Commonwealth Edison
1400 Opus Place
Downers Grove, Illinois 60515

June 10, 1991

Dr. Thomas E. Murley, Director
Office Of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Attn: Document Control Desk

Subject: Byron Station Units 1 and 2
Braidwood Station Units 1 and 2
Supplement to Application for Amendment to
Facility Operating Licenses
NPF-37, NPF-66, NPF-72 and NPF-77,
Appendix A, Technical Specifications
NRC Docket No.s 50-454, 50-455,
50-456 and 50-457

Reference: (a) March 17, 1989 S.C. Hunsader letter to T.E. Murley

(b) August 25, 1989 S.C. Hunsader letter to T.E. Murley

(c) March 12, 1990 S.C. Hunsader letter to T.E. Murley

Dear Dr. Murley:

In reference (a) pursuant to 10 CFR 50.90, Commonwealth Edison (Edison) proposed to amend Appendix A, Technical Specifications, of Facility Operating Licenses NPF-37, NPF-66, NPF-72 and NPF-77. The proposed amendment requested a change to Technical Specification 4.5.2 to modify the existing surveillance requirements for venting of ECCS discharge piping. This change is expected to reduce exposure to radiation in accordance with ALARA guidelines without reducing the safe operation of the ECCS equipment.

In reference (b), Edison supplemented reference (a) with additional information that presented the amount of radiation exposure expected to be saved.

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On September 25, 26, and 27, 1989, meetings were held at Braidwood Station between Edison and the NRC staff to discuss the bases for references (a) and (b) and to provide the NRC staff the opportunity to physically see the ECCS piping applicable to Technical Specification 4.5.2. As a result of the discussions during that meeting it was determined that sufficient bases exist to support a change to the proposed Technical Specification amendment wording provided in reference (a). This change would allow the discontinuance of performing the venting surveillance required by Technical Specification 4.5.2, inside containment. Reference (c) provided the results of the completed Edison reviews in that regard and to addressed additional information requested by the NRC staff.

A teleconference with NRC staff on March 14, 1991 resulted in several questions including a request for additional engineering analysis. The attachment lists the questions and Edison's responses.

Edison is notifying the State of Illinois of this supplement to the application for amendment by transmitting a copy of this letter and its attachments to the designated State Official.

To the best of my knowledge and belief the statements contained herein are true and correct. In some repsect, these statements are not based on my personal knowledge but upon information received from other Commonwealth Edison and contractor employees. Such information has been reviewed in accordance with Company practice and I believe it to be reliable.

Please direct any questions you may have concerning this submittal to this office.

Very truly yours,

Allen R Checca

Allen R. Checca
Nuclear Licensing Adminstrator

Attachment

cc: W. Kropp, Resident Inspector-Byron
S. DuPont, Resident Inspector-Braidwood
R.M. Pulsifer, Braidwood Program Manger - NRR
A.H. Hsia-Byron Program Manager - NRR
W. Shafer-Region III
M.C. Parker - IDNS

State of Ill, County of Cook
Signed before me on this 12th day
of June, 1991 by [illegible]

Notary Public [illegible]

OFFICIAL SEAL
[illegible] C. LARA
NOTARY PUBLIC, STATE OF ILLINOIS
MY COMMISSION EXPIRES [illegible]

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ATTACHMENT

Response to NRC of teleconference of March 14, 1991.

Item 1:
Provide a waterhammer analysis based on completely voided discharge line, showing the maximum forces as a percentage of the design support values.

Response:

The RH ECCS supply line to loop 1 inside containment has been previously evaluated for the maximum credible bubble size. This line was chosen based on its pipe diameter, pipe length and pipe routing (especially with respect to pipe elevation), which maximize the effects of an air bubble in the piping.

This line has been reevaluated assuming the RH discharge piping has an air bubble from the pump to the RCS. The supports, piping, penetrations and nozzles are evaluated for the effects of this bubble size.

ID	Estimated Waterhammer load (lbs)	(1) % of S/L B Load	(2) % of S/L D Load	(3) % of Load Cap.
1SI01018S	950.	55.	21.	9.
1SI01019X	475.	14.	6.	5.
1SI01021S	950.	61.	32.	9.
1SI01023R	950.	30.	17.	9.
1SI01026R	950.	37.	24.	16.
1SI01029S	1425.	47.	21.	14.
1SI01030S	475.	20.	6.	5.
1SI01035S	1425.	42.	25.	14.
1SI01072X	475.	22.	10.	8.

It is evident from this table that the supports see smaller loads for RH flow with an air bubble than those corresponding to an operating basis earthquake (OBE) (S/L B). Based on this, any nozzles or penetrations experiencing loads due to the air bubble would also see loads smaller than the OBE load; therefore, these items are also qualified for the air bubble load. Finally, because the support loads are smaller for the air bubble load than the loads corresponding to an OBE, it follows that pipe stresses due to the air bubble load are also lower than the OBE stresses, and are therefore acceptable. A rigorous piping analysis would show that pipe stresses are well below Code allowables for the air bubble load.

Notes: (1) S/L B refers to the Service Level B load, the restraint design load.

(2) S/L D refers to the Service Level D load, the restraint faulted load.

(3) Load capacity refers to the rated capacity of the weakest standard component of the existing restraint. The auxiliary and main steel have not been evaluated for the load capacity.

ITEM 2:

Commonwealth Edison asserted in the response to question B4 that the earthquake would be over in about 10 seconds. Is this consistent with the USFAR?

Response:

The response to question B4 stated: "It should be noted that the accident forces (seismic, blowdown, and waterhammer) would not be simultaneous. The earthquake would be over in about 10 seconds. It would take about 30 seconds for the reactor coolant system to depressurize enough to allow the RH pumps to deliver flow." This point was made to justify not adding seismic, blowdown, and waterhammer forces together.

The UFSAR in several locations refers to an earthquake of 10 seconds duration. The page references are:

page	revision
2.5-79	rev 1 - December 1989
2.5-80	rev 1 - December 1989
3.7-32	

Marked copies of these references are attached.

The in situ densities used in the analysis are given in Table 2.5-23. They are approximately the lowest values found during testing. The actual test results are found on Figures 2.5-87 and 2.5-88. The use of these values in the liquefaction analyses will yield more conservative results.

The results of laboratory resonant column and dynamic triaxial compression tests performed on intact and reconstituted samples are summarized on Tables 2.5-22 and 2.5-20, respectively and in Subsection 2.5.4.7.2. The values of the dynamic shear modulus and damping ratio, as a function of shear strain level, are shown on Figures 2.5-89 and 2.5-90, respectively. The procedures for obtaining and preparing samples and conducting the dynamic laboratory tests are described in Subsection 2.5.4.7.2.

In order to assess the effect of variations of the dynamic soil parameters on the dynamic response of the deposit, lower-bound (Case 1) and upper-bound (Case 2) values of the measured dynamic shear moduli were selected for analysis as shown on Figure 2.5-89. In the selection of the upper- and lower-bound values, the test results obtained from reconstituted samples were eliminated from consideration for the following reasons:

a. A large difference was noted between the dynamic behavior of reconstituted samples compared to intact samples at similar densities. The intact samples are considered to be more representative of the in situ structure of the granular deposit since particle segregation is difficult to prevent during reconstituting samples and reconstruction of a packing representative of the in situ condition may not be obtained. Comparing the test results of the reconstituted samples versus the intact samples also shows consistently higher shear moduli for the reconstituted samples, as shown on Figure 2.5-89. Therefore, it was concluded that reconstituting the samples altered the dynamic properties of the material.

b. Since all liquefaction tests were performed on intact samples, the dynamic response and liquefaction behavior should be based on test data obtained from intact samples prepared in the same manner.

The solid curve shown on Figure 2.5-90 was used to represent the damping characteristics for both Case 1 and Case 2. This curve was selected as a reasonable estimate of the damping characteristics as measured on the intact samples.

2.5.4.8.3.2 Dynamic Response Analysis

Initially the base rock motion used in the dynamic response analysis was that of an artificial earthquake of 10-second duration, selected to essentially envelope the standard NRC broad

band spectra scaled to a maximum horizontal ground acceleration of 0.12g at the bedrock level. The horizontal acceleration time history for the artificial base rock motion is presented on Figure 2.5-91. The corresponding response spectra, compared to the NRC broad band response spectra are shown on Figures 2.5-93 through 2.5-95 for various damping ratios.

Subsequently two other base rock motions were used in the dynamic response analysis. These consist of the first 10-second duration of two real earthquakes; namely, the S80E component of the March 22, 1957 Golden Gate Park earthquake and the N-S component of the 1935 Helena, Montana earthquake. The horizontal acceleration time histories for the two earthquakes are presented on Figure 2.5-92, scaled to a maximum acceleration of 0.20g. The corresponding response spectra are shown on Figures 2.5-96 through 2.5-99 for various damping ratios.

The dynamic response of the alluvial deposit was evaluated by means of a wave propagation analysis of a one-dimensional model of the deposit. The one-dimensional model is considered appropriate for this deposit since the ground surface and bedrock surface have an average slope of less than 5% for several hundred feet in all directions. The deposit was subdivided into a series of 14 discrete horizontal layers, each characterized by appropriate values of the relevant soil parameters, including unit weight, shear modulus, and damping ratio.

The one-dimensional layered system was subjected to the artificial base rock motions shown on Figure 2.5-91 for the two sets of dynamic soil parameters described previously. The numerical analysis was performed by a digital computer using the wave propagation technique. Several iterations were performed to achieve compatibility between the shear strains in each individual sublayer and the corresponding dynamic shear moduli and damping ratios. The shear stress time histories for the middle of the individual sublayers were computed from the strain compatible solutions.

Since the analyses utilizing the upper-bound dynamic soil moduli produced higher shear stresses, only the upper-bound value of the dynamic soil properties (Case II) were utilized in the one-dimensional wave propagation analysis for the two base rock motions of the two real earthquakes (Figure 2.5-92).

2.5.4.8.3.3 <u>Laboratory Liquefaction Tests</u>

A series of laboratory dynamic triaxial tests were performed on intact samples obtained from the borings using a Dames & Moore Type U Sampler. As discussed previously in Subsection 2.5.4.8.3.1, the testing of intact samples was considered to be the most representative and most consistent method of determining the dynamic behavior of in situ soils.

where

$$\Sigma_{ij} = |\omega_i' - \omega_j'| \,/\, (\xi_i' \omega_i + \xi_j' \omega_j) \qquad 3.7\text{-}46$$

$$\omega_i' = \omega_i \sqrt{1-\xi_i'^2} \qquad 3.7\text{-}47$$

Thus a modified damping factor should be used for the damped frequency. Amin and Gungor (Reference 17) and Singh, Chu and Singh (Reference 9) also used the modified damping factor for the damped frequency in their computation of the correlation coefficient of closely spaced modes.

For a lightly damped system and an earthquake duration of 10 seconds as in the Byron/Braidwood design basis, the damped frequency based on an uncorrected damping factor are approximately the same. However, on a theoretical basis, the modified damping factor should be used for the damped frequency in the evaluation of the correlation of the closely spaced mode response. For a 10-hertz system with 2% damping and 10-second earthquake duration, the damped frequency using modified and uncorrected damping factors is 9.9973 hertz and 9.9980 hertz respectively. Thus the use of either modified or uncorrected damping factor does not affect the results.

The following description is applicable to safety-related components and systems within Westinghouse's scope.

The total unidirectional seismic response is obtained by combining the individual modal responses utilizing the square root of the sum of the squares method. For systems having modes with closely spaced frequencies, this method is modified to include the possible effect of these modes. The groups of closely spaced modes are chosen such that the difference between the frequencies of the first mode and the last mode in the group does not exceed 10% of the lower frequency. Combined total response for systems which have such closely spaced modal frequencies is obtained by adding to the square root of the sum of the squares of all modes the product of the responses of the modes in each group of closely spaced modes and a coupling factor.

This can be represented mathematically as:

$$R_T^2 = \sum_{i=1}^{N} R_i^2 + 2 \sum_{j=i}^{S} \sum_{K=M_j}^{N_{j-1}} \sum_{\ell=k+1}^{N_j} R_k R_\ell \varepsilon_{k\ell} \qquad (3.7\text{-}48)$$

ITEM 3:

Describe the Byron and Braidwood containment leak detection system and its capability to discover a leak in the residual heat removal system.

Response:

Section 5.2.5 of the UFSAR describes the means for detecting and monitoring leakage into containment. The system most likely to detect an RH system leak is the containment floor drain sump. UFSAR excerpts are provided below.

The containment floor drain sump contains a weir box for detecting and monitoring unidentified leakage. Leakage is routed to the unidentified leakage weir box through the containment floor drain system. In the unidentified leakage weir box, no normal leakage is expected and therefore its design allows detection and monitoring of 1 gpm of leakage into the weir box. Signals from a transmitter are recorded and alarmed in the main control room. The weir plate has a rectangular 1/8 inch (1/4 " at Byron) sharp-crested weir notch. The horizontal crest is located above the bottom of the weir box. Assuming constant flow rates of 1 gpm for unidentified leakage, the height of the water behind the weir was calculated. The change in level is a function of flow and is detected by a differential pressure transmitter fed by a bubbler system. The verification of flow sensitivity was performed in the preoperational test by passing a known measured flow into the sump and detecting the desired response . The weir boxes do not communicate directly with the containment atmosphere because the sumps, including the weir boxes, have a steel cover plate. Therefore, if flashing occurs, it will be substantially contained within the sump thus preventing the loss of sensitivity of the dew-point instruments to an unidentified leak.

The reactor cavity sump collects leakage in the reactor cavity. Similar to the containment floor drain sump a weir box is provided in the sump to monitor and detect leakage. The reactor cavity sump normal leak rate was determined to be zero during plant startup testing. The weir box design will allow the detection system to respond to a 1 gpm increase in leakage into the weir box. The signal from a transmitter in the weir box is recorded and alarmed in the main control room.

An additional means of determining sump flow for the reactor cavity and containment floor drain sumps is provided by sump pump run time totalizing meters. This method provides an indication of water processed through the sump.

The time required for these sumps to respond to and alarm a leak is a function of the location of the leak relative to the sump, and is a function of whether or not the leakage begins to reach a sump. The sump design will respond to and alarm a 1 gpm leak in one hour or less.

ITEM 4:

Provide calculations that show the minimum flow rate to sweep air from the residual heat removal piping and describe how often this is done. Describe the methods used to sweep air from the RH system high points.

Response:

The minimum flow rate needed to flush an air bubble from an 8 inch sch. 160 line is 489 gpm (4.3 fps), as indicated in the attached calculation (attachment A). The velocity is determined based on the following relationship:

$$Fr = \frac{V}{\sqrt{gD}} \quad \text{where:}$$

Fr = Froude number
V = fluid velocity
g = gravitational acceleration (ft/s^2)
D = diameter of pipe (ft)

When Fr = 1, the pipe runs full. Using this relationship for a 10 inch sch. 140 line (for the point where the RH discharge flow enters the accumulator piping), the necessary flow is 908 gpm (4.8 fps). Typically, the RH pump flow rate in the shutdown cooling mode of operation exceeds the necessary rate to supply 908 gpm to the accumulator piping. Approximately 3300 gpm is supplied to two cold leg injection lines. Therefore, any air bubbles in the RH discharge piping will be swept away when the pump is running.

An additional concern was voiced for the accumulator line in particular. The concern was that an air bubble may be pushed into the accumulator line from flow in the RH piping. Once flow stops, the air bubble may then travel back into the RH discharge piping. This is unlikely since the RH discharge piping intersects the accumulator line at an elevation lower than the RCS. Therefore, any air bubble pushed into the accumulator line will be swept into the RCS. Attachment B shows a typical piping configuration (applicable to Byron and Braidwood Units 1 and 2) at the location where the RH piping intersects the accumulator line.

BVS 0.5. -2. RH. 2 "Residual Heat Removal System Valve Stroke Test", a Byron Procedure, is performed each refueling outage. The flow paths required to complete the surveillance are:

A RH pump - from RCS hot legs to A and D cold legs
B RH pump - from RCS hot legs to B and C cold legs
A RH pump - from RCS hot legs to A and C hot legs

All pump flows are required to be greater than 3300 GPM. This surveillance is typically performed towards the end of the refueling outage; however, it could be performed at any convenient time during the outage. An equivalent procedure is performed at Braidwood each refueling outage. In addition, the technical specifications require RH system operations almost continuously in mode 5 and 6. As an operational convenience, RH trains are routinely swapped during the post outage manuevers which creates an opportunity to sweep air from the RH high points prior to entry into higher modes.

ITEM 5:

Describe Byron's and Braidwood's experience and describe the results of venting surveillances.

Response:

Edison's operating experience in performing this surveillance has found insignificant or no quantities of air during venting on the discharge side of RH pumps. Previous revisions of the monthly surveillance did not require documentation of the amount of gas present. During the September, 1989 meeting, a Braidwood Station operator who has performed this surveillance (representing the views of other operators who have performed this surveillance) summarized that significant quantities of air had not been seen during surveillances. In addition, in April, 1991, sixteen Braidwood operators were interviewed who have performed the monthly surveillance. All reported never seeing more than insignificant amounts of air or gas during the venting surveillance following initial filling and venting of the system. Any air seen has been a very small "burping" prior to fluid flow through the vent valve. Also at Byron, six recently performed venting surveillances were reviewed and all indicated no air was found.

ITEM 6:

Describe the methods used to provide guidance to the Shift Engineers if excessive air is discovered when venting.

Response:

The current venting surveillance requires that the Shift Engineer be notified if air or gas is discovered. Byron and Braidwood have initiated procedural changes to provide the Shift Engineer with guidance on actions to be taken if air or gas is discovered. These actions will include a requirement to involve the technical staff in a determination of the sources of the air.

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ITEM 7:

Describe potential air in-leakage volumes created when the RH system is at negative pressure and the air removal methods available.

Response:

During most modes of operation the RH injection lines are under a gravity head from the RWST. If a leak developed in the pipeline the flow through the leak would be entirely water out. There would be no air in-leakage. In certain modes of operation the high points can be under partial vacuum. These vacuum conditions only occur for brief periods during the year when in refueling or during mid loop operations. However, during these conditions a pipeline leak would allow air inleakage.

During refueling operations the reactor vessel head is off and the RWST is not connected to the RH pump suction unless the reactor cavity level is being raised. In addition, the RWST level can be as low as 410 feet which is below the high point elevation of the RH injection lines, 421.5 feet. For these reasons, the RWST is not typically pressurizing these pipelines during the refueling mode.

Technical Specifications require that an RH pump be in operation if the reactor cavity level is less than 23 feet above the vessel flange. If the pumps are operating, the flow rate will usually be high enough to sweep any air out of the pipeline and the line pressure will usually be high enough to prevent inleakage. RH flow rates are usually maintained at 3300 gpm or higher. This corresponds to a flow rate of 1650 gpm per injection line. This flow rate is greater than the 908 gpm required to sweep away an air void. However, the technical specifications require a minimum flow rate of only 1000 gpm so the possibility of falling below 908 gpm exists but is remote. The pressure at the high point can be subatmospheric even if the RHR system is operating. In the worst case, the vessel head would be off and the water level would be at the vessel flange (400'). The pressure at the high point would be atmospheric pressure reduced by 22 feet of water column and increased by the pressure loss due to frictional effects of flow between the high point and the reactor vessel. If a leak existed under these vacuum conditions, air could enter the pipeline and the air could accumulate if the line flow is less than 908 gpm. Any air which did accumulate would be flushed away by subsequent operations which are described in other sections of this supplement.

In accordance with Technical Specifications when the reactor cavity level is above 23 feet, an RH pump can be secured for periods as long as 1 hour to facilitate fuel movements. However, in practice this situation only occurs a few times in a typical refueling and the pump is usually only throttled back to 1000 gpm rather than secured. There is no risk of air inleakage when the level is this high because the cavity level is just above the high point of the RH lines.

There is a small risk of air inleakage during refueling operations for the reason discussed above. However, in the time period between bubble formation and entry into hot shutdown there are routinely operations which will flush the air void out. Two of these are:

a. The RH pumps are operated continuously during cold shutdown at flow rates exceeding the air bubble flush criterion until the RCPs are started.

b. Check valve leakage tests are usually performed at the end of the refueling outage. During these tests, flow rates are maximized.

During cold shutdown, the RH pump suctions are usually connected to the RCS and the injection lines are not subject to RWST head. Flow is usually maintained through RH but the technical specifications allow the RH pump to be deenergized for a period up to 1 hour. This technical specification allowance is seldom used. In cold shutdown there is only one condition during which the RH injection line is subatmospheric. The line is subatmospheric during mid-loop operation. The pressure at the high point will be equal to RCS pressure (0 psig) less the elevation difference between the high point and the reactor water level, plus the head loss due to flow in the injection line. Total RH flow rates during this period are usually above 2000 gpm so any air which enters through a leak would be flushed into the vessel. Any air remaining in the line due to low flow and a leak would be flushed out when normal flow rate is reestablished.

Braidwood and Byron are equipped with reactor coolant loop isolation valves which minimize the need for midloop operations. The RH connections to the RCS are on the reactor side of the loop isolation valves which permit steam generators and reactor coolant pump maintenance without entering midloop operations.

Air Elimination Through a Pipeline Leak

It has been suggested that since the time period during which subatmospheric conditions exist are short compared to the time periods during which the pipeline is pressurized, it is likely that any air leakage would be expelled through the leak once the pipeline was restored to the normal configuration with the RWST full and pressurizing the line. This is only true if the leak is at the high point in the pipeline. Otherwise when the pipeline was repressurized, air could remain at elevations above the leak. In this situation, the air would be expelled once normal RH flows were re-established.

In the case of a leak at the high point it is true that the air expulsion will occur fast enough to allow clearing the air bubble promptly. In order to compare flow rate of air in and compare to the flow rate out, it is necessary to compare the minimum line pressure and the RWST over pressure. The pressure will range from a minimum of -22 feet of water column (gauge) to a maximum of 38 feet of water column (gauge). The rate of air flow out of the pressurized pipeline will be 1.3 times larger than the rate of air inleakage. Thus if the pipeline was under vacuum for the 1 hour, only 46 minutes would be required to expel the air once the pipeline was reconnected to the RWST.

Attachment A

STONE & WEBSTER ENGINEERING CORPORATION

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Mr. James Cumiskey
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May 31, 1991

J.O. No. 18869.32

ECC VENT STUDY FOR COMMONWEALTH EDISON CO.

Enclosed is a discussion of the minimum flow velocity required to sweep an air bubble out of a pipeline. Both horizontal and vertical pipes are considered.

This information was requested by Bill Benjamin and Ray Belair during our May 30, 1991 telephone conference call. Please FAX the attached information to Commonwealth Edison for a Monday (6/3/91) meeting.

Please contact J.W. Rooney at 617-589-1624 or me at 617-589-1433 if you have any questions regarding this transmittal.

Daniel A. Van Duyne

Daniel A. Van Duyne
Assistant Chief Engineer
Engineering Mechanics Division

1. OBJECTIVE

The purpose of thir task is to determine the minimum water velocity required to sweep an air bubble out of a piping system. The system of interest is the Emergency Core Cooling System (ECCS) at Commonwealth Edison's Braidwood Power Station.

2. ASSUMPTIONS

2.1 The fluid flow is turbulent.

2.2 The ECCS is an open system and the RCS Cold Leg acts as a large reservoir for air bubble discharge.

3. METHOD

An air bubble may be purged out of a piping system by ensuring that the pipe "runs full" at all times. This means that the incoming water front fills the entire pipe cross sectional flow area. This may be determined by use of the Froude number (Ref. 4.1), which is defined as the ratio of the inertial force to gravity force and may be expressed as:

$$Fr = \frac{V}{\sqrt{gD}} \qquad (1)$$

where: V = fluid velocity (fps)
g = gravitational acceleration (ft/sec^2)
D = pipe inside diameter (ft)

If $Fr = 1$, the pipe runs full. This equation is applicable for filling horizontal, inclined, and vertical pipes.

An additional item to consider is that if an air bubble is trapped in a vertical leg of a piping segment it will rise to the top of that leg at a certain bubble rise velocity. The incoming water front must overcome this bubble rise velocity so that the bubble may be swept out of the system. This bubble rise velocity (V_b) is based on the flow regime transition from annular to slug flow with the bubble rise up the pipe centerline (Ref. 4.2) as:

$$V_b = C_0(V_f+V_g) + C_1\sqrt{(\rho_f-\rho_g)\frac{gD}{\rho_f}} \qquad (2)$$

where: V_f = liquid superficial velocity (fps)
V_g = vapor superficial velocity (fps)
ρ_f = saturated liquid density (lb/ft^3)
ρ_g = saturated vapor density (lb/ft^3)
C_0, C_1 = constant coefficients (0.9,0.6)

Hence, if V_f = 0 fps and since ρ_f is much smaller than ρ_l, the necessary downward liquid velocity that causes ascending bubbles to rest (V_b = 0 fps) is:

$$V_f = -0.67\sqrt{gD} \qquad (3)$$

The negative sign means flow is downward.

It is noted that equation (3) is a fraction of equation (1) for Fr = 1, so the filling velocity determined by equation (1) is still bounding.

4. REFERENCES

4.1 Wallis, G.B., Crowley, C.J., and Hagi, Y., "Conditions for a Pipe to Run Full When Discharging Liquid Into a Space Filled With Gas", Journal of Fluids Engineering, Vol. 99, June 1977, pages 405 - 413.

4.2 Martin, C.S., "Vertically Downward Two-Phase Slug Flow", Journal of Fluids Engineering, Dec. 1976, pages 715 - 722.

4.3 SWEC Calculation No.- 18866.01-NP(B)-01-FA, Rev.1, including CN#1, "Fluid Transient Study of the Emergency Core Cooling System (ECCS) Piping Due to Pump Start-up With Air Bubble".

5. ANALYSIS

An air bubble may be swept out of a piping system if the Froude number Fr = 1, as discussed is Section 3. The resulting filling velocity for horizontal and/or vertical 8" sch 160 pipe (ID = 0.5678 ft) is:

$$V = \sqrt{32.2(.5678)} = 4.3\ fps \qquad (4)$$

This corresponds to a flow rate of 489 gpm.

6. SUMMARY OF RESULTS/CONCLUSION

The minimum flow velocity required to sweep an air bubble out of a piping system may be determined by using a criteria where the pipe "runs full" at all times. This criteria is that the Froude number is equal to 1 as discussed in Section 3. This results in a filling velocity greater than or equal to 4.3 fps or 489 gpm (see Section 5) for the piping inside containment in the Emergency Core Cooling System (ECCS) at Commonwealth Edison's Braidwood Power Station.

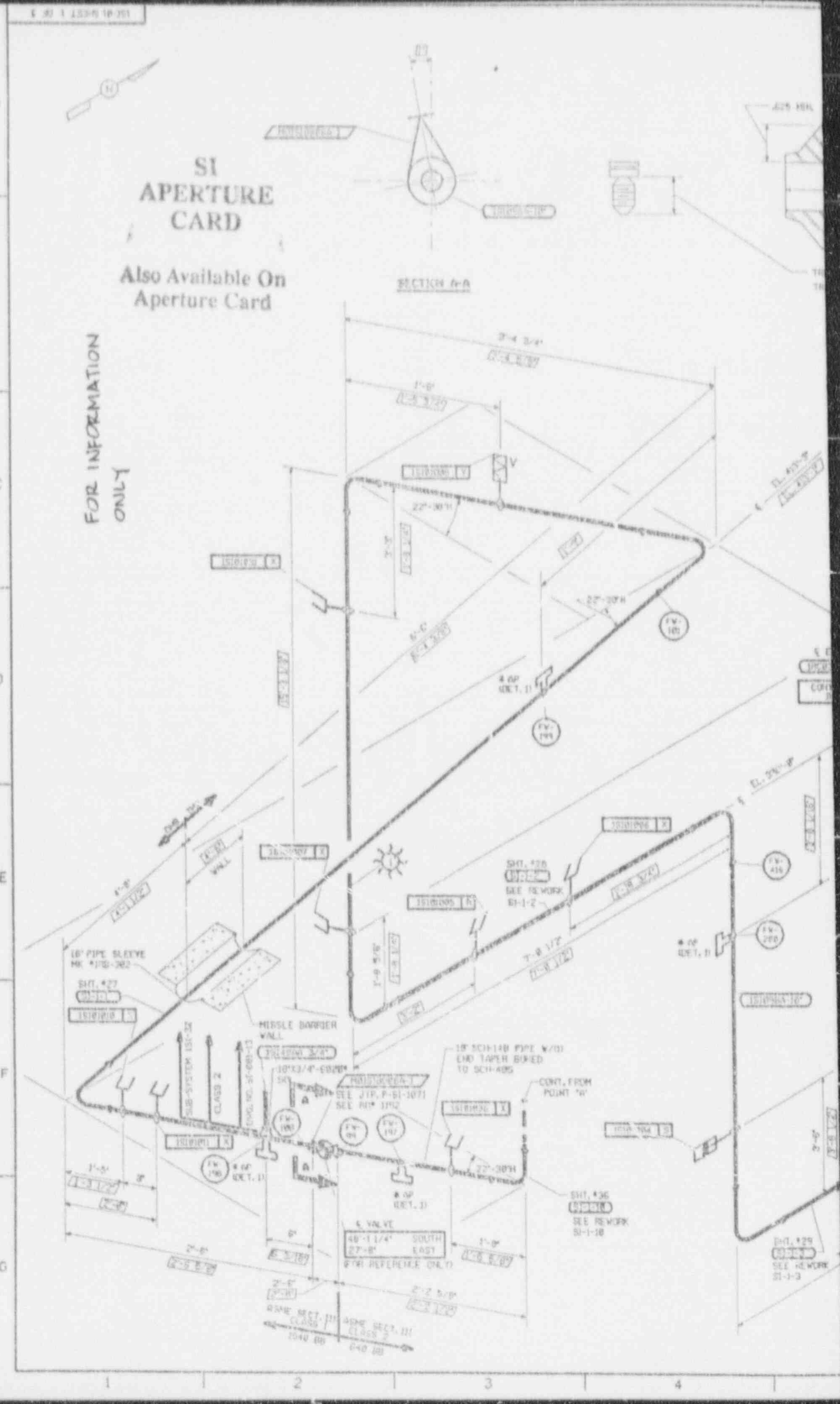
Since the pump rated flow is 4500 gpm (Ref. 4.3), any air bubble in the upper flow split path (Q = 2225 gpm) will be purged out of the system for just about any case of pump start-up.

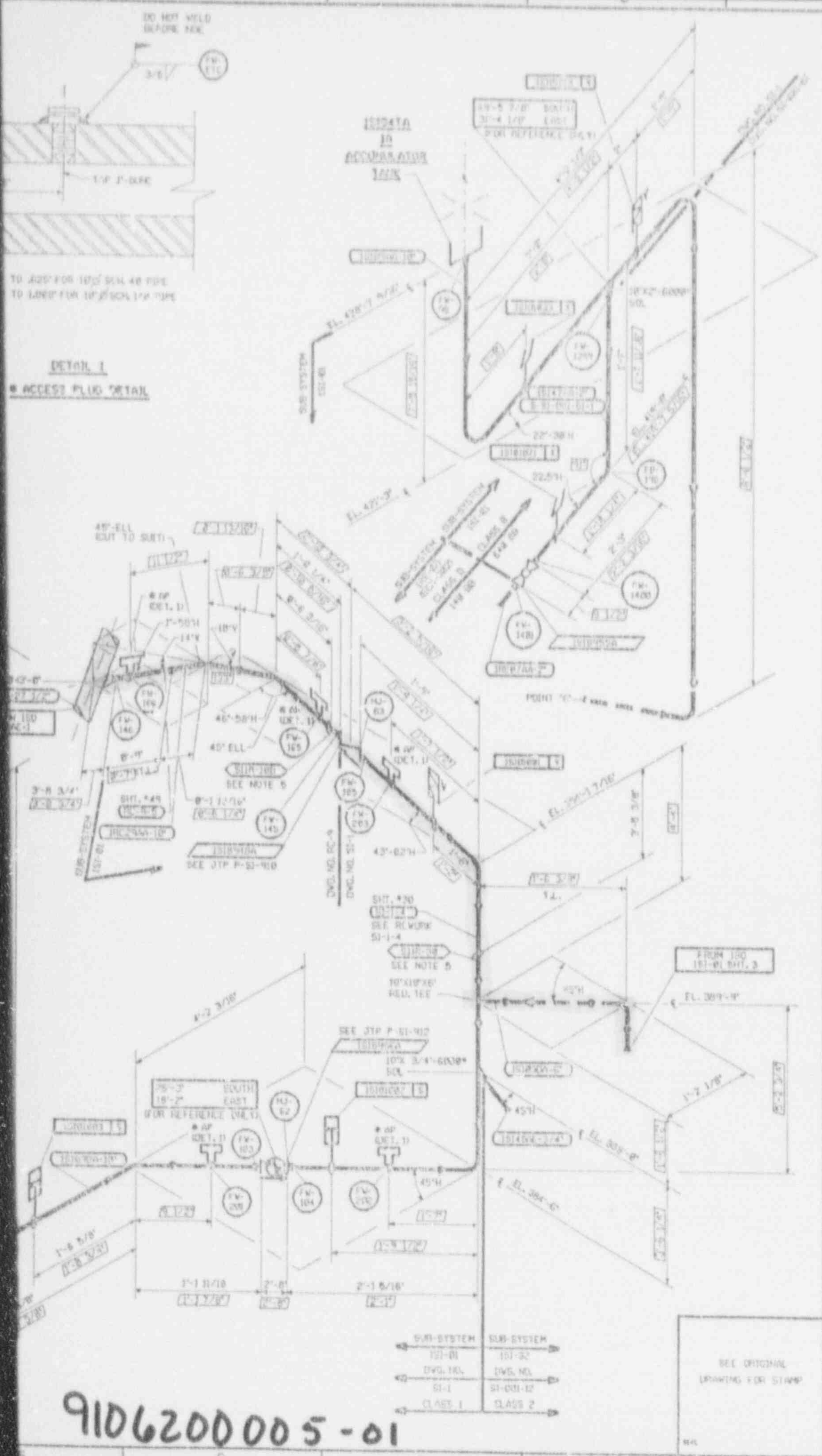
Attachment B

SI
APERTURE
CARD

Also Available On
Aperture Card

FOR INFORMATION
ONLY





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NOTES

1. ALL ELBOWS ARE LONG RADIUS 90° UNLESS OTHERWISE INDICATED.
2. ALL AS-BUILT DATA WILL BE SHOWN IN A BOX. ALL DIMENSIONS ALONG THE LONGITUDINAL AXIS OF THE PIPE LINE WHICH ARE NOT BOXED INDICATE THAT A COMPONENT WASN'T INSTALLED AT THE TIME OF THE AS-BUILT.
3. FOR SUPPORT ORIENTATIONS AND TYPE, SEE THE APPLICABLE SUPPORT DRAWINGS FOR VERIFICATION.
4. ALL BENDS HAVE A BEND RADIUS OF 5 TIMES THE NOMINAL PIPE SIZE UNLESS OTHERWISE INDICATED.
5. DIMENSIONS SHOWN TO LOCATE PIPE WHIP RESTRAINTS SUH-100 AND SUH-30 ARE TO THE CENTER LINE OF THE RESTRAINT ASSEMBLY. SEE SARGENT AND LUNDY DRAWING S-1677-1 FOR THE PIPE WHIP RESTRAINT DETAILS.

FOR LEGEND & SYMBOLS SEE KEY DIAGRAM

SHOP DETAIL LIST

QUAN.	DWG. NO.	SHT. NO.
1	RC-9	49
1	SI-1-1	27
1	SI-1-2	28
1	SI-1-3	29
1	SI-1-4	30
1	SI-1-10	36
1	SI-001-01-1	-

ASME CODE SECTION III DIV. I CLASS 1 & 2
DESIGN SPECIFICATION QUALITY CLASS A & B
PIPING DESIGN TABLE 04PDD & J04BBB

FOR HISTORICAL INFORMATION REFER TO ORIGINAL DRAWINGS

THIS CAD DRAWING SUPERSEDES THE FOLLOWING DRAWINGS. FOR SUB-SYSTEM 1SI-01 ONLY

DRAWING NO.	REVISION	DATED
RC-9	7A	01/27/89
SI-1	12	09/13/87
SI-001-01	2B	11/15/83

REFERENCE DRAWINGS

M-60 SHT. 1B REV. AV - DIAGRAM OF REACTOR COOLANT LOOP 1
M-61 SHT. 5 REV. T - DIAGRAM OF SAFETY INJECTION SYSTEM
S-1677-1 REV. AL - SAFETY INJECTION LINE WHIP RESTRAINTS
RC-9 REV. 7A - REACTOR COOLANT SYSTEM
SI-1 REV. 12 - SAFETY INJECTION SYSTEM
SI-001-01 REV. 2B - SAFETY INJECTION SYSTEM
ECN-302

NUCLEAR SAFETY RELATED

ISSUED FOR RECORD
ISSUED PER DCR-90-241

SEE ORIGINAL DRAWING FOR STAMP

CHICAGO SARGENT & LUNDY ENGINEERS ILLINOIS

SAFETY INJECTION SYSTEM
BYRON NUCLEAR STATION UNIT #1
COMMONWEALTH EDISON COMPANY
CHICAGO, ILLINOIS