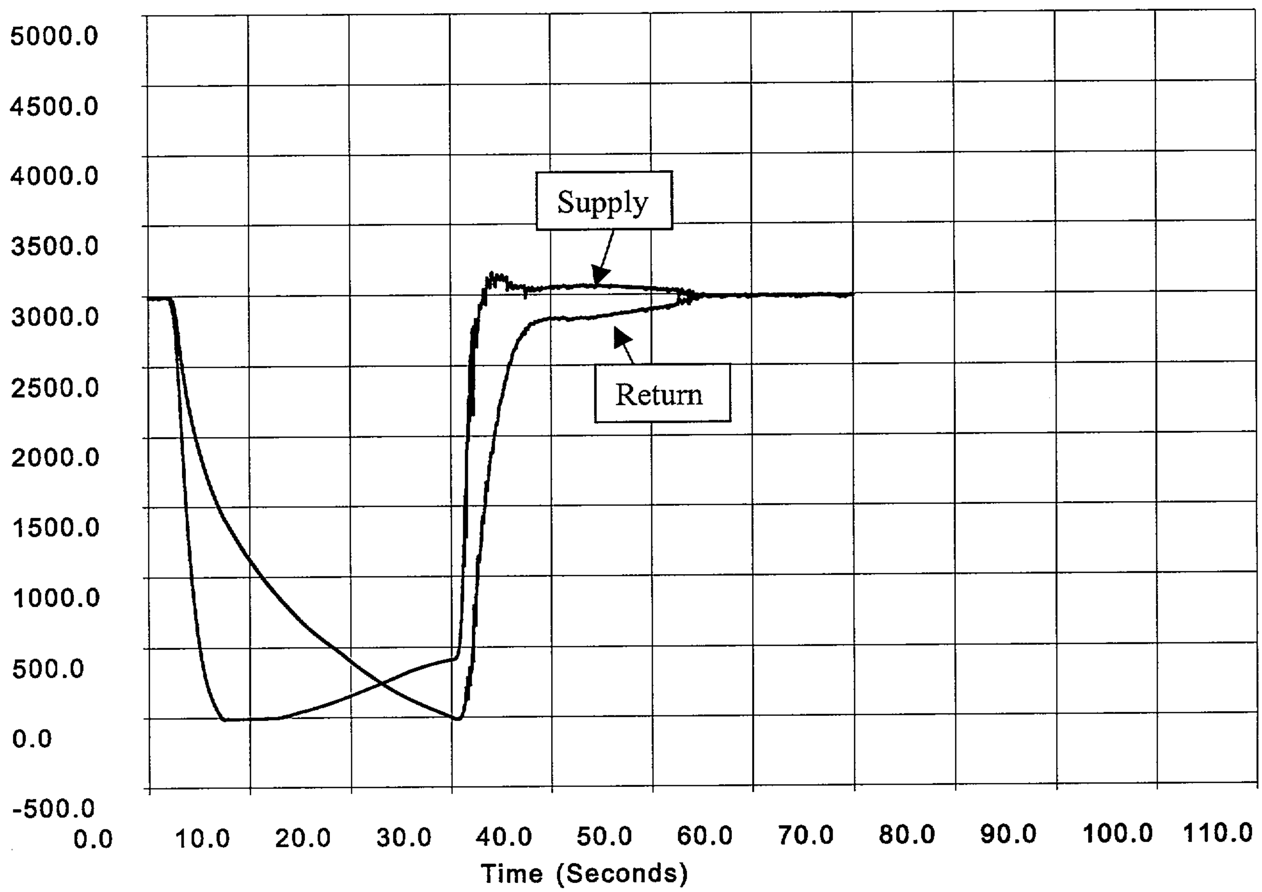


FIGURE 3

Main Supply and Return Mass Flows (in GPM) During Loss of Off-Site Power Transient

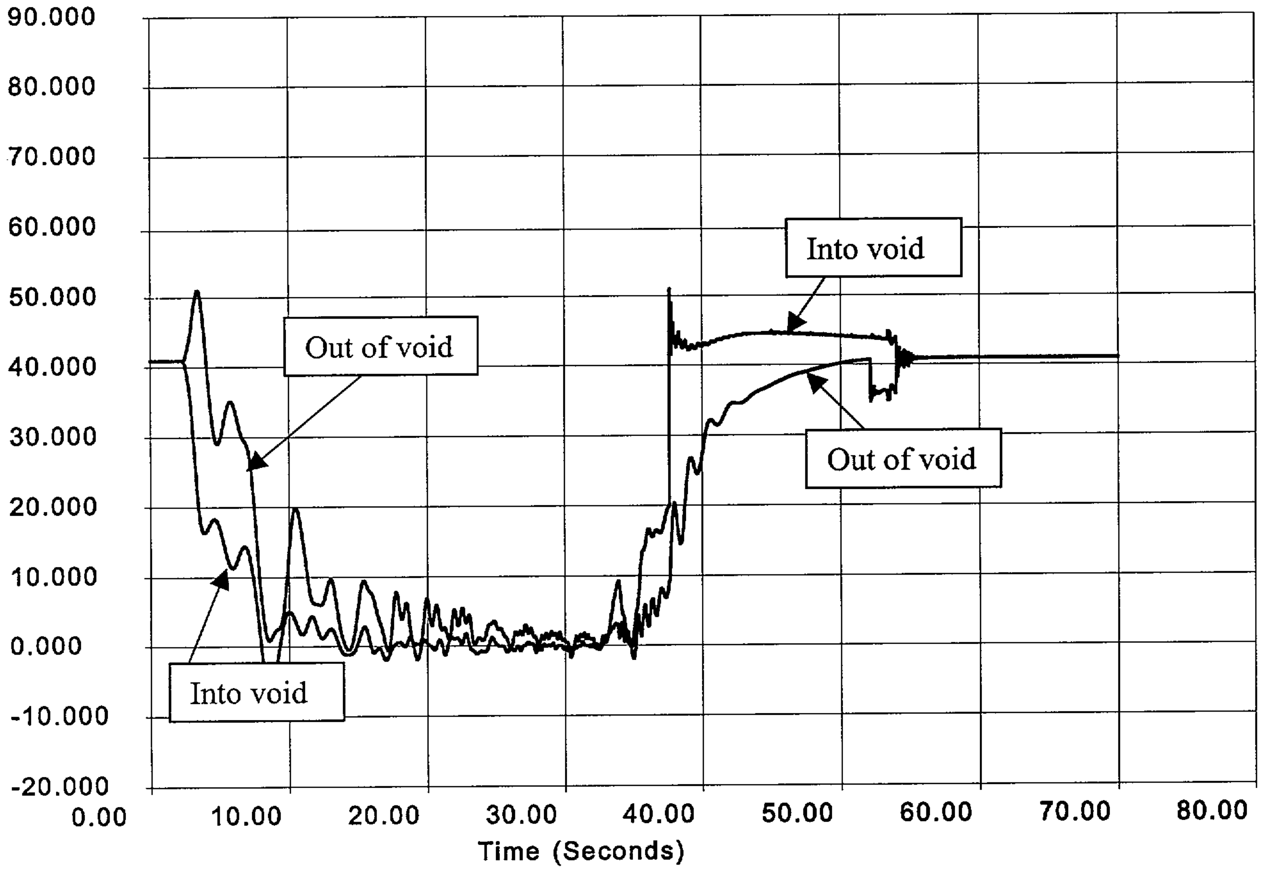


FIGURE 4

Mass Flow (in lb/sec) into and out of Final Void

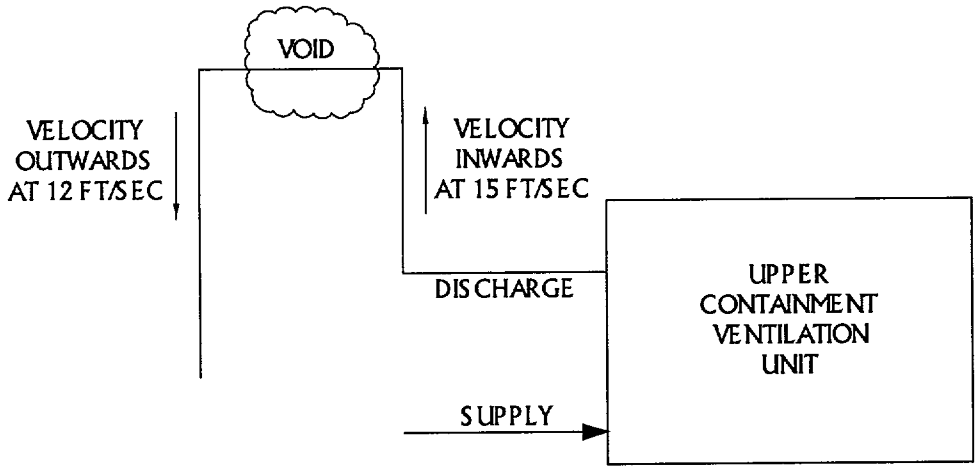


Figure 5

Flow Conditions Prior to Final Void Collapse

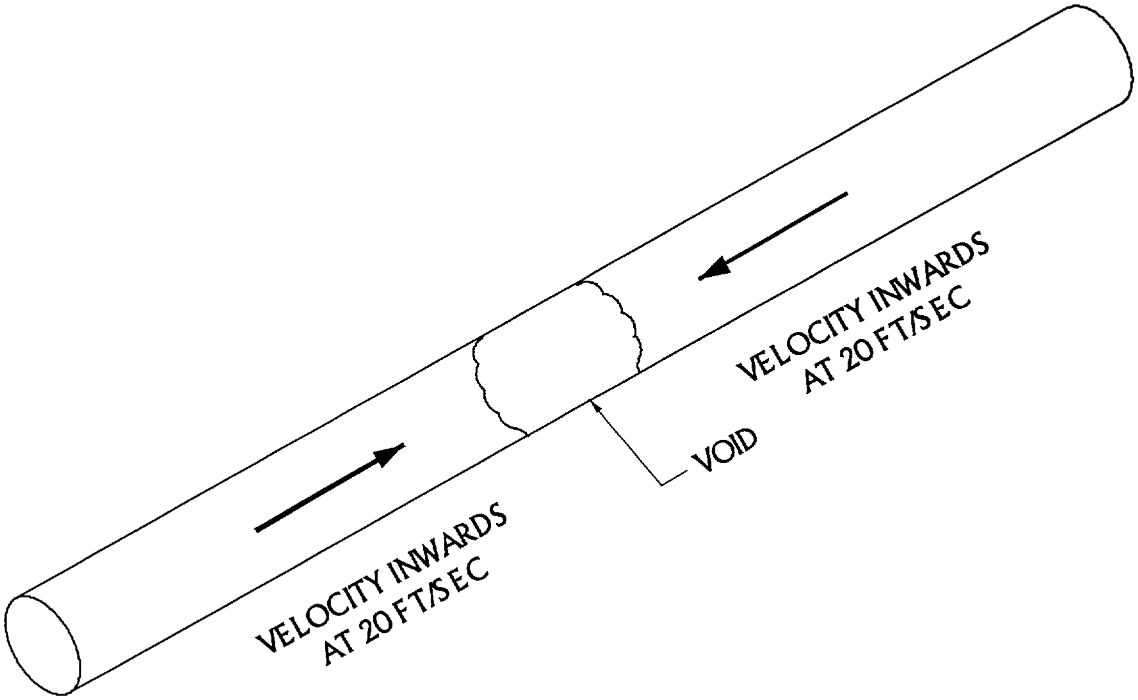


Figure 6

Sample Problem Flow Conditions Prior to Void Collapse

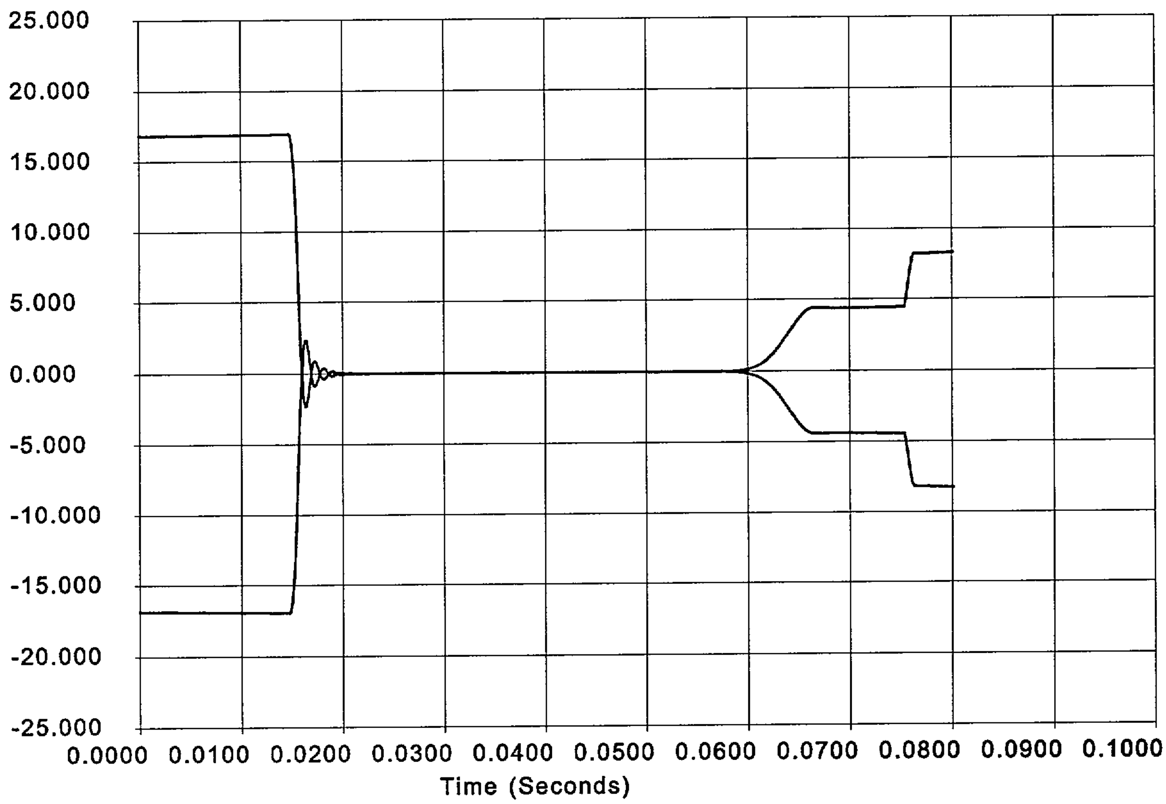


FIGURE 7

Velocities (in ft/sec) of Water Columns for Sample Problem

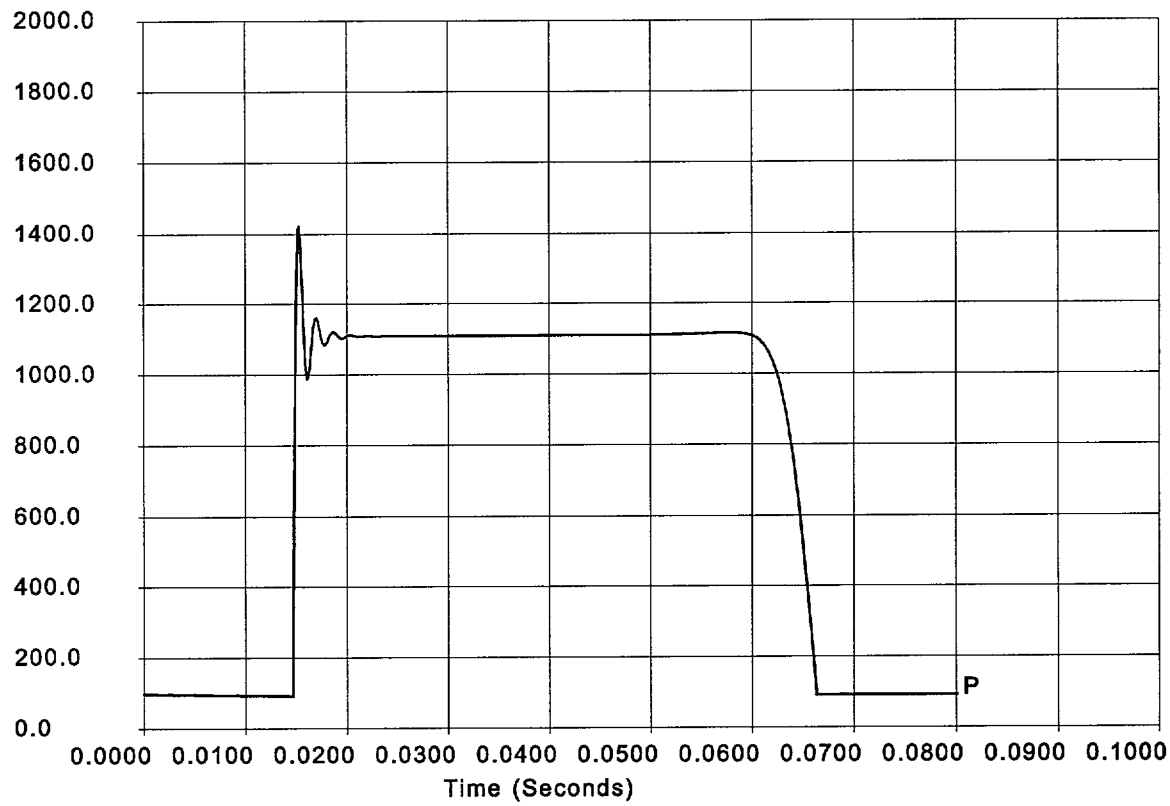


FIGURE 8

Pressure Response (in psia) for Sample Problem